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ICT Applications in Disaster Resilience in a Smart City in Colombo Area of Sri Lanka

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Abstract

Public policy on Smart City, in terms of disaster resilience, is a developing concept in Sri Lanka. To manage disasters in Sri Lanka, several disaster resilience plans have been implemented in collaboration with responsible government bodies. With the purpose of flood mitigation in the Metro Colombo area, a disaster management plan, called "Metro Colombo Urban Development Project" (MCUDP) was initiated in 2012. This plan consists of a sub-project called Real-Time Control System which embeds ICT.

The main purpose of this paper is to discuss how the government utilizes advanced ICT applications in disaster resilience in the Colombo area with reference to the Real-Time Control System (RTC). With the use of both secondary data and primary data, the study examines the effectiveness of ICT application in the disaster resilience plan. The data collection was conducted during August 2019 and November 2019. Descriptive methods were used to analyze the data.

The Real-Time Control system in the Colombo area has not succeeded as intended due to improper utilization of ICT in disaster resilience. Other drawbacks are; the same data is processed by various authorities, lack of free data sharing policies and lack of free data dissemination. To make a Colombo area a Smart City, a proper disaster resilience system needs to be initiated. For that, all planned activities should be implemented without any delay and the Municipalities should be the central coordination point. Also, a proper early warning system, a free data sharing policy with a proper monitoring system must be established, all parties should also collaborate with government agencies, and continuous training must be provided to the relevant officials.

Keywords: Smart City, Disaster Resilience, Real-Time Control System, Sri Lanka.

Introduction

Due to urbanization, the world population is increasing day by day. Most people in the world will live in vulnerable urban areas. By 2025, about 70% of the world population will live in urban areas (Solutions for Smart Cities, 2019). “Approximately 3,351 coastal cities and 64 percent in developing and developed countries, 35 of the 40 largest coastal or coastal cities in Asia, 18 of the 20 largest coastal cities, on the coast river or delta and 17 percent of Asia's urban population live in coastal highlands” (Ranasinghe, 2011).

Most of the countries are already struggling to cope with problems due to rapid urbanization. Today, the concept of smart cities is considered as an emerging trend in urban planning.

Most of the countries have already created smart cities to address various problems including disaster threats. ICT is useful in all stages of the disaster lifecycle including disaster resilience. "In case of a disaster, most cities have become vulnerable due to the lack of access to information, lack of capacity and lack of capital to respond promptly" (United Nations, 2007, as cited in Ranasinghe, 2011). For better living conditions of people in a city, the negative impacts of disasters need to be minimized. In a Smart City, an effective disaster-resilient system is a must. Alonso (2017) pointed out that in order to maintain an effective disaster management plan, countries need to be able to inform and warn their citizens about potential natural disasters. This can only be achieved by combining different technologies that can detect potential risks, identify potential threats to a country, region, or small area, and disseminate information to as many people as possible (Alonso, 2017). In this process ICT applications in disaster resilience plays a major role.

Background of the Study and Problem Identification

As per the State of Sri Lankan Cities Report (2019), Sri Lanka is a South Asian developing country with a population of 21 million people with a land of 65,610 square kilometers. "The country is urbanizing rapidly, with at least 50% of its projected 22 million population expected to be living in urban local authorities by 2020. The estimated urban growth is 3% annually and the urbanization trends show a rapid transformation of rural areas in becoming urban" (The State of Sri Lankan Cities Report, 2019). The majority of the urban population in Sri Lanka lives in disaster vulnerable areas in coastal areas, riverbanks and other vulnerable locations. For example, due to the Tsunami incident which happened on 26 December

2004, a large number of people and property were damaged. There is no effective mechanism for disaster resilience in Sri Lanka.
According to the State of Sri Lankan Cities Report (2019), about 70% of the urban population and 80% of the national economic infrastructure focus on disaster-affected coastal cities. These cities are particularly vulnerable to disasters and the effects of climate change (rising sea levels, sewage, storms, floods, soil erosion) and malaria/dengue epidemics, all of which have a negative impact on human settlements, urbanization and service delivery - especially for the poor. These disasters are often directly related to the country's efforts to achieve the Millennium Development Goals, especially at the local level (The State of Sri Lankan Cities Report, 2019).

