A Smart Disaster Management System for Future Cities

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ABSTRACT
Smart cities have recently become the mainstream approaches for urbanisation. Environmental, social and economic sustainability, digital inclusion and high quality of life are considered important elements in smart cities design. Emergency response system and resilience are among the most crucial dimensions of smart and future cities design due to the increase in various disruptions caused by frequent manmade and natural disasters such as September 2001 and Philippines Typhoon Haiyan 2013. Disasters cause great economic and human losses each year throughout the world. Transportations and Telecommunications play a crucial role in disaster response and management. Our research is focused on developing emergency response systems for disasters of various scales with a focus on transportation systems. We have proposed and evaluated a disaster management system that uses Intelligent Transportation Systems including Vehicular Ad hoc Networks (VANETs), mobile and Cloud Computing technologies. In this paper, we report our recent work on two major evacuation strategies, Demand Strategies (DS) and Speed Strategies (SS), which provide better evacuation results in smart cities settings.

Keywords
Smart Disaster Management System; Intelligent Transportation Systems; VANETs; Cloud Computing; Microscopic Simulations; City Evacuation Strategies

1. INTRODUCTION
Smart cities are the latest trend in urbanisation. Environmental, social and economic sustainability are considered as fundamental ingredients in smart cities design. Smart Cities rely on a converged, ubiquitous infrastructure to provide high quality of life to its people through efficient use of resources.

WiMobCity'14, August 11, 2014, Philadelphia, PA, USA.

http://dx.doi.org/10.1145/2633661.2633670

The importance and scope of emergency response systems have grown tremendously over the recent years particularly after September 11, 2001, 7 July 2005 London bombings, and the 2011 Japan tsunami disaster. Disasters, manmade and natural, are a cause of great economic and irrecoverable human losses each year throughout the world. For example, the Typhon storm caused over 10000 deaths and the economic cost has been estimated around $14 billion [1]. The overall cost of the 2011 Japan earthquake and tsunami disaster alone was in excess of 200 billion USD in addition to the irrecoverable loss of over 18 thousand lives. This has driven many new initiatives and programs in countries throughout the world, in particular in the US, Europe, Japan and China [2], [3], [4], [5] and [6].

Transportation and ICT (information and communication technologies) are already playing critical roles in responding to emergencies and minimizing disruptions, human and socioeconomic costs. We have witnessed unprecedented advancements in ICT over the last few decades and the role of ICT technologies in Intelligent Transportation Systems is growing at a tremendous rate. Vehicular Ad hoc Networks (VANETs), sensor networks, social networks, Car-to-Car (C2C) and Car-to-Infrastructure (C2I) technologies are enabling transformational capabilities for transportation (see e.g. [7] and [8]). Our ability to monitor and manage transportation systems in real-time and at high granularities has grown tremendously due to sensor and vehicular network that generate huge amount of extremely useful data. However, a major challenge in realizing the potential of Intelligent Transportation Systems (ITS) and Smart Cities is the interworking and integration of multiple systems and data to develop and communicate a coherent holistic picture of transportation, environment and other systems. This is particularly difficult given the lack of data and systems interoperability as well as the business models to develop such an advanced infrastructure which requires coordination between many stakeholders and general public.

Cloud Computing has emerged as a technology, coupled with its innovative business models, which has the potential to revolutionize the ICT, ITS and Smart Cities landscape. It is making a huge impact in all sectors through its low cost of entry and high interoperability. Moreover, the technology allows one to develop reliable, resilient, agile, and incrementally deployable and scalable systems with low boot-up time, and at low costs, while giving users access to large shared resources on demand, unimaginable otherwise.

In our earlier work [9], we leveraged the advancements in the ICT technologies - including ITS, VANETs, social networks, mobile and Cloud computing technologies - to propose a smart disaster management system for future (smart) city environments. By exploiting these latest technologies the system is able to gather information from multiple sources and locations (using VAENTS, Smartphone and other technologies), including from the point of incident, and is able to make effective strategies and decisions (using e.g. high performance computing (HPC)), and propagate the information to vehicles and other nodes in real-time. Cloud computing exploits the virtualisation technology and hence is able to provide interoperability. Moreover, in a disaster situation, it allows both the data (traffic and other data) as well as the computing (software in execution, algorithms etc) to be saved (time snapshot) and moved to another (safer) physical location quickly at the speed of light. Data and system back up in far locations can be done easily. We described the cloud system architecture and elaborated on the traffic models used to provide transport intelligence. The effectiveness of our system was demonstrated through modelling the impact of a disaster on a real city transport environment. We modelled two urban scenarios: firstly, disaster management using traditional technologies, and secondly, exploiting our computationally smart, VANETs Cloud based disaster management system. The comparison of the two scenarios demonstrated the effectiveness of our system in terms of the number of people evacuated from the city, the improved traffic flow and a balanced use of transportation resources.

The system proposed in [9] was extended in [10], in that the system model was improved by means of introducing a novel message propagation algorithm through VANETs, and the effectiveness of the system was validated by means of extended simulation results. These earlier works were based on macroscopic traffic modeling. We are now focusing on microscopic models for design and evaluation of our system with the aim to gain additional insight into the problem domain, to validate the earlier system analysis, and to improve system functionality and performance. Specifically, in this paper, we develop a model to investigate the disaster management system performance on the evacuation operation by employing different city evacuation strategies. In this paper, we report our recent work on two major evacuation strategies, Demand Strategies (DS) and Speed Strategies (SS) which provide significantly improved evacuation results in smart cities settings.

