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# Disaster Resilient Rescue of Coastal Community on Cyclone Warning

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## Abstract

Bangladesh is in the front line of battlefield of disasters due to geographical location and global warming faced over 200 natural disasters in past 40 years and most of the disasters were cyclones. People need to be evacuated and rescued before a cyclone landfall. In current practice, multipurpose cyclone shelter (MPCS) provides short-term safety for the disaster victims in Bangladesh, where people are rescued after disasters which cannot ensure survival of lives. This study aims to develop a method for efficient evacuation and rescue to reduce death tolls in the events of disasters. This study used Wi-Fi scanner and smartphones to detect people. An inbuilt index that includes name, address, mobile number, photo, service set identifier (SSID), and media access control (MAC) of smartphone was developed for 90 registered participants. In this controlled experiment, few new participants turned on hotspot in every five minutes. A new index of people with MAC/SSID was developed in MPCS simulating an emergency. Missing people were detected by comparing inbuilt index and new index, and ordered them self-evacuation. This method captured 100% evacuees. Most importantly, the proposed method will reduce death tolls because the people are rescued earlier to a disaster hits a specific area.

**Keywords:** Wi-Fi scanner, MAC/SSID, cyclone, disaster, hotspot, rescue, evacuation

## 1. Introduction

Bangladesh is one of the topper rank disaster prone countries due to its geographical location and global climate change. It is one of the largest delta areas and comprises three major rivers including Ganges, Brahmaputra and Meghna [1, 2]. Climate change accelerates catastrophic tropical cyclones and storm surges during the period of pre-monsoon (April–May) and post-monsoon (October–November) in Bangladesh [3]. In recent decades, devastating cyclones with storm surges, e.g., Amphan (2020), Fani (2019), Bulbul (2019) landfall almost every year that make the coastal area of Bangladesh more vulnerable [4]. During the period of 1969–1990 on an average annually thirteen depressions were formed in the Bay of Bengal and adjacent Indian ocean where nearly 4.6 was altered on to cyclones and almost in all the causations were resulted into disasters [3]. In 21st century, 13-cyclones have already hit Bangladesh [4]. So, cyclone is a common phenomenon in the coastal zone of Bangladesh. Furthermore, flood is a regular event in Bangladesh, which

causes extensive damage to properties and seasonal crops [2]. Following the great Bhola cyclone (1970) and cyclone Gorky (1991) caused death toll of 500,000 and 138,000 people, respectively [3]. The huge death tolls in 1970 is attributed to the inefficient cyclone tracking system, improper early warning and issuance of evacuation order.

In order to increase the awareness and reduce the death tolls, GoB developed early warning system and cyclone preparedness program (CPP). Bangladesh Meteorological Department (BMD) and Storm Warning Centre (SWC) are involved in weather forecasting and warning. Warning is passed as special weather bulletin via fax, teleprinter, telephone etc. to radio, television, press media/news agency, CPP, disaster preparedness programme (DPP) for necessary action and messages to the prime minister's office, ministry of disaster management and relief (MoDMR), directorate of relief, concern ministries, airport, seaport, naval base etc. Fishermen get messages from the seaport at least one/two days advance [5]. CPP volunteers circulate warning via hand siren, megaphone (e.g., miking), signal light and flags [5], while local stakeholders claimed that siren and flag do not remain active in maximum cases. Besides, most of the poor coastal residents do not have access to online newspapers, radio, television and they do not get the warning in proper time and this miscommunication of information makes them vulnerable and discourage to evacuate [1, 3, 6].

As a part of preparedness, GoB, NGOs and development partners constructed more than 2500 MPCs in 19 coastal districts of Bangladesh including the study area Barguna [7, 8]. Few shelters have been extended with the killas as a shelter for livestock. Approximately 200 raised earthen platforms called killa have been constructed in the cyclone prone areas and one killa can accommodate 300–400 livestock. Most of the killas have been found are full of bushes and become a habitat for snakes and harmful insects due to lack of maintenance [9]. The CPP was established in 1972 was collaborated with Bangladesh Ministry of Disaster Management and Relief (MoDMR) and the Bangladesh Red Crescent Society (BDRCS) with 49,365 trained volunteers and 16,455 of those are women [9]. Those volunteers are dedicatedly involved to disseminate cyclone warning signal, assist people to move in MPCs, rescue distressed people and provide first aid to the injured people [1].