Many natural disasters such as floods, landslides, hurricanes, droughts, coastal erosion, tsunamis, sea currents, and sea-level rise threaten Sri Lanka. These natural disasters have resulted in human losses as well as extensive damage and destruction of property.

Colombo city is considered as the commercial capital situated in the Western Province. The city has an area of 699 square kilometers (270 sq. mi) with a population of 5 Million with a very high population density. During the last few years, the city of Colombo has experienced several disasters and natural disasters which have caused loss of lives and serious damages and destruction to property and people in the country. Hence, Sri Lanka faces considerable challenges especially, in the area of urban planning and the country has to be developed with a proper mechanism of disaster resilience. While encompassing all potential disasters, Colombo emerges as the most common region followed by other regions (Ranasinghe, 2011).

Floods in the Colombo and Gampaha districts are mainly caused by unplanned urban migration, the establishment of flood-prone settlements, infrastructure development despite the risk of floods and inadequate rehabilitation of the flood water supply system (Impact of disasters in Sri Lanka, 2016). “In 2016, the worst flooding occurred in the districts of Colombo and Gampaha, which were mostly affected because of the rising level of the Kelani River. Floods in Colombo district have affected 228,871 members of 54,248 families in the 10 divisions namely Colombo, Homagama, Kaduwela, Kesbawa, Kolonnawa, Kotte, Maharagama, Padukka, Seethawaka and Thimbirigasyaya” (Post-Disaster Needs Assessment; Floods and Landslides, 2016). The most affected division in the country was Kolonnawa where 155,062 people were affected, which is 81 percent of the total population in this category (Post-Disaster Needs Assessment; Floods and Landslides, 2016).

A combined post-flood survey conducted in May 2010 by the Disaster Management Center of Sri Lanka revealed that the total number of damage and losses in the five districts of Colombo, Kalutara, Gampaha, Galle and Matara was 5,059 million rupees. The impact of the disaster was disproportionately distributed geographically. The total amount of damage and losses incurred in the western province (3,091 million rupees) was higher than in the southern province (1,960 million rupees) (Impact of disasters in Sri Lanka, 2016). The number of people affected in Colombo district due to the disasters that occurred from 2014 to 2018 is shown in the table below.

Table 01: Number of families victimized by disasters from 01-01-2014 to 31-12-2018 in Colombo District

Name of the Disaster	No of Events	No of Deaths	Injured	Families Affected	Houses Damaged	Houses Destroyed
Flood	59	11	03	81,278	2,831	38
Strong Wind	72	10	19	5,735	6,093	66
Land Slides	03	-	-	06	03	01
Heavy Rains	07	05	25	137	137	-
Fire	31	07	1	80	14	178
Tornado	1	-	-	09	09	-
Total	173	33	48	87,245	9,087	283

Source: http://www.desinventar.lk, 2019

According to the above data, from 2014 to 2018, 87,245 families were affected and 33 deaths and 48 injured persons were reported due to floods, landslides, heavy winds, fire, heavy rains, and tornado and 9,087 houses damaged and 283 houses were destroyed.

To manage disasters in the Colombo area, several disaster management plans have been implemented in collaboration with various responsible government bodies. However, the level of utilization of ICT applications in disaster resilience seems to be very low. There are several weaknesses in using ICT in disaster resilience planning in Sri Lanka.

In the Colombo area, a disaster resilience plan has been implemented with the usage of ICT infrastructure.

This paper discusses how the government utilizes advanced ICT applications in disaster resilience and also examine the effectiveness of applications of ICT in disaster resilience in the Colombo area of Sri Lanka with reference to Real-Time Control System.

Literature Review

This section describes the concept of Smart City, disaster risk reduction and disaster resilience, advanced ICT tools in disaster resilience, best practices of ICT applications in disaster resilience in cities.