This paper is organised as follows. Section 2 provides a literature review relevant to smart cities, disaster management and evacuation models (please see, for example, our earlier work for introduction to the component technologies of the proposed system). Section 3 provides details on the proposed smart disaster management system including the evacuation strategies; also, therein, the S-paramics ITS micro simulation model and methodology are described. In Section 4, the evaluation results of two employed evacuation strategies are presented. Finally, Section 5 concludes the paper.

2. RELATED WORK

A Smart city can be defined as “A city that meets its challenges through the strategic application of ICT goods, network and services to provide services to citizens or to manage its infrastructure” [11].

In practical, the implementation of the evacuation plans including the use of various resources requires an effective and cooperative pre-evacuation planned to achieve the goal. In short, transportation network based evacuation operations include a range of activities that can be represented by the combined operation of smart mobile technologies, applications and strategies which are used within the disaster management system in both cases; before and after the disaster, in order to mitigate the damage. Thus, evacuation planning has been given considerable attention over the last decade.

2.1 Smart Cities

Smart-X has become one of the most commonly used terms in different aspects. Smart-X could refer to: Smart Cities, Smart Transport, and Smart Technologies including Smartphones. Also, for diversity purposes, other terms are used in different resources such as intelligent and innovative [11]. Smart city depends primarily on providing the information and communication technologies and services to be available to the population through web access services for both personal and business.

A digital economy aims to enable sustainable replacements and organizations of the various socio-economic interactions and activities that we undertake, using technologies such as internet, mobile phones, sensor and social networks. Digital technologies offer huge potential for providing efficient and easy access to public services. They can connect people in rural areas, enable remote access to healthcare, build social inclusion, and help solve our energy crisis. Many governments have described clearly just how vital the ICT infrastructure is; in the UK, it has been estimated that it contributes £102 billion in gross value-added, and employs over 2.5 million people [12]. Consequently, to build or transform to a smart city, the governments and different agencies must start to place emphasis on increasing the penetration of the ICT technologies while they contribute effectively to enhancing economic growth. Meanwhile, promoting innovative, cities with highly technology, is crucial and considered essential for establishing efficient management systems [13].

2.2 Works Focused on Specific Technologies

Buchenscheit et al [7] proposed an emergency vehicles warning system that exploits vehicular network technologies. The emergency vehicles could transmit radio signals and detailed route maps to other vehicles and signals in their path in order for those vehicles and people to take appropriate and timely action. A system prototype has been built and tested in a traffic environment comprising emergency vehicles and traffic signals. However, the system was conducted specifically for emergency vehicles. The prototype implemented offers a significant time reduction in emergency situation.

An approach to disseminate spatio-temporal traffic information in order to reduce chaos in evacuation scenarios using VANETs is presented in [8]. This work is further extended by the authors in [14] by exploiting WiFi and WiMAX to provide high end to end network connectivity and minimise network contention and interference. The proposed scheme is evaluated using simulations. Park et al [15] investigated a serious problem of reliable transmission of multimedia data in VANETs for safe navigation support applications. Their approach is based on network coding and is evaluated using simulations.

Serhani et al [16] proposed a service discovery and reservation technique for mobile ad hoc networks (MANET) tailored to support disaster recovery and military operations environments. Their technique locates the resources taking service levels and requirements into account. They build a purpose built simulator to evaluate their technique and report its usefulness in locating and reserving services in varying network density, rate of requests and other operational conditions.

2.3 A Historical Perspective on Evacuation Models

In the transportation network environment analysis, evacuation management is considered as one of the critical processes during a disaster which can be modelled as dynamic flow problems. In a normal scenario, the vehicles have their destination preferences from the respective origins. A few minutes after the disaster occurred, there is no interface capable of transmitting transport network status, effective evacuation strategy implementations enable the system to represent the movement of vehicles in the event of the existence of forward planning.

Significant improvements of the network performance can be achieved depending on the efficient management of the demand-supply problem at the evacuation network. As chaos status appears the number of evacuees often far exceeds the route capacity; i.e. the number of vulnerable people who needs to be evacuated from the disaster area is higher than route capacity design in a unit time, which results in unbalanced evacuation demand-transportation supply relation. However, most existing evacuation management approaches address the problem from the supply-side, emphasising network design and capacity enlargement, such as contra-flow strategy [17].

Simulation model was one of different approaches has been used to investigate the traffic evacuation impact [18]. Hereby, providing dynamic traffic system increases the opportunity of improving the disaster emergency decision response and performance, and hence the evacuation strategies implementation and results.