The capacity of MPCs varies from 400 to 1600 people [8]. Sometimes small capacity and inadequate facilities for women discourage the people to be evacuated there. Community people are encouraged to be evacuated in MPCs as safer places before a cyclone landfalls.

The conventional evacuation systems include early warning, notice for evacuation, miking by volunteers, and cyclone shelters preparedness. Emergency medical and food supply are ensured by the local authority with the support of central authorities. When early warning about devastating cyclones is disseminated, the community people need to be evacuated in MPCs. Generally, rescue operation is conducted after disasters which cannot save some lives from disasters. Current system cannot ensure evacuation of all vulnerable community people because the evacuation is a volunteer/self-evacuation process. During cyclone SIDR 90% of vulnerable people were warned but only 10% people evacuated [1]. Therefore, community people should be rescued before a disaster occurs.

While evacuation order is issued, most vulnerable people should evacuate to MPCs. Many people stay in their houses to protect their properties, e.g., domestic animals. In MPCs, maintaining a manual register to confirm the name and number of people is very difficult during disasters. Therefore, the shelter authority cannot immediately identify the missing people in the community before the disaster. Therefore, a system should be developed to ensure rescue of all people before a disaster hits a specific area in the era of information and technology. Recently,

Wi-Fi scanner, a cheap and available technology, has received much attention to detect the human mobility. The Wi-Fi scanner makes an active scan by using the probe requests. A probe request is a special frame sent by a client station requesting information from either a specific access point, specified by SSID, or all access points in the area, specified with the broadcast SSID [10].

This research aims to develop a more disaster resilient evacuation system where authority can easily identify the missing people and rescue them before a cyclone landfalls. The smart-phone and Wi-Fi scanner can contribute for the identification of the missing people. The Wi-Fi scanner can detect all the people within the shelter with turned on Wi-Fi in their smartphones. Therefore, it will be very easy to indexing the missing people to be rescued before cyclone landfalls using Wi-Fi scanners and smart-phones. This method helps to rescue the people earlier to a cyclone hits the area. In the proposed method, the people will be rescued earlier to the cyclone. As a result, all the stakeholders will be safe in the event of a cyclone.

### **1.1 Related works**

As discussed above evacuation and rescue response depends on different factors. Manual evacuation through warning messages cannot be assured successfully. In the era of information and technology, technological interventions are noticed for disaster mitigation and evacuation responses. Global Positioning System (GPS) and Global Service for Mobile Communication (GSM) web services are together referred as Smart Life Tracking and Rescuing (SLTR) system are being used for the disaster management in India. This GPS and GSM web services are effective to identify the affected areas and possible routes to reach the location [11]. Wireless sensor networks are also used for detecting disaster, providing alert signals and completing rescue operations immediately [12, 13].

Sensor using internet of things (IoT) is being used in vehicular tunnels, and it detects the vehicle where an accident occurs [14]. A server that receives location of mobile phone user in the affected area with their environmental condition is also provided. After that automated voice inquiries store their responses and forward to emergency assistance agencies, are also displayed in electronic map and involved in rescue operation [15]. Requesting rescue by a user terminal is controlled by an informing server and a rescue centre through mobile communication network. When informing, server provides signal to rescue centre and they become able to detect the position of user terminal and evacuation can be maintained successfully [16]. Twitter can also be used for rescue operation considering some disadvantages [17].

During disaster and/or rush hour, traffic congestion can be created in the road for evacuation and this problem can be managed through contraflow evacuation method. This type of technology helps to evacuate the distress people safely without making any congestion in the road [18]. Using of Doppler Radar for cyclone wind field monitoring and identifying location of tornadoes is prescribed in some cases [19]. For effective and reliable network management in disaster prone area collaborative rescue robots are used [20].