Smart City

Smart City is the latest trend in urbanization. Environmental, social and economic sustainability are considered as major components in smart cities design (Alazawi et al., 2014). "There is no universally accepted definition of a Smart City which means different things to different people. The conceptualization of a Smart City, therefore, varies from city to city and country to country, depending on the level of development, willingness to change and reform, resources and aspirations of the city residents" (What is Smart City, 2017). Thus, a Smart City can easily be described as cities that use ICT to improve the quality of life of its citizens while contributing to sustainable development (Capdevila & Zarlenga, 2015). A city is considered to be smart "when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure, fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance" (Capdevila & Zarlenga, 2015). As Alazawi et al. (2014) pointed out Smart Cities relies on an integrated, global infrastructure to provide a high standard of living for its people through efficient and effective services. The aim of the smart cities mission is to drive economic growth and improve the quality of life of the people by empowering local development and the use of technology, especially technologies that lead to intelligent results. (What is Smart City, 2017). "Smart Cities use ICT to enhance service levels, citizen well-being, sustainability, and economic development. Smart City technology can make cities more effective and efficient, which is necessary to give the projected rapid growth in urban populations over the next few decades" (Rujan, 2018). A report on "Smart City Resilience in Japan – 2013" has stated that "Currently, many cities in the world are turning to smart technologies to control traffic congestion, provide users with real-time updates to relieving congestion during peak travel times, smart transportation technologies, such as smart parking management and also cities have already started investing in smart technologies to help and promote a safer community". This report mentioned that Smart Cities have used CCTV cameras with facial recognition to better monitor their citizens and advanced CCTV cameras also have travel and smoke equipment, as well as fire alarms and cities around the world that place increasing importance on building resilience to natural disasters. "Threatened by a natural disaster, smart cities can use modern ICT infrastructure and analytical capabilities to improve and coordinate the information flow between multiple public agencies, such as transport authorities, emergency services and energy providers, and citizens and with the help of mobile networks, a city municipality can reach the majority of its citizens at a short notice" (Smart City Resilience in Japan, 2013).

Hartama et al. (2017) stated that “a good Smart City can be carried out using the IT Resource owned by the City Government in the face of a disaster. The use of IT consisting of resource infrastructure, human resource, and relationship resource can help mitigation and preparedness of natural disasters occurring in big cities. The benefits of building Smart City are not only to provide benefits to government authorities but also can help people to guard against disasters and manage efficiently to achieve goals” (Hartama et al., 2017).

Disaster Risk Reduction and Disaster Resilience

The idea of resilience comes from the environment. Holling (1973) is often cited as the first to apply and explain the concept of resilience in the field of environment after publishing his article entitled "Resilience and Stability of the Eco-Logical Systems" (as cited in Mayunga, 2007). Further, Holling (1973) defined the term resilience for the ecosystem as a measure of the ecosystem's ability to engage in transformation and is ongoing (as cited in Mayunga, 2007). Two decades later, he reconsidered his definition and redefined the concept of resilience as a “buffer capacity or the ability of a system to absorb perturbation, or the magnitude of the disturbance that can be absorbed before a system changes its structure by changing the variables” (Holling, 1973, as cited in Mayunga, 2007).

According to Alwang et al. (2001) resilience is “the ability to resist downwards pressures and to recover from a shock” (as cited in Mayunga, 2007). Thus, Disaster Risk Reduction is to minimize disaster risk and disaster resilience is the ability to bounce back from the negative impacts of disasters.

Advanced ICT Tools in Disaster Resilience

Various ICT tools are used in disaster resilience. Real-time Control System is one of the disaster resilience methods, especially, in flood mitigation. Some examples of the application of Real-Time Control System of several countries are described below.

The USA government has introduced new flood alert system in Houston with the support of Rice, Houston and Galveston Universities which give warning to residents in real-time in Houston in 2019. They have used a lot of technology from the Brays Bayou system to improve the White Oak system, which relies on the actual amount of radar-based rainfall as the rain falls near the water (Mccaig, 2019). Further, he stated that the system takes new radar information every five minutes and creates a flood map, which is updated every 15 minutes. "The colour coding shows where and how to navigate potential floods. The flood map not only has the ability to zoom in and out of violent areas and highways that have been flooded several times in the past, but also shows flood hazards in selected critical transport areas in White Oak Bayou" (Mccaig, 2019).

Puerto Rico in the United States has adopted a Real-Time Flood Alert System (RTFAS) web-based computer program. Developed as a data collection tool, and designed to enhance the ability of emergency managers to accurately and accurately predict flood conditions in Puerto Rico (Puerto Rico Emergency Management Agency, 2019). Further, Puerto Rico Emergency Management Agency (2019) revealed that the system includes software and relationship databases to determine temporary and temporary rainfall distribution, water levels in streams and lakes, and associated storms to detect potentially dangerous and potential flood conditions. The interface contains several tabs where the user can quickly access the data collected and processed by the above agencies (Puerto Rico Emergency Management Agency, 2019).