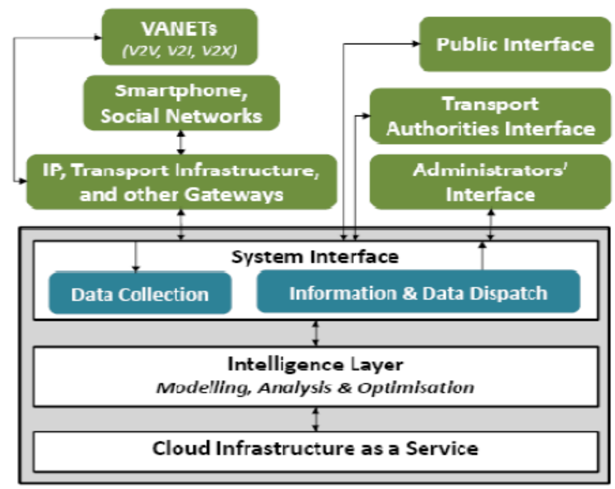

Figure 1. The porposed Cloud-based Disaster Management System

3. SMART EVACUATION MODEL DESIGN

3.1 Disaster Management System Architecture

The architecture of our proposed smart disaster management system is presented in previous works, [9] and [10]. We briefly revisit the architecture of the proposed system using Figure 1, which is taken from our earlier work. As shown in the figure, vehicular emergency response system. The system consists of three main layers. The Cloud infrastructure layer provides the base platform and environment for the intelligent emergency response system. The Intelligence Layer provides the necessary computational models and algorithm in order to devise optimum emergency response strategies by processing of the data available through various sources. The System Interface acquires data from various gateways including the Internet, transport infrastructure such as roadside masts, mobile smart phones, social networks etc.

The vehicles interact with the gateways through Vehicle-to-Vehicle (V2V) or Vehicle-to-Infrastructure (V2I) communications (seeFigure 1). For example, vehicles may communicate directly with a gateway through Internet if the Internet access is available. A vehicle may communicate with other vehicles, road masts, or other transport infrastructure through point-to-point, broadcast or multi-hop communications. The emergency response system provides multiple portals or interfaces for users to communicate with the system, i.e. the Public Interface, the Transport Authorities Interface, and the Administrators' Interface. The Public Interface allows any individual to interact with the system. The purpose is to interact with the system on one-to-one or group/organisation basis with the system, either to request or provide some information. Of course, an authentication, authorization and accounting system is expected to be in place to allow and control various activities and functions. The Transport Authorities Interface is a high-privilege interface for the transport authorities to affectively manipulate the system for day-to-day operational management. The Administrators' Interface provides the highest privilege among the system users and is designed for policy makers and strategists to enable highest level system configuration. For further details, please see [9] and [10].

3.2 Micro-Simulation Model: S-paramics ITS System

As mentioned earlier, the data received from various sources and communication gateways such as VANETs; goes through an internal validation layer before it is accepted by the modelling and analysis layer. In this study, a micro-simulation model is employed to optimise the use of the smart system proposed on the various evacuation strategy combinations and subsequently to improve the emergency operation performance.

In this paper, S-Paramics ITS micro-simulation software 2010.1 is used. The S-Paramics is a micro-simulation software package which is simply defined as "A powerful communications tool because it is able to present its outputs as a real-time visual display" [17]. The microscopic models are based on some traffic factors which have the ability to manage the movement of individual vehicles in a transport network. High level of powerful graphics offered by most software packages that show individual vehicles traversing networks which include a variety of road categories and junction types [18].

Microscopic models have a wide range of advantages. It has been reported that they are extremely useful tools, and could be the next generation of traffic models [19]. One of the most important characteristic that S-paramics is able to offer is that there is a potential of an external software to communicate with a running simulation, to extract data from it, and to adjust parameters within it [20]. The S-paramics ITS system is designed to allow a controller to link to a running simulation and take information from the simulation at pre-determined intervals. Using this system has several advantages such as the ability to adjust signal timings at junctions as well as to pass messages to vehicles in the simulation by broadcast device or by information on variable message signs [21]. The system has been used in many other ad-hoc control applications [20] and [22]. We improve a traffic micro-simulation model (i.e. using S-Paramics), the model should be capable of taking into consideration the limitations of previous models using the existing rules and set of orders.

Table 1. The Spreadsheet components

Spreadsheet components	Explanation
Paramics Model Location	Model location, where the model is stored in the PC. For example, C:\Paramics evacuation\Controller\Demand
Paramics Version	S-Paramics ITS system version. In this study, we use the 2010.1 version
ITS Strategies Sheet	The name of the worksheet with the list of evacuation strategies which are implemented in this study. For example, Demand Strategies
ITS Responses Sheet	The name of the worksheet with the list of response profile.
Batch or Visual	Number of the mode. For example, in this study we have the "Visual" mode.
Number of runs	1
Number of strategies	The number of the rows in the strategies sheet

3.3 SNMP Tool Design

SNMP stands for Simple Network Management Protocol. It is a mechanism for exchanging information between a manager and a set of managed objects on remote sitesBasically, the SNMP agent serves data defined by a Management Information Database (MIB) over a network using standard Internet Protocol (IP) communications. Furthermore, an ActiveX control; known as PController, has been developed to enable using of interface by employing Visual Basic (VB). [23].

Here, the underlying communications mechanism is SNMP. The "controller" starts the simulation and establishes a connection to it. Once a connection is established, the controller creates the links to the objects in the simulation it intends to manage. In this case these are message passing ITS controllers, traffic signals and smart technologies, such as V2V and V2I, that have been employed in the proposed disaster management system.