Now-a-days, smart devices are being used for the detection of the mobility of vehicles and people by identifying the Media Access Control (MAC) of such devices, e.g., smartphones, Wi-Fi scanners. Abbott-Jard et al. [21] studied the travel time using Bluetooth scanners by detecting MAC of smartphones within its communication range and the vehicle is detected while it passes through the range of a detector. Wi-Fi Scanners are also being used for the detection of vehicles using smart devices [22–26]. Shiravi et al. [26] used Wi-Fi scanners for travel time estimation with combination of Bluetooth and Bluetooth increases the reliability of data. Similar applications are noticed in different existing studies [22, 25].

Despite the application of GPS and GSM for disaster management in different parts of the world, Wi-Fi scanners are not still being used for the detection of people in MPCs in order to promote the early rescuing of people to reduce death tolls. From this point of view this research focused on developing disaster resilient method for successful disaster evacuation and reducing death toll by detecting human mobility in the cyclone shelters.

## **2. Methodology**

The study proposes a disaster resilient evacuation and rescue method in case of a disaster, e.g., cyclone, flood, and storm surge. This research develops a very simple method of detecting the missing people in the catchment area of a cyclone shelter in order to rescue them before a cyclone landfalls. There are several techniques for the detection of human mobility, e.g., Wi-Fi scanner, Bluetooth scanner, global positioning system (GPS) and call record data (CDR). This study proposes a method for detecting human mobility and rescuing them earlier to disasters by using Wi-Fi scanner and smartphones. Wi-Fi probe request identifies the MAC of a smartphone while Wi-Fi is turned on. Wi-Fi probe request identifies the SSID of a smartphone when the hotspot is turned on. By observing MAC/SSID, it observes the mobility of people.

A field experiment was conducted in a MPCs at Patharghata in Barguna district of Bangladesh. Total 90 people participated in the experiment who were community people. The index of the participants was made by name, address, mobile number, SSID and MAC. A MacBook Pro was used as a host computer and Wi-Fi scanner. The host computer used Wi-Fi probe request. All participant used their smartphones. They turned on the hotspot of their smartphones on request. The turned-on Wi-Fi scanner detected the preregistered participants who turned on hotspot of their smartphone in every five minutes of time interval. The index of the preregistered participants was compared with the new index during the experiment, that gave the index of missing people. The index of missing is required to be updated continuously. If some people go to different shelter other than host shelter, the inter-shelter data processing will identify the actual missing people. The proposed method includes: a) inbuilt index of people, b) indexing of people in the shelter, and c) updating of index and determining the missing people continuously. Due to the privacy reason, we cannot present all information of participant, e.g., photos, mobile number etc.

### **2.1 Inbuilt index of people**

An index of the registered participants (resembling community people in the catchment area) of a multipurpose cyclone shelter (MPCs) was prepared earlier to the events of an emergency. The registration of people was facilitated by the authors as imaginary shelter authority. The registration included the name, address, photos, mobile phone number, and MAC and SSID of smartphone. This inbuilt index was used for the search and rescue of the people. Each MPCs is concerned of people who have already registered. **Figure 1** shows the process of developing inbuilt index.

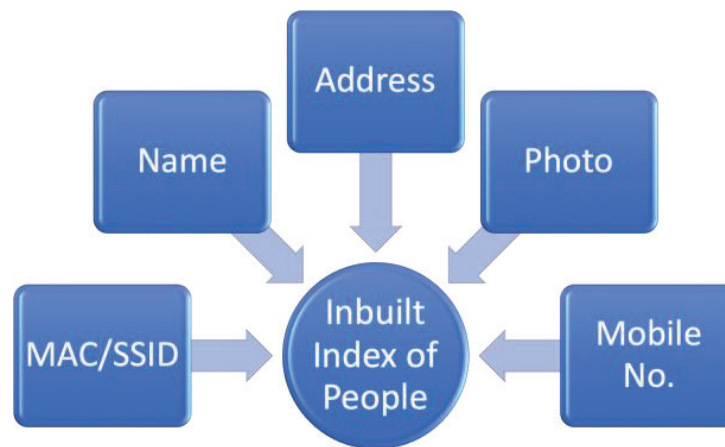
### **2.2 Identification of missing people**

The administrative staff of the MPCs is to prepare the control room and necessary instruments while hoisting the danger signal of cyclone or flood. The people