The wireless flood monitoring system in southern Thailand was established with the aim of using remote sensing data in the process of early warning, mitigation and management of flood disasters in floodplains (urban and port) (Sunkpho & Ootamakorn, 2011). As per Sunkpho & Ootamakorn (2011) the system is designed to monitor important flood-related information (water level, rainfall, and rainfall) and generate timely warnings (Short Message Service (SMS), FAX, and email) in the event of floods, which will be distributed to local stakeholders and these flood warnings are based on the results of a point-predicting model, called warning profiles. Further, the authors noted that it serves as a source of information between the relevant authorities and experts in their work of producing and sharing information in the flood season. This system serves as a source of information from the public web, responding to their need for information about the state of water and floods (Sunkpho & Ootamakorn, 2011).

As noted by Natividad & Mendez (2018) in the Philippines, they have established a Flooding and First Warning using an Ultrasonic Sensor. Ultrasonic sensing techniques are widely used in various fields of engineering and basic science. As per the Natividad & Mendez (2018) another advantage of ultrasonic sensors is its outstanding exploratory power within the non-destructive purpose because ultrasound can rotate through any type of media including solids, liquids and gases. This program provides information on water quality detection and early warning systems (via website and/or SMS) alerting affected agencies and individuals about any possible flooding event (Natividad & Mendez, 2018). “A questionnaire has been put in place to make it more interactive where people in the community can ask the actual water level and the location of the area you want or the area affected by the flood with an SMS keyword. The innovation of this work falls under the use of Arduino, ultrasonic sensors, GSM module, web monitoring and early warning system in helping participants reduce flood-related injuries" (Natividad & Mendez, 2018).

Best Practices of ICT Applications in Disaster Resilience in Cities

Alcatel-Lucent (2012) mentioned that "there are more than 100 smart city projects underway globally. Scale and the rate of ICT utilization differ from one to another. Main areas in which the smart city approach has been initiated can be listed as energy, telecom networks, transportation, business support, intelligent community framework, public utilities, industry sectors and eco-sustainability" (Alcatel-Lucent 2012, as cited in Karadag, 2013). "Resilient communities have sound and practised emergency response arrangements. While work is being progressed in relation to warning systems and new technologies for communicating timely messages when disaster attacks, more need to be done to ensure communities receiving and interpreting information and take appropriate actions" (COAG National Disaster Resilience Statement, 2009). Examples of the best practices of ICT applications for disaster resilience in cities are given below.

In Australia, they have a Trusted Information Sharing Network (TISN) for Critical Infrastructure Resilience. Through TISN, government and business partners are working together to raise awareness of risk in critical infrastructure, share information on threats and risks, develop strategies and strategies to assess and reduce risk, and build resilience in organizations. (COAG National Disaster Resilience Statement, 2009).

In Afghanistan, their irrigation systems are well maintained and fully operational where, the advanced warning from the satellite imagery would help Government and communities better prepare for, and manage drought (Asia-Pacific Disaster Report, 2017).

The UK energy sector under the direction of the Energy Networks Association (ENA) has created an Engineering Technical Report on Resilience of Flooding of Grid and Primary Substations (ETR 138). The electricity transmission and distribution industry has set targets (standards) for the durability of various assets in their sector (The World Bank, 2012).

In Japan, where the federal government launched an emergency warning system in February 2007, it provided its municipalities with a plan and solution to respond to natural disasters. Local and national governments around the world have learned the Japanese way after the 2011 earthquake and used it as a blueprint for their warning and recovery plans (Smart City Resilience in Japan, 2013). The report of the 'Smart City Resilience in Japan' (2013) revealed that Japan's city municipalities, which serve as key liaison centers for the use of disaster prevention and recovery have direct responsibility for emergency response operations. All three mobile network operators in Japan, NTT DoCoMo, Au and Soft Bank Mobile have used the Cell Broadcast Service System, designed for this purpose, to send text messages in five languages to mobile users warning them of emergencies. Also, the Japanese Broadcasting Corporation (NHK) has warned people and radio stations to transmit similar messages. It also disseminated information on the effects of earthquakes and tsunamis, as well as emergency shelters (Smart City Resilience in Japan, 2013).