The interface for the controller is a Spreadsheet, it is the run sheet to enter the information. It has been written in Visual Basic macro language because it is accessible and it is ideal for interfacing to the dynamically linked library that implements the SIAS SNMP interface. It is also modifiable without the use of any special software tools and the source code is clearly visible, Figure 2shows the Spreadsheet.

Paramics Model Location	C:\Paramics evacuation\Controller\Demand
Paramics Version	2010.1
ITS Strategies Sheet	Demand_Strategies
ITS Responses Sheet	Responses
Batch or Visual	Visual
Number of runs	1
Number of strategies	10
	Run

Figure 2. Proposed Spreadsheet which representing the interface to the tool

It consists of several of rows, simplification of the Spreadsheet can be seen in Table 1. The "Run simulation" button runs the requested number of actions of the specified model and may or may not log data as required. Different versions of this Spreadsheet will allow different strategy combinations to be tested and the results will be analysed to investigate the effect of strategy choice.

The detail of the parameters for each action will vary with each action type, but will be set on the action row in one or more cells. A number of strategies/actions can be applied through the Spreadsheet. In this tool, the ITS devices are the key element as they control the actions of vehicles moving in the simulation.

4. RESULTS AND EVALUATIONS

The proposed disaster management system [9], together with the controller developed, is considered to evaluate two evacuation strategies together to verify their usefulness. In order to investigate the tool design objective we demonstrate the tool using data from a real city which we refer to it as city X.

4.1 Disaster Scenario

This city is located in the United Kingdom and comprises 25 zones and 315 nodes, each node carries different characteristics, such as the type of traffic control, while links carry the characteristics of traffic and geometric design (e.g. speed, visibility, directional movement, etc.). Figure 3 presents the transportation network of the city X in base situation.

The network demand is calculated based on the Origin-Destination (O-D) matrix which has been used in Fratar model [24]. The numbers of trips in the O-D matrix are calculated in the mid-week period.

From different potential risks; natural and man-made disasters, we assume the city is affected by an explosion (for example) which calls for an immediate and adequate response (in the form of a pre-planned range of evacuation strategies).

Figure 4 represents a snapshot of the city at the disaster scenario. We consider the incident hits the city at 8:00am at the rush hour, peak hour represents the maximum number of vehicles moving across the transport network, as we are able to test the tool in the worst conditions, thus enabling us to suggest and recommend the appropriate strategies.

The disaster creates the chaos situation throughout the city and most of the city links become blocked (depicted by the roads colored in black). In addition, it is important to note that the roads connecting the disaster area with the zones located in the lower part of the city have very low vehicular volume, below 500 vehicles per hour (depicted by the roads colored in red), accompanied by a number of roads which have volumes between 500 and 1000 vehicles per hour (represented by roads colored in blue).