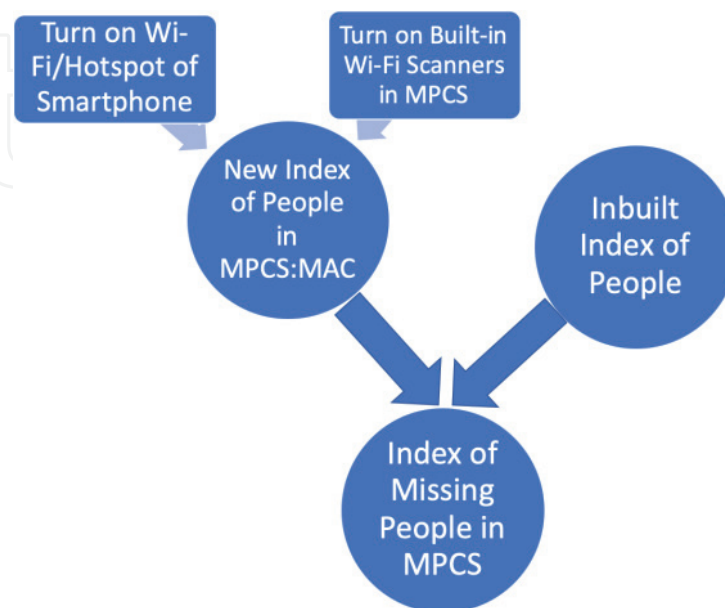
are suggested to move to the shelters while the evacuation order is issued by the authorities of disaster management (DM). The participants were divided in some groups to facilitate the experiment. The few groups of participants in the shelter were requested to turn on the Wi-Fi/hotspot of their smartphones at a time. The inbuilt Wi-Fi scanners detected them by the MAC/SSID and made a new index of people in MPCs. The new index of people in the shelter comprises the MAC and SSID. The inbuilt index and new index were compared which gave the index of missing people. The procedure of detecting the missing people in the shelter is shown in Figure 2.

### 2.3 Updating the index of the people in the shelter

The index of the missing people is required to be updated continuously. This study considered five minutes interval for updating the index of missing people. In every five minutes, the newly arrived people were observed in the shelter. A preinstalled software is to develop that has to proceed data and develop the index of arrived people in the shelter. The inbuilt index and new index have to be cross



**Figure 1.**  
*Inbuilt index of the stakeholders in the catchment area of a MPCs.*



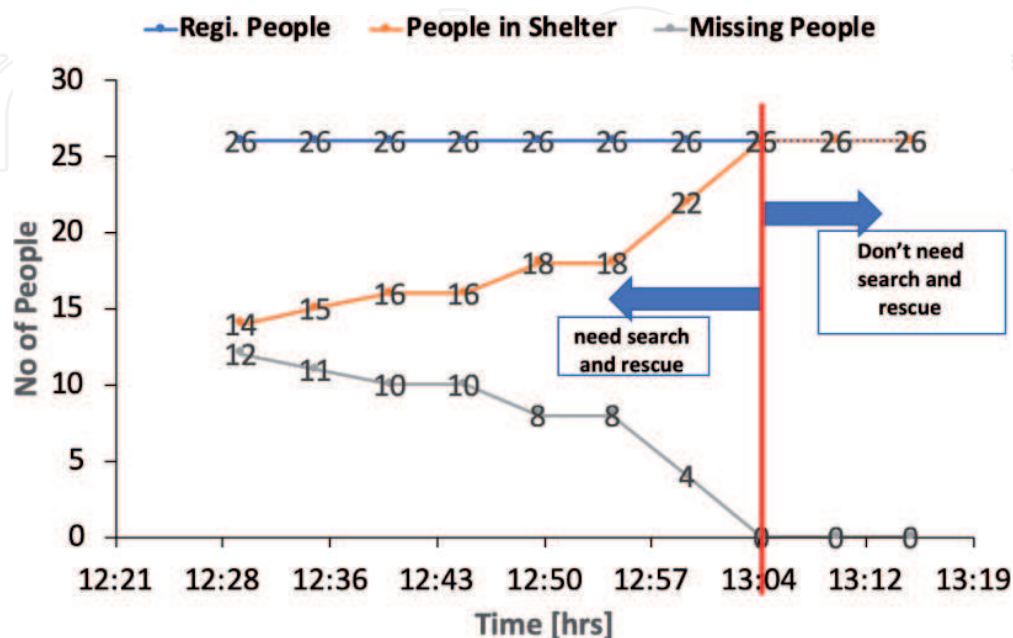
**Figure 2.**  
*Indexing of the people in the cyclone shelter and detection of missing people.*

matched that may produce the index of missing people in the shelter. The updating of index notified the list of the missing people to all refugees in the shelter. **Figure 3** shows the process of updating the index of missing people.