Buenos Aires is a port city built on nine rivers, where severe flooding is unusual. Buenos Aires has upgraded and updated its IT infrastructure with

SAP's Mobile Platform technology and SAP Process Integration technology (www.india.smartcitiescouncil.com, 2018). “It has installed radar-enabled sensors in the canals to monitor flooding and 1500 km of pipeline infrastructure is operational. The information is included in the SAP HANA (SAP High-Performance Analytic Appliance) program in which city authorities analyze weather reports, the status of waste collection, and citizens' complaints about blocked canals and uncontrolled waste. The SAP HANA system supports city officials to analyze sensory data in real-time and enables them to take timely action in the event of a crisis, such as a flood” (www.india.smartcitiescouncil.com, 2018).

Methodology

This study describes how the government utilizes advanced ICT applications in disaster resilience and also examines the effectiveness of applications of ICT in disaster resilience in the Colombo area of Sri Lanka with reference to Real-Time Control System. Both primary data and secondary data were used. The primary data was collected through in-depth interviews with officers from relevant government authorities (Ministry of Megapolis and Western Development, Disaster Management Centre) and with people who live in the Colombo area (Colombo Municipal Council area, Sri Jayawardanapura Kotte Municipal Council area, Dehiwala- Mount Lavinia Municipal Council area and Kolonnawa Urban Council area). Convenient sample method was used to select the respondents from related areas. Ten (10) respondents were selected from each area. Descriptive methods were used in data analysis. Effectiveness was examined in terms of the four objectives of the Real-Time Control System and its weaknesses were examined from both officials’ and citizen’s perspectives.

Analysis and Discussion

ICT Applications in Disaster Resilience in Colombo Area in Sri Lanka

This section discusses how ICT applications have been used in disaster resilience in Colombo area in Sri Lanka.

The Metro Colombo Urban Development Project (MCUDP) was initiated in 2012 with the intention of flood mitigation in Colombo area. This is an attempt to transform the Colombo Municipality into a modern, world-class, middle-class country. The government introduced an outstanding economic and physical rehabilitation program including sustainable, long-term, disaster risk management plan (Projects Highlights, 2013).

This project is funded by the World Bank and the total project cost is USD 321Mn and the project started on July 2012 and is in progress at the moment (www.landdevelopment.lk, 2019).

The main objective of this project is “to complement ongoing urban regeneration programs of the Government of Sri Lanka by reducing the physical and socioeconomic impacts of flooding in the Metro Colombo Region and improving priority local infrastructure and services” (www.landdevelopment.lk, 2019). It has been pointed out that the current outgoing capacity of the system is insufficient for a hazardous event and the filling of the existing storage facilities increases the situation. Therefore, a lot of reductions are expected under the MCUDP, while maintaining existing storage facilities (www.landdevelopment.lk, 2019). The first major involvement projects under MCUDP was completed by the end of 2014. According to the Sri Lanka Land Development Corporation website (2019), detailed projects for the major projects shown, have also been completed and implementation is underway at a number of project boundaries.

The Metro Colombo Urban Development Project was established under the auspices of the Megapolis Department of Western Development. Managed by the Project Management Unit, the Metro Colombo Urban Development Project is made up of three components of the Project Implementation Agency (PLAs); Sri Lanka Land Reclamation & Development Corporation (SLLRDC), Urban Development Authority (UDA), and Colombo Municipal Council (CMC) (www.landdevelopment.lk, 2019).

There are 19 sub-projects under the Metro Colombo Urban Development Project. Real-Time Control System project is one of the sub-projects. The following section describes about this system.

Real-Time Control System (RTC)

The construction of the Real-Time Control system was expected to operate flood control areas based on rainfall conditions and flood strength. It brings environmental services and information for integrated water management in the city (Projects Highlights, 2013).

This system could make aware of the rainfall conditions of the higher water feeding areas of the Kelani river and then could predict the flooding levels, and it helps to predict what areas will be affected by flooding, how many habitats will be affected by flooding, etc.