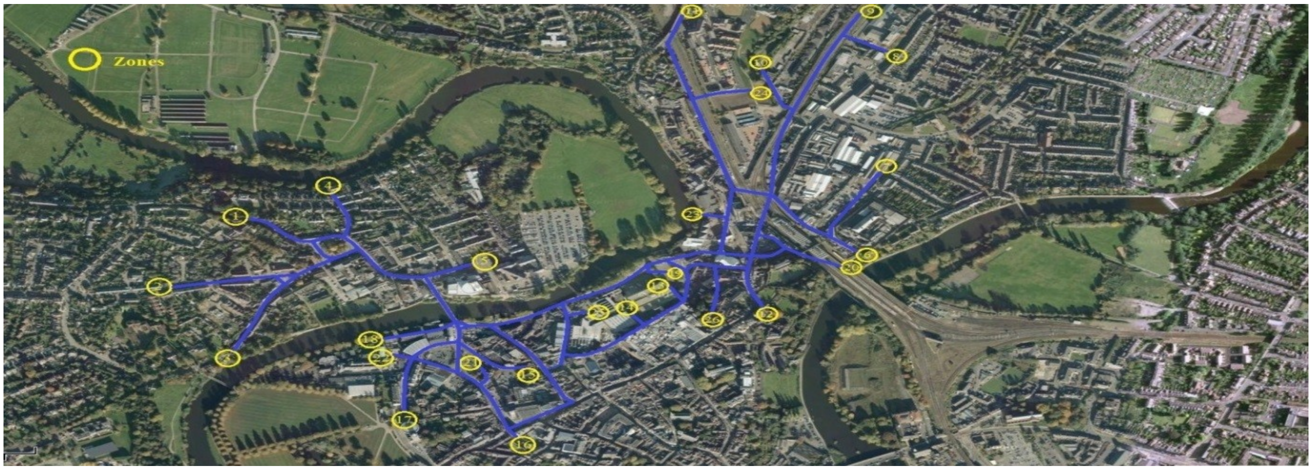

Figure 3. City X transportation network in base situation

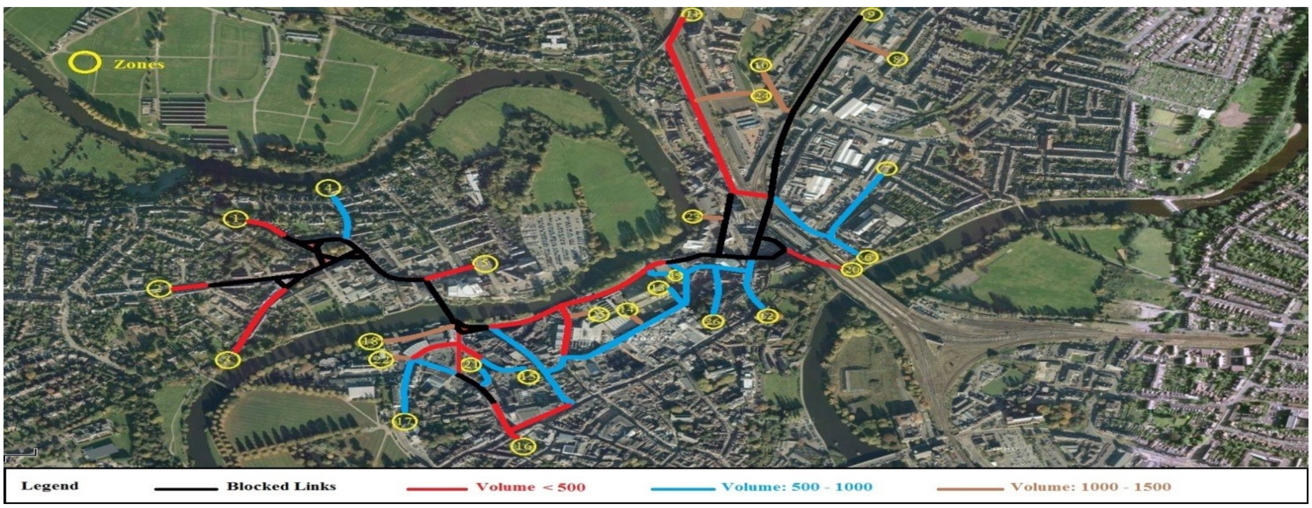

Figure 4. The transportation network after the disaster hits the City X

4.2 Evacuation Strategies

Our smart disaster management system is selected to be in place and is able to present, send and receive the real-time data. Meanwhile, different evacuation strategies can be applied such as Demand, Speed, Lane Reversal and Redirect movement destination. Consequently, the proposed smart system enables the disaster management center to suggest and recommend a range of suitable evacuation strategies and there is an opportunity to change the strategy according to the real-time information. In previous works, we develop and evaluate a tool to facilitate the use of ITS measures in simulated evacuations [25]. Here, in this paper, two different evacuation strategies are applied simultaneously. Speed and Demand strategies are selected to present the effectiveness of the smart proposed system.

4.2.1 Speed and Demand Strategies, (SS and DS)

In order to examine a broad scope of possible evacuation outcomes for the city X, multiple evacuation scenarios can be modelled. The disaster centre has received and gathered the data collected from different sources. Also, the disaster centre propagates the suitable strategy/s. In this work, we apply different strategy scenarios; we change the critical input data in the speed and demand worksheet. Table 2 and Table 3 show examples of these various input data.

Table 2. An example of demand strategy worksheet input data

Demand strategy						
Reference	**Evacuation strategy start time, hh:mm**	**Evacuation strategy end time, hh:mm**	**Strategy**	**Matrix**	**From zone**	**To zone**
1	08:05	09:00	Demand	1	1	5
2	08:05	08:30	Demand	1	2	6
3	08:30	09:30	Demand	1	3	7
4	08:30	09:00	Demand	1	4	8

Table 3. An example of Speed strategy worksheet input data

Speed strategy							
Reference	**Evacuation strategy start time, hh:mm**	**Evacuation strategy end time, hh:mm**	**Strategy**	**Controller name**	**Link name**	**Speed suggested, mph**	**Line number ***
1	08:05	09:00	Speed	Urban_3	L22:21	5	1
2	08:05	08:30	Speed	Urban_6	L21:142	10	2
3	08:30	09:30	Speed	Urban_7	L142:20	40	3
4	08:30	09:00	Speed	Urban_8	L20:21	50	4

*presents the percentage of driver response, from the response sheet

In a normal situation, most city links are limited to 30mph. However, after the disaster hits the city and vehicles start to move under shock results in anarchy. So, we recommend applying the smart disaster management system, means real-time network information, including different evacuation strategies. While traditional system means sending late warnings, because of some tools limitations we will not be able to change/update the strategies; conditions, depending on the real network situation. In the case of using the SS, a wide range of conditions is applied. For example, we are able to increase the speed limit for some critical links as we aim to facilitate the escape from the dangerous area as quickly as possible, and/or slow the speed for other links to prevent vehicles moving towards the disaster area and other affected links. Also, different start and end times can be assumed depending on what system we employ, an smart disaster management system gives the opportunity to send and receive the information earlier than the traditional management systems. Meanwhile, we could control the duration of each scenario depending on the real-time data received from various communication technologies including VANETs. The Demand Strategy has different input data to the SS, see Table 2 and Table 3, and still can be implemented simultaneously.