The evacuation of the missing people needs to be confirmed by the shelter's authorities as shown in **Figure 4**. The administrative staff of MPCS will call the missing people and request to join the shelter. The local elected bodies have to contribute to bring the community people into the shelter. Mobile network operators will be given the mobile phone number and they have to send message and call for evacuation. Some people may go out and move to those shelters in emergency situations. Few people may visit their relatives and stay in the neighbouring shelters.



**Figure 3.**  
Updating the index of the missing people in the shelter.



**Figure 4.**  
Conceptual observation curve of the missing people in the shelter.

The dataset of a MPCs will be shared with the surrounding shelters to ensure the presence of missing people in those shelters. **Figure 4** shows a conceptual graphical observation curve to facilitate the search and rescue operation.

### 3. Empirical analysis

The smart devices are being used for the mobility detection of the car and people, but for the rescuing of people during cyclone that had very limited application. This research proposes a very simple method of detecting the missing people in the catchment area of a MPCs by using Wi-Fi scanner in order to rescue death tolls before a cyclone landfalls. The proposed method includes indexing of the community people in the catchment area, indexing of people in the shelter, determining the missing people, and updating the index of missing people.

This study used smartphones and a Wi-Fi scanner. A MacBook Pro laptop was used as a Wi-Fi scanner. Experiment was conducted on 11/12/2020, 8/01/2020 and 9/01/2020. The data obtained on 9th January 2020 was used for this analysis. Total 90 participants joined in the experiment. The experiment was a control experiment to simulate the field conditions. All participants were requested to turn off their hotspot of smartphone. Few participants were asked to turn-on the hotspot of their smartphones and Wi-Fi scanner detected the MAC address with SSID of the participants. This process was continued till all participants were detected with a time interval of five minutes. The penetration rate was 100% for this experiment that means all participants were detected during the experiment. The MACs and SSIDs are not disclosed for the privacy reason. Only number of people detected and participated are being used for this study.

#### 3.1 Inbuilt index

An inbuilt index was prepared for this investigation for all participants which comprised the name, address, MAC, SSID, picture and mobile number. There were total 90 registered participants. So, inbuilt index included 90 participants for this experiment. An example of the inbuilt index is shown in **Table 1**. The name was used to identify the people by which he/she is familiar in the community. MAC and SSID were be used to build-up the new index in the MPCs for the comparison and detection of missing people. The missing people could be communicated using their mobile number during the search and rescue operation.

#### 3.2 Detection of people

Manual counting of people takes long time to identify and to rescue them. To facilitate the identification of people in MPCs, this study proposes the application of Wi-Fi scanners and smartphones for automatic detection of people. According to the Bangladesh Telecommunication Regulatory Commission (BTRC), 156 million people subscribed mobile phone at the beginning in 2019 in Bangladesh where penetration rate of smartphone is satisfactory. For detecting people in MPCs, all participants turned on Wi-Fi/hotspot of their smartphones. Wi-Fi has a total inquiry time of as little as 8 ms. This allows detection of devices every second, allowing people with using Wi-Fi who stays in the range of a detector at a much quicker rate. In this controlled experiment, the number of participants was captured for each 5-minutes. There were 90 participants who joined the experiment. At the beginning of the experiment, all participants turned-off Wi-Fi/hotspot of their smartphones. In each five minutes, few new participants



Name	Address	SSID	MAC	Mobile No.
X	House # 32, BRTC Road, Patharghata, Barguna-8720.	Y	11:3A:09:3B:8D:22	017xxxxxxxx
A	House#1, BRTC Road, Patharghata, Barguna-8720	A	7c:a1:77:1e:39:9a	017xxxxxxxx
B	House#2, BRTC Road, Patharghata, Barguna-8720	B	a4:50:46:16:51:ed	017xxxxxxxx
C	House#3, BRTC Road, Patharghata, Barguna-8720	C	40:D3:AE:73:01:88	017xxxxxxxx
D	House#4, BRTC Road, Patharghata, Barguna-8720	D	94:B1:0A:92:33:EB	017xxxxxxxx