The project has several objectives;

1. Develop an integrated flood management and water management system
2. Provide early warning support in the Metro Colombo area
3. Establish appropriate rules for the operation of flood control areas such as pumps and storage areas with regard to potential storage and use of water to create a humorous urban environment

4. Assess current and future water-related risks in Megapolis from urban development and climate change

To achieve the above objectives, a number of activities are planned as follows;

1. Improvement of rainfall data integration system, using available sources such as satellite rain monitoring, statistical weather forecasts and rainfall estimates
2. Establish rainwater monitoring stations in the Colombo area
3. Improve drainage/river/lake water quality monitoring measures and the establishment of a canal flow measurement system
4. Establish communication links from monitoring devices to flood control and water management
5. Develop a flood forecast system that includes rainwater harvesting, water forecast model, hydrodynamic flood forecast model
6. Build a decision support system using all inputs to calculate the efficiency of the gates and pumps and set up a SCADA control system for real-time pumping
7. Establishment of a data collection center, information dissemination and provision of Metro Colombo water management services
8. Establish a system for continuous research and development to assess the risks posed by urbanization and climate change and to propose remedial measures

Components of the Project

As mentioned in the project plan, it contains the following five items.

• Urban Water Center which is an infrastructure structure where monitoring and forecasting information is collected, analyzed and disseminated

• Modeling systems that include (a) Rain integration and forecast (b) Hydrologic and Hydro-dynamic forecast to monitor and predict rainfall and (c) Risk assessment and implementation processes

• Computer environment with servers for modelling, archiving and distribution with web-based content management system. The computer environment is set in the cloud platform

• A monitoring and control system consisting of rainfall measurements, water levels and SCADA control units for local operations that provide real-time information to the facility

• Stakeholder collaboration and access methods

Effectiveness of the Real-Time Control System

This section examines the effectiveness of the Real-Time Control system and highlights its weaknesses from both officials' and citizen's perspectives. Effectiveness was examined in terms of the four objectives of the Real-Time Control System.

Officials' Perspective

In here, information was gathered from the officials of the Ministry of Megapolis and Western Development by conducting informal interviews and website surveys. The Ministry of Megapolis and Western Development is a major body responsible for the real-time management system. In developing an integrated flood management and water management system as a priority, a number of projects have been completed. Currently, the first stage of the real-time monitoring sensor arrangement has been started. It has three types of devices, namely; "(a) weather stations that measure rainfall and other weather parameters (b) rain gauges that measure only rainfalls and (c) water level sensors using both radar and ultra-sonic devices". Rainfall patterns are most prevalent in schools on the Kelani River and bring real-time estimates to the RTC system (www.landdevelopment.lk, 2019). As per the Sri Lanka Land Development Corporation website (2019) schools have access to RTC facilities through their educational activities. Three types of inundation simulations are now available at RTC and are used to predict daily performance. Those are the types used to predict when there is a threat of floods in the city (www.landdevelopment.lk, 2019).

Currently, in RTC system of Metro Colombo Urban Development Project, 16 rainfall levels and weather stations within the Kelani River Basin have been adjusted to block the distribution of rain within the Kelani area (www.landdevelopment.lk, 2019). To avoid any problems with data access or data transfer in the CUrW (Center of Urban Water) database, these gauges need constant maintenance. Therefore, regular field visits are conducted by RTC Research engineers (www.landdevelopment.lk, 2019). As mentioned in Sri Lanka Land Development Corporation website (2019), this will enable RTC to detect any potential field problems with sensors and communication modules. Internet of Things (IoT) is powered by Gauges of water levels tested and installed in the Colombo canal system. These devices will assist RTC to obtain high accuracy of water timing data to be used for flood monitoring and to improve the reliability of the flood forecast system and to follow the Model systems have also been improved and some of them are in the graduation phase (www.landdevelopment.lk, 2019).

- The default satellite rain data feed for hours is available and installed.
- System A three-day climate plan for a 3km state of the country is being developed and automated.
- A real-time data processing platform with both temporary and local domains is being phased out. A hydrological model has been developed and validated.
- Models Active power models (250m and 150m resolution) have been developed and validated. A detailed modelling system (in 30m resolution) is now complete and operational once notifications have been made.
- In the risk assessment, the city infrastructure has now been completed and the potential for damage to the flood structure (pre-disaster damage assessment) has been completed. Mapping information will be done soon to assess economic vulnerability. Areas that are likely to be flooded and people at risk of flooding have been established.