4.2.2 Results and Discussion

Due to a disaster impact, a considerable number of vehicles is trapped and accumulated within the network. An effective evacuation strategies policy is demonstrated to control the traffic network. Figure 4 shows the city X network while it is under the disaster impact and without any emergency system. An example of the SS implementation while we are capable to change the different speed conditions, such as increasing and decreasing the speed limit, applying different driver response, is shown in Table 3. In this study, we consider 100% driver response to strategies guidance.

Traditional disaster management systems dispatch the disaster information slightly late. The driver behaves random, they might select the least congested routs, or follow others as they prefer to stick with the majority or follow the routs that they feel familiar with them, or select the routs that have been selected by the decision makers. Random selection above would likely consume time and increase the opportunity of having a chaos network and hence makes the emergency strategies more difficult to be implemented. Figure 5 shows the city traffic movement in case of applying traditional disaster system.

Literally, 30 minutes after the disaster hits the city is enough to prevent of employing the strategies. For example, the vehicles keep going out of the zones without any idea what is going around them and increase the congestion and it becomes very difficult to drive the vehicles out of the danger area and might obstruct implementing other strategies.

In contrast, using our proposed smart disaster system and propagating the speed and demand strategies, a considerable improvement can be seen in the traffic network performance, see Figure 6. The system propagates the effective and practical strategies and makes huge difference in the traffic performance. Here, we are able to exploit the strategies, isolate and together, as we have time to prevent the vehicles to go towards the city and monitor the vehicles that already driving inside the network. In other words, we stop drivers to enter the city network through utilizing the demand strategy and same while control the drivers movement by implementing the speed strategy, by imposing different limitation according to the need, and try to slow the movement towards the disaster area.

Also, here we emphasis on very important issue that we can implement successfully both strategies together as stopping the drivers from entering the network would help to decrease the number of vehicles already inside the network and facilitate the speed strategy implementation.

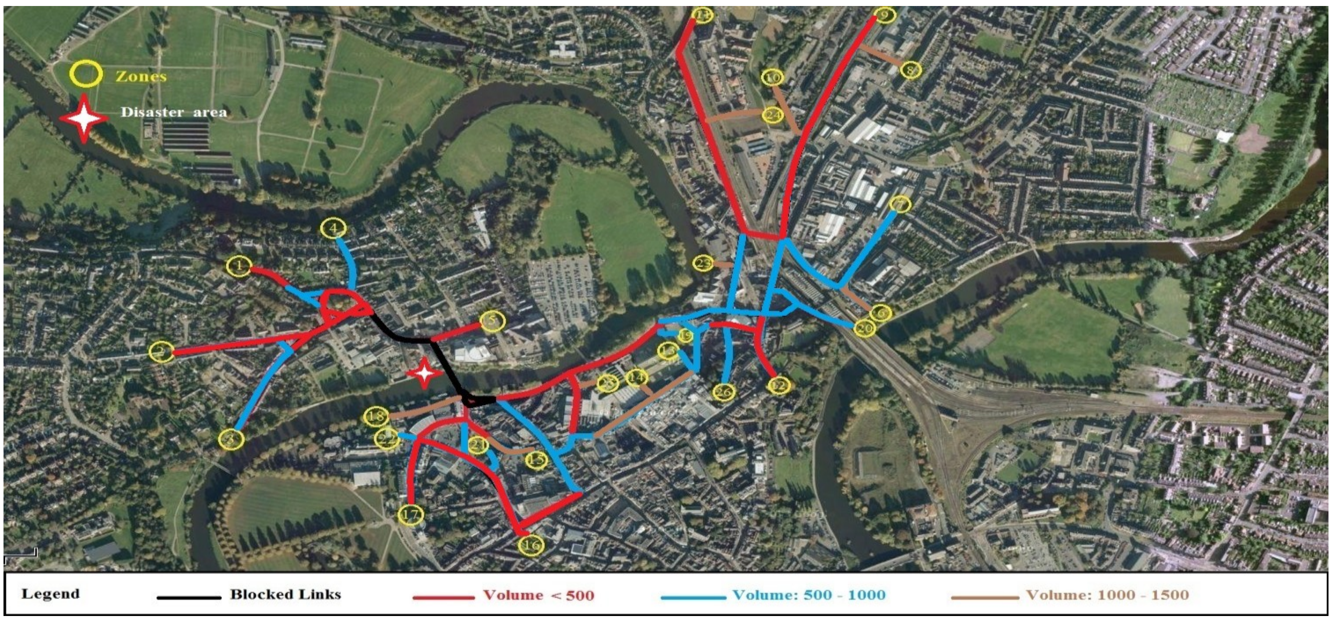

Figure 5. Transportation network of city X with applying the speed and demand strategies, traditional disaster management system