**Table 1.**  
An example of inbuilt index of the community people.

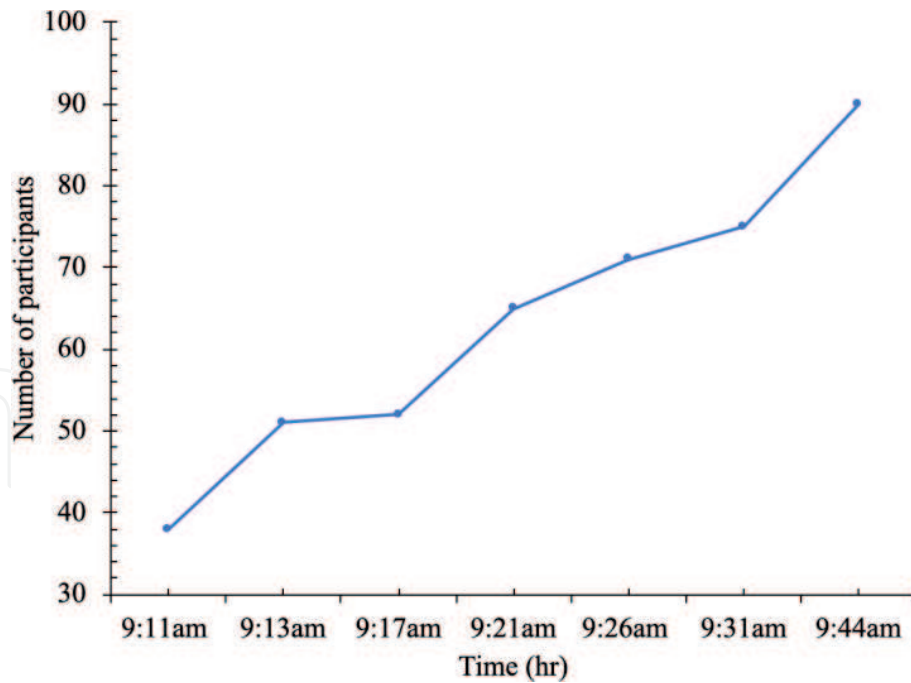
turned-on Wi-Fi/hotspot of their smartphones and were detected. For each time interval, the number of detected people was increased with the increase of active devices as observed. **Figure 5** shows the detection of people during the experiment.

### 3.3 Index of missing people

Wi-Fi scanners can identify the MAC address of the smartphones that has turned on Wi-Fi [22]. People come to the shelters while evacuation order is issued by the disaster management authority. The people who were in the shelter turned on Wi-Fi/hotspot and detected. In every five minutes, few new people were detected. A new index of people was developed with SSID/MAC. A SSID is simply a wireless network name to distinguish it from other networks in neighbourhood [27]. MAC addresses are unique identifiers defined by IEEE as a communication protocol for wireless Wi-Fi connection [26]. The inbuilt index (**Table 1**) and new index were compared that produced an index of missing people. An example of index of missing people is shown in **Table 2**.

In inbuilt index, there were 90 registered participants. While evacuation order was issued, participants started to come into the shelter and Wi-Fi scanner detected people by MAC/SSID and developed a new index. After that the inbuilt index and new index were compared that produced the index of missing people as shown in **Table 2**. The number of missing people was decreased with time as shown in **Figure 6**. At the beginning of the experiment more than 50 participants were detected as missing people. For every five minutes, few new people were detected and missing people were decreased. At a certain time, there were no missing people that meant all participants were detected and rescued. The search and rescue operation will be stopped at red line. The index of the missing people is required to be updated continuously in order to observe the newly arrived people in the shelter. The updating of index notifies the list of the missing people. The index of missing people should be displayed in a bigger screen. The family members can easily identify the missing people and contact with them. The evacuation and rescue team of the MPCs can rescue the missing people.