The computational environment is already established in Google Cloud. It helps to establish the communication links from the monitoring devices to the flood control and water management centre. A Centre for data integration, information dissemination and providing water management services for Metro Colombo is still not established. However, they have a plan to build a new building in land for this purpose.

Providing early warning support for the Metro Colombo area is still under development. But the system does not yet have a procedure to give the direct warning to the public, because there are a number of government agencies that provide information to people during a disaster and the government decides which agency to provide information. But the system has the capability to send warnings directly to the public. Further, information on water levels obtained from 42 places such as Yakbedda, Folk Art Center and Wellampitiya Diyasaru Uyana is constantly updated in this system. This shows the fluctuations in the water levels and can be used to monitor the behaviour at risk level. Also, the rainfall data obtained from 27 selected monitoring stations are predicting the rainfall scale.

When achieving the objective of developing optimal operational rules for the flood control facilities such as pumps and storage facilities considering also the potential storage and use water to make a pleasant urban environment, pumps and storage systems are being developed under this project for flood control. These systems are to be built along the rivers (Kelani River), which is the major source of flooding in the city of Colombo. The goal is to create an operating system to automate all of pumps and storage systems. The operating system is designed to automatically execute some commands, such as when to open them, and at what water level they should be opened. But it is still at the test level.

Climate changes in Sri Lanka mainly occur due to rising temperature and rising sea level. Under the influence of these two factors, the method of predicting rainfall for the next 50 years is studied by examining the rainfall pattern of the past years and the present rainfall pattern. But this system is also still in the experimental level.

The third and fourth objectives of the system have not been implemented yet. Following table shows the completion level of planned activities under the Real-Time Control system.

Table 02- Completion Level of Planned Activities

Objective	Item	Status of the completion level
1. Developed an integrated flood control and water management information system	real-time monitoring sensor deployment	Has been started
	rain gauges	Located and they deliver real-time measurements
	Three inundation simulation models	Established
	Automated Satellite rainfall data feeds	Received and integrated
	Weather forecast system for three-day forecasts	Established and automated
	Real-time data assimilation platform	Established and automated
	Operational hydro-dynamic models	Established and confirmed
	Detailed inundation modelling system	Complete and used once alerts are generated
	Building footprint of the city	Completed
	Pre-disaster damage	Completed

		estimation	
		Exposure mapping	Will be carried out in the near future
		Possible evacuation locations and people at risk for different flood frequencies	Have been established
		Computational environment in Google Cloud	Already established
		A Centre for data integration, information dissemination and providing water management services	Not established
2.	Provide early warning support for the Metro Colombo area	Early warning system	Not established
3.	Develop appropriate rules for the operation of flood control areas such as pumps and storage areas to take into account the potential storage and use of water to make the city more attractive.	Automatic system for operating pumps and storage system	Not started

4.	Assess current and growing future water-related risks to Megapolis from urban development as well as climate change	system for predicting rainfall for the next 50 years	Not started

Source: Field Data

Citizen's Perspective

Forty respondents were interviewed from four areas (Colombo Municipal Council area, Sri Jayawardanapura Kotte Municipal Council area, Dehiwala-Mount Lavinia Municipal Council area and Kolonnawa Urban Council area) to get the feedback related to the system. Even though the government has constructed pumping stations to pump stormwater from the Colombo catchment area into the Beira Lake and also New Mutwal Storm Water Drainage Tunnel built in Colombo North aiming to mitigate the physical impact of floods in the Colombo metropolitan area, people are not aware of any information regarding the flood mitigation system.

The RTC system plans to provide early warning support for the Metro Colombo area, but people have not received any message from the early warning system. However, early warning messages were given only to Police and Grama Niladhari officers. Majority of residents are not aware of such a flood warning project. However, people suggested that mobile early warning alerts are the easiest method to warn the public.

Only people who live near the Kelani River are aware of the establishment of the water level monitoring system. Thus, the people in these areas do not over panic in case of a water level rising. They can always check the water

level and decide to evacuate. Also, they are not given services like flood controlling facilities and information system regarding water management.
In this context, the Real-Time Control (RTC) system project has been able to complete several activities to fulfil only one objective.