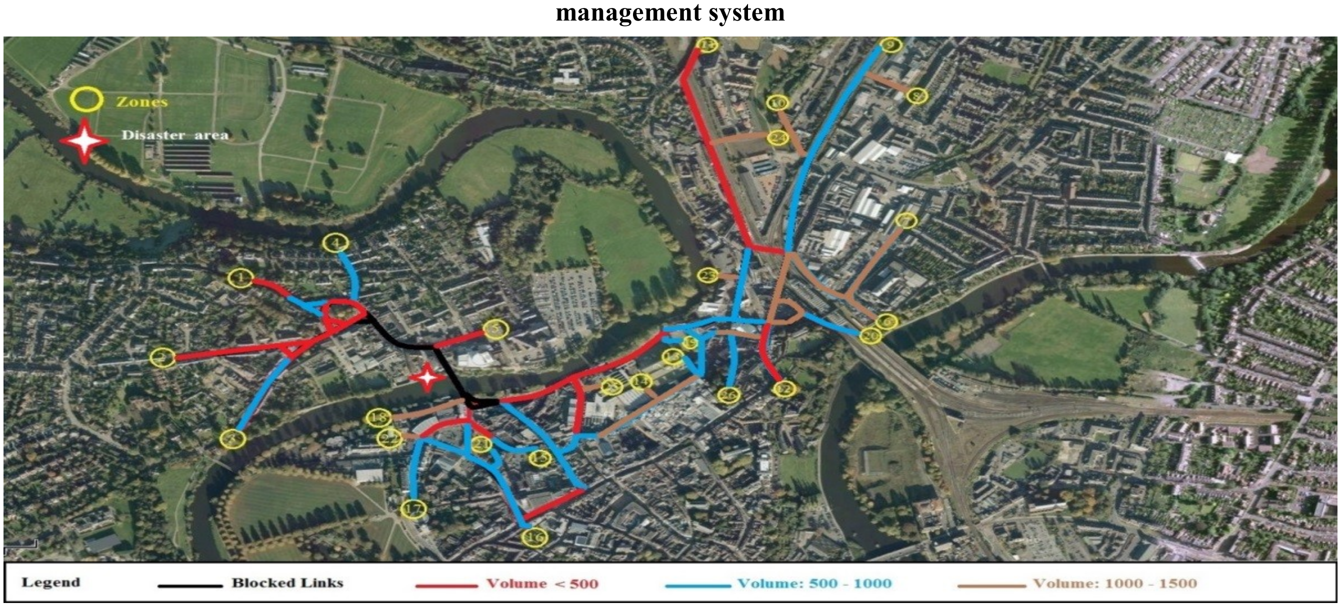

Figure 6. Transportation network of city X with applying the speed and demand strategies, proposed disaster management system

Figure 6 shows the improvement in flow rate of critical links. Many blocked links which have zero volume, depicted by the roads colored in black, are turned into red and some blues which means an improvement seemed to occur to the whole network can be realized. Also, note that few links which are colored in brown, represents the volume between 1500-200 veh/hr, become blue or red which means that the volume of these links has been increased because we want to balance using the network links as much as possible. Finally, we should mention here that the human lives' saving is initially done by using the demand strategy.

5. CONCLUSION

Smart Cities rely on a converged, ubiquitous infrastructure to provide high quality of life to its people through efficient use of resources. The importance and scope of emergency response systems have grown tremendously over the recent years particularly after September 11, 2001. Disasters, manmade and natural, are a cause of great economic and irrecoverable human losses each year throughout the world. We have witnessed unprecedented advancements in ICT over the last few decades and the role of ICT technologies in Intelligent Transportation Systems is growing at a tremendous rate. VANETs, sensor networks, social networks, C2X technologies are enabling transformational capabilities for transportation. Our ability to monitor and manage transportation systems in real-time and at high granularities has grown tremendously due to sensor and vehicular network that generate huge amount of extremely useful data. However, a major challenge in realizing the potential of ITS and Smart Cities is the interworking and integration of multiple systems and data to develop and communicate a coherent holistic picture of transportation, environment and other systems. This is particularly difficult given the lack of data and systems interoperability as well as the business models to develop such an advanced infrastructure which requires coordination between many stakeholders and general public. Cloud Computing has emerged as a technology, coupled with its innovative business models, which has the potential to revolutionize the ICT, ITS and Smart Cities landscape. In our earlier work, we leveraged the advancements in the ICT technologies - including ITS, VANETs, social networks, mobile and Cloud computing technologies - to propose a smart disaster management system for future (smart) city environments. By exploiting these latest technologies the system is able to gather information from multiple sources and locations (using VAENTS, Smartphone and other technologies), including from the point of incident, and is able to make effective strategies and decisions (using e.g. high performance computing (HPC)), and propagate the information to vehicles and other nodes in real-time. The system proposed in [9] was extended in [10], in that the system model was improved by means of introducing a novel message propagation algorithm through VANETs, and the effectiveness of the system was validated by means of extended simulation results. These earlier works were based on macroscopic traffic modeling. We are now focusing on microscopic models for design and evaluation of our system with the aim to gain additional insight into the problem domain, to validate the earlier system analysis, and to improve system functionality and performance. Specifically, in this paper, we developed a model to investigate the disaster management system performance on the evacuation operation by employing different city evacuation strategies. We reported our recent work on two major evacuation strategies, Demand Strategies (DS) and Speed Strategies (SS) which provide significantly improved evacuation results in smart cities settings. The results show significant improvements in terms of the number of vehicles used. The future work will focus on further analysis and validation of additional disaster evacuation strategies.

6. REFERENCES

[1] "The Impact of the Philippines' Typhoon on Global Trade & Economy," *The Smart Cube*, 2013. [Online]. Available: http://www.thesmartcube.com/insights/blog/blog-details/insights/2013/11/14/the-impact-of-the-philippines-typhoon-on-global-trade-economy. [Accessed: 05-May-2014].