From the index of missing people, phone calls could be made to confirm the location of people and they would be requested to take shelter in MPCs. From phone call, we could identify the current status such as age, disability, and other burdens that prevent themselves from evacuation. Beside more information could be provided about the MPCs to him/her for taking shelter there.



**Figure 5.**  
 Detection of people in the MPCs.

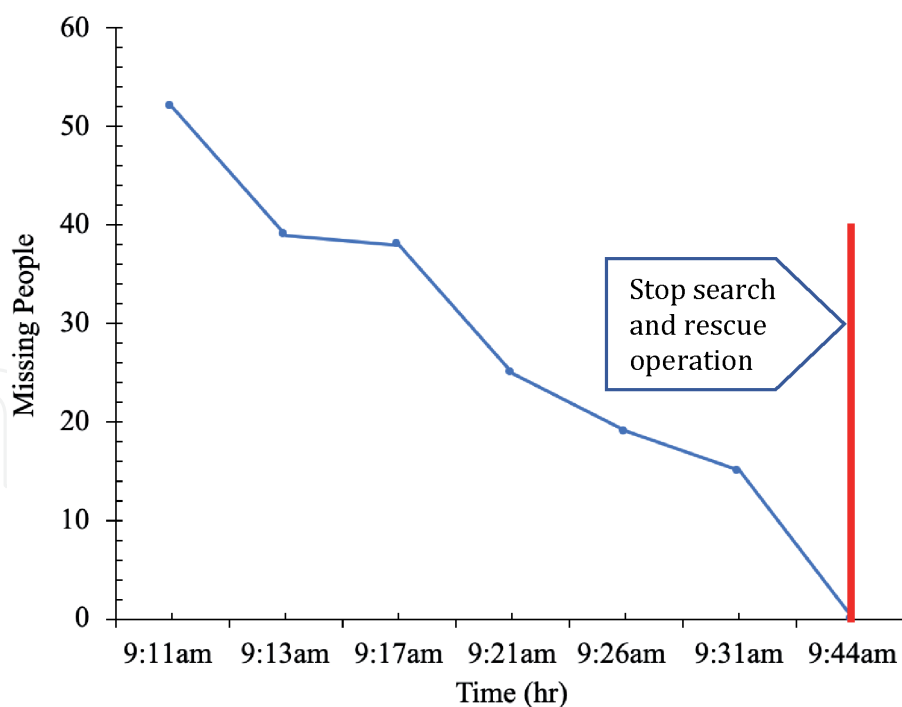
Name	Address	SSID	MAC	Mobile No.
X	House # 32, BRTC Road, Patharghata, Barguna-8720.	Y	11:3A:09:3B:8D:22	017xxxxxxxx

**Table 2.**  
 An example of index of missing people in MPCs at a certain time.

**Figure 6** shows the number of missing people in different time stamp. There were 90 registered participants. In the very beginning of experiment, 52 participants were detected as missing people. Later, missing people were recorded as 39, 38, 25, 19, 15, and 0 with elapsing of time and increasing the participants. While reaching zero, all community people were rescued in the MPCs. The proposed method of detecting the missing people is an efficient method as it can detect 100% of participants. In **Figure 6**, the red line was drawn as the demarcation of search and rescue operation. This is the end point of rescue operation.

The evacuation decision and destination are influenced by many factors, e.g., distance of MPCs, facilities in MPCs, access road, weather condition, crowdedness, socioeconomic condition, psychological, physical, cultural and personal factors etc. Level of education and household income affect the access to radio, television and online newspapers. However, the ownership of radio and television, listening to cyclone warning, improper understanding of signals, late warnings, sudden change in signals, and issuance of premature evacuation order are the obstacles to successful evacuation [3, 28]. Signals are hoisted for seaports and people cannot understand the signals outside the port areas and evacuation becomes uncertain in that cases [5]. Past experience on the failure of warning known as false alarm effect, disbelief on existing warning signals, hampering income earning activity with pro-active evacuation responses, missing the target position and weaker condition of cyclone demotivated people for evacuation [5, 6, 29].