Weaknesses of Using ICT Applications in Disaster Management Plans in Sri Lanka

There are some drawbacks of using ICT in the disaster resilience in Sri Lanka. These limitations are discussed as follows;

1. *The same data is processed by various authorities*

The main problem is that the same data is processed by different authorities such as Disaster Management Center, and Meteorological Department.

2. *Lack of free data sharing policies*

Another problem is the lack of free data sharing policies in Sri Lanka. That means, there is no policy to share disaster-related data which are collected by one agency to be shared with other agencies.

3. *No free data dissemination*

There is no free data dissemination in Sri Lanka; the relevant institutions have to pay some payments on disaster-related data. For example, the Disaster Management Center pays for the data they receive from the Meteorological Department for its analysis because the Meteorological Department has collected these data for research purposes. Due to this problem, data is not used in an effective manner, where some data may be expired. Also, there are no developed information systems and is also a big problem.

Conclusion and Recommendations

Suggestions for Policy Measures

In a Smart City, a proper disaster resilience system is a must. In order to that, the Sri Lanka government has established the Real-Time Control (RTC) system by using advanced ICT tools in disaster resilience. However, the study revealed that the effectiveness of the Real-Time Control (RTC) system is limited. Therefore, with the intention of maintaining effective disaster resilience, proper utilization and better implementation of ICT, the following policy measures have been suggested.

- All planned activities should be implemented without any delay.
- The municipalities should be the central coordination point. For an example, Japan’s city municipalities, which act as central coordination points for the implementation of disaster prevention and recovery, have a direct responsibility to carry out emergency response operations (Smart City Resilience in Japan, 2013).
- There should be a risk resilient critical infrastructure. Under that, a proper comprehensive emergency warning system should be established with observation systems, information gathering capabilities, data analysis, and decision-making applications and all linked together interactively. In Japan, they have a comprehensive emergency warning system, developed by the Japan Meteorological Agency, which highlights how intelligent cities can, during a disaster recovery integration, continue to take data from surveillance systems and feed data processing forums (Smart City Resilience in Japan, 2013).
- A property monitoring system should be established and a proper feedback system should be established to get ideas of the public.

- In disaster resilience planning, all parties such as mobile operators, TV and radio channels, utility and transportation companies, and technology vendors should be in cooperated along with government agencies.
- A proper early warning system should be established. By that system, people can receive early warning messages in the case of a disaster. Sunkpho & Ootamakorn (2011) pointed out that the wireless flood monitoring system in the south of Thailand has generated Timely alerts (Short Message Service (SMS), FAX, and email), in the event of a flood, will be distributed to local stakeholders. The system acts as a source of information based on the public web, responding to their need for information about the state of water and floods.
- Free data sharing policy should be established to the relevant institutions for getting disaster-related data without any payment.
- Training must be given to the officials who are responsible in maintaining the system.

Conclusion

Sri Lanka is facing various disasters. Disaster resilience is important to reduce the impact of disasters. The concept of disaster resilience has not been properly included in the Disaster Risk Management policy research in Sri Lanka. Public policy on Smart City in terms of disaster resilience is an emerging concept in Sri Lanka. To become a Smart City in the Colombo area, there should be a smart resilience system. In this context, ICT can play a vital role.

By using the Real-Time Control system, the government of Sri Lanka has used advanced ICT tools in disaster resilience. The system planned four objectives to achieve within the period of 2012 to 2020. However, in the stage of implementation, only one objective was achieved that is developing an integrated flood control and water management information system and other objectives were not achieved.

Proper utilization of ICT is an advocate, to make Colombo area a Smart City. To manage disasters in Sri Lanka, some disaster resilience plans have been implemented. But it is still in the initial stages. Therefore, the utilization of ICT in disaster resilience, especially the application of RTC is not properly and fully implemented in Sri Lanka. In order to maintain effective disaster resilience, proper utilization and better implementation of ICT are essential which will lead for a better living condition for its citizens.

Limitations and Further Research

The research has a number of limitations which needed to be addressed. For example, the citizen's perspective was taken from limited respondents. Therefore, studying citizen's perspective from a larger sample through a longer period would give a better understanding about the real-time control system. Also, this study was conducted covering only Colombo area. Taking the whole country is impracticable and not effective due to time constraints. Therefore, further studies could be undertaken by covering other parts of the country with empirical data.

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