[2] K. C. Vasconez and M. Kehrli, "Highway Evacuations in Selected Metropolitan Regions: Assessment of Impediments," 2010.

[3] N. Owens, A. April, S. Paul, M. Carol, P. Sullivan, N. Diane, B. Rebecca, and T. Todd, "Traffic Incident Management Handbook," 8301 Greensboro Drive McLean, VA 22102, Science Applications International Corporation (SAIC), Technical Report FHWA-HOP-10-013, Jan. 2010.

[4] FHWA, "Emergency Transportation Operations." [Online]. Available: http://ops.fhwa.dot.gov/eto_tim_pse/index.htm. [Accessed: 27-Jun-2011].

[5] Metropolitan Government of Nashville and Davidson County, Tennessee, "Emergency Preparedness Survey for Davidson County, TN." 2008.

[6] R. Drake, "The Hierarchy of Emergency Preparedness," in *Safeguarding Homeland Security*, S. Hakim and E. A. Blackstone, Eds. New York, NY: Springer New York, 2009, pp. 31–40.

[7] A. Buchenscheit, F. Schaub, F. Kargl, and M. Weber, "A VANET-Based Emergency Vehicle Warning System," presented at the Vehicular Networking Conference (VNC), IEEE, 2009, pp. 1–8.

[8] S. R. A. Rizvi, S. Olariu, M. E. Rizvi, and M. C. Weigle, "A Traffic Chaos Reduction Approach for Emergency Scenarios," presented at the Performance, Computing, and Communications Conference, IPCCC, IEEE Internationa, 2007, pp. 576–578.

[9] Z. Alazawi, S. Altowaijri, R. Mehmood, and M. B. Abdljabar, "Intelligent Disaster Management System Based on Cloud-Enabled Vehicular Networks," in *11th International Conference on ITS Telecommunications (ITST)*, Russia, 2011, pp. 361–368.

[10] Z. Alazawi, M. Abdljabar, S. Altowaijri, A. Vegni, and R. Mehmood, "ICDMS: An Intelligent Cloud Based Disaster Management System for Vehicular Networks," in *Communication Technologies for Vehicles*, vol. 7266, Springer Berlin / Heidelberg, 2012, pp. 40–56.

[11] N. Lövehagen and A. Bondesson, "Evaluating Sustainability of using ICT Solutions in Smart Cities – Methodology Requirements," in *Proceedings of the First International Conference on Information and Communication Technologies for Sustainability*, Zurich, 2013.

[12] J. Hunt and D. Willetts, "Digital Infrastructure." Council for Science and Technology, 2010.

[13] "Smart Cities Study: International Study on the Situation of ICT, Innovation and Knowledge in Cities," The Committee of Digital and Knowledge-based Cities of UCLG, Bilbao, 2012.

[14] S. R. Rizvi, M. C. Weigle, and M. E. Rizvi, "In VANETs for Rirst Responders," 2008.

[15] J.-S. Park, U. Lee, S. Y. Oh, M. Gerla, and D. S. Lun, "Emergency Related Video Streaming in VANET Using Network Coding," Los Angeles, CA, USA, 2006, pp. 102–103.

[16] M. A. Serhani and Y. Gadallah, "A Service Discovery Protocol for Emergency Response Operations Using Mobile Ad Hoc Networks," presented at the Telecommunications (AICT), 2010 Sixth Advanced International Conference on, 2010, pp. 280–285.

[17] SIAS, "S-Paramics Principle." 2009.

[18] P. Ryder, "The Use and Application of Microsimulation Traffic Models, Interim Advice Note (IAN 36/01)." Highwats Agency, Jun-2001.

[19] S. Algers, E. Bernauer, M. Boero, L. Breheret, C. D. Taranto, M. Dougherty, K. Fox, and J.-F. Gabard, "Review of Micro-Simulation Models." Smartest, 1997.

[20] P. Sykes, F. D. J. Grontmij, R. Bradley, G. Jennings, and G. McDonnell, "Planning Urban Car Park Provision Using Microsimulation," *Traffic Eng. Control*, vol. 51, no. 3, Mar. 2010.

[21] P. Sykes and D. Bennett, "Including ITS in Microsimulation Models," in *The 7th International IEEE Conference on Intelligent Transportation Systems*, 2004, pp. 1018–1022.

[22] G. Thomas, K. Baffour, and T. Brown, "Simulating and Implementing a SCOOT UTC Strategy for a Planned Event," *Traffic Eng. Control*, pp. 117–122, 2009.

[23] SIAS Limited, *SNMP Reference Manual*. UK, 2011.

[24] P. Shen, "Efficient Methods for Trip Generation and Distribution Forecasts: A Case Study," presented at the Compendium of Technical Papers, 64th ITE Annual Meeting, 1994.

[25] Z. Al_azawi, O. Alani, M. B. Abdjabbar, and R. Mehmood, "An Intelligent Disaster Management System Based Evacuation Strategies," presented at the 9 th International Symposium on Communication Systems, Networks & Digital Signal Processing (CSNDSP2014), UK, 2014.