Lack of kills and public transport discourage community people to evacuate. In some cases, people avoid evacuation due to over age, perceived level of risk, fear of



**Figure 6.**  
*Detection of missing people in the MPCs.*

robbery, belief on fate, false sense of secured house and embankment. Some people believe cyclones come as punishment from god and stay home is safe by praying to god. In conservative societies women cannot leave their houses without husbands' permission, and putting men and women under the same roof affects women's status in their family and society. This fatalistic attitude makes the people in great danger. Women also desire separate facilities and sufficient water supply as they hold more dependent members like children and adults [1, 9].

Super cyclone SIDR (2007) caused 3460 death tolls [1, 9]. Strong disaster management committees, construction of MPCs, and monitoring cells decrease death tolls in recent cyclones, e.g., eight death tolls in cyclone Fani. Reduced death tolls do not indicate successful evacuation of all vulnerable people. Despite the dynamic efforts of GoB, evacuation of people has become difficult and most of the respondents did not evacuate in some cases of cyclones, e.g., Amphan. Successful evacuation depends on evacuation preparation, order and timing, and rescue operation before cyclones landfall. If the warning become location specific and order is given within 2–3 hours before cyclone landfalls then evacuation will be effective [9]. The evacuation prior to cyclone landfall is considered as one of the best practices to minimise death tolls from a catastrophe by moving people from exposed areas to the safer places and MPCs, temporarily.

Though there are several man-made and natural factors that discourages self-evacuation of community people, disaster management authorities are responsible to encourage and rescue them into MPCs. This study developed an easier search and rescue operation that could be implemented in the coastal zone of disaster-prone countries like Bangladesh. This investigation emphasises on the evacuation and rescuing of vulnerable community people earlier a cyclone hits an area to reduce death tolls to zero.

#### 4. Conclusion

This study was conducted to reduce the death tolls in disasters. The current existing practice is to rescue the local people after cyclone landfalls that cannot

ensure survival of people in the affected area. To save lives, people should be identified and rescued before the occurrence of extreme events. Manual detection of people is time consuming that is not available during an extreme event but it could be easy by adopting technological intervention. The smartphone can contribute to this issue for the identification of the people in the shelter. The Wi-Fi scanner can detect all the people within the shelter with turned on Wi-Fi in their smartphones. The proposed method recommends the application of Wi-Fi scanners and smartphones for the detection of human mobility in MPCs. The results showed that the proposed method can detect 100% people in the shelter area and this method will accelerate the evacuation and rescue operation.

To identify missing people, it had only 4 easy steps: 1) developing inbuilt index, 2) developing new index of people in MPCs, 3) producing index of missing people by comparing inbuilt index and new index, and 4) evacuation and rescuing of missing people. Therefore, it is very easy to indexing the missing people to be rescued before cyclone landfalls and efficient to reduce death tolls. Thus, this proposed method maximises the safety of stakeholder and minimises life risk against disasters.

The proposed method is utmost important to reduce the death tolls because all vulnerable people will be rescued before a cyclone landfall. This study is to ensure the evacuation of all community people in the catchment area of a MPCs. Forced evacuation is suggested when we have enough information about their location and family burdens. People will be safe in the MPCs. We expect “zero death tolls” that could be a dream in case of a disaster. Though this investigation has some important implications, it requires improvement in future research. This study investigated for small number of participants. This study should be extended for 400 to 2500 people to simulate the capacity of the MPCs. The penetration rate of smartphone does not reach 100%. Several MPCs and community people could be included in the experiment for successful implementation.

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## **Conflict of interest**

The authors declare no conflict of interest.

## **Appendices and nomenclature**

Pre-monsoon	April–May
Post-monsoon	October–November
false alarm	failure of warning
MPCS	multipurpose cyclone shelter
CS	cyclone shelter
MoDMR	Ministry of Disaster Management and Relief
CPP	cyclone preparedness program
BMD	Bangladesh Meteorological Department
SWC	Storm Warning Centre

DPP	disaster preparedness programme
SSID	service set identifier
MAC	media access control
BTRC	Bangladesh Telecommunication Regulatory Commission
DM	disaster management
BDRCS	Bangladesh Red Crescent Society
GoB	Government of Bangladesh
NGO	Non-profit Organisation
GPS	global positing system
CDR	call record data
GSM	Global Service for Mobile Communication
SLTR	Smart Life Tracking and Rescuing
Participants	the people who participated in the experiments. These participants are assumed as community people


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