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Title: Simulation Model to Measure the Effectiveness of Evacuation Warning Message Dissemination

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ABSTRACT

Effective communication during large-scale emergencies is essential for saving lives. This study proposes an agent-based simulation model to simulate the warning message dissemination among the public, through unofficial channels (people-to-people communication among friends and neighbours), and also official channels (e.g. TV, radio and sirens). The proposed model was developed in NetLogo for a hypothetical area, and requires input parameters such as effectiveness of each official source (%), estimated time to begin informing others (min), estimated time to inform others and estimated percentage of defaulters (who do not relay the message). This model would help the decision makers to estimate the maximum possible coverage under a given condition. The time series results of the model would help in estimating the time required to inform the desired proportion of the public. The sensitivity of the input parameters on the time required to inform desired proportion of the public, was also studied.

INTRODUCTION

In the past 20 years, natural hazards alone have claimed about 2.8 million lives and disrupting about 820 million lives due to rapid onset of disasters (Bernard and Milburn 1991). In 2005 during Hurricane Katrina, about one in every fifteen persons (approximately 75,000 people) was not evacuated from the danger region due to various reasons, including poor communication. Even though there were more severe hurricanes in the Caribbean regions than in Haiti Island, the death toll was lower in the Caribbean regions, due to knowledge & awareness of the public and warning system (Red Cross, 2005). Effective communication during the large-scale emergency situation is essential for saving lives, by ensuring that the maximum proportion of population are well-informed about the imminent danger.

Warning message dissemination is achieved through both ‘formal systems’ (from official warning through TV, radio, telephone, sirens, to door-to-door knocking) and ‘informal systems’ (personal notification from neighbours, friends). The National Steering Committee on Public Warning and Information, UK (NSCPWI, 2003) has classified the official warning systems into audible systems (e.g. sirens, tannoys, route alert), telecommunication systems (automated caller systems, emergency phone diallers, bulk messaging service), mass communication systems (broadcasting through television, radio and ham-radios) and verbal information (door-to-door knocking). Various names are used to describe the warning message dissemination with the public as ‘informants’, like unofficial system (Parker and Handmer, 1998), informal system (Sorensen, 2000), people-to-people (Red Cross, 2005), folk and personal system (VICSES, 2007). During the warning dissemination planning stage the policy makers adopt scenario based approach to set operational targets. ‘Shearon Harris Nuclear plant’ board decided a policy to notify 100% population within 15 minutes within 5 miles surrounding the plan area (Sorensen, 1992). As a worst case scenario of ‘summer season night time’, the target was set to 95% within 5 mile zone. The officials couldn’t rely on sirens alone to achieve the target and recommended to motivate public to relay message to others. The policy maker responsible of warning and informing has to choose the best available option for informing the public during the event.

Moreover, community involvement in the dissemination of warning message or evacuation notifications, along with other official sources, would increase the credibility of information, leading to favourable response from the public. Public as ‘informants’ would depend on their behavioural traits (Kreps, 1984), which will inform their willingness to disseminate such information. Effectiveness of a warning channel is defined as the proportion of the households that receive the warning message within a specified duration from that channel. As individual warning channels have their own effectiveness and reliability, a warning system with multiple channels (official and unofficial) needs a comprehensive analysis to determine the overall system effectiveness.

This paper will present a tool to evaluate the effectiveness of warning systems when the public is used as an informal source to transmit the warning. The paper begins by reviewing previous studies about the various aspects of warning message dissemination, including principles of emergency communication, behavioural influences on the spread of the message and ways to model this behaviour. Then, the proposed model development is presented and illustrated with different warning dissemination policies. Finally, results are discussed, as is the scope for further research.

REVIEW OF LITERATURE

A study on the effectiveness of warning message dissemination system would involve various areas of research like principles of emergency communication planning, social communication networks, modelling and simulation tools. This article attempts to obtain a detailed account on the previous studies related to the effectiveness of mass emergency communication system, and identify the gaps for potential study and improvement.

Principles of emergency communication planning

An effective disaster planning should consider both technical and social dimensions of the problem (Kartez 1987; Quarantelli 1997). Fritz and Williams (1957) emphasised the need for considering human factors in planning warning systems. McLuckie (1970) expressed that the human or social component is more important than the technological component of a warning system. Designing a warning system requires the choice of message format, timing of informing the public and delivery of the message. Handmer

(2001) classified issues pertaining to flood warning system as ‘micro-issues’ (design of message format, psychological and demographic factors) and ‘macro-issues’ (system design, community engagement, risk group identification).

In order to maximise the lives saved during disasters, the warning message must be timely, clear (Fritz and Williams, 1957; Reynolds and Seeger, 2005), intelligible to public (Dynes 1990; Becker, 2004), in a non-technical language (Glik et. al., 2004), have details relevant to local area (Fritz and William, 1957), designed for a specific disaster (Becker, 2004; Glik et. al. 2004) and suggest expected actions (Handmer, 2001). Montanari et al. (2007) proposed a ‘Policy-driven warning system’ (PWS) for automated creation and dissemination of message during emergency. These messages are customized to the type of disaster, locality, weather, etc. A consistent message across various warning channels evades vagueness and increases credibility of the message, which leads to the desired response from the public (Parker and Handmer, 1998; Glik et. al. 2004; Burnside et. al. 2007).

Apart from the message format, the delivery of warning message depends on the warning channel used. Each warning channel has various features, namely effectiveness of dissemination, reliability, credibility and availability (NSCPWI, 2003). The effectiveness of the channel such as TV or radio is variable depending on the time of the day due to variation in the viewership (Sorensen, 2000). Some of the audible systems (e.g. route alert using handheld sirens, official door knocking) require personnel for operating each unit, which might be a limiting resource during emergency.

Bernard and Milburn (1991) proposed a satellite-based emergency alert system which could bring down the response rates to less than a few minutes with high dissemination rate. However, some of the telecommunication systems (TV, telephone network) might get disrupted and not available during emergency. When a disaster strikes in the midnight, the proportion of public that could be reached through television and radio systems is limited. Relying only on high technology solutions to reach individual households could prove fatal, due to non-availability of these systems after the onset of disasters (NSCPWI, 2003). Hence the choices available to the policy maker (who is responsible for warning message dissemination) are limited by the availability of technology, personnel and time of the day.
Findings from the study conducted by Victoria State Emergency Services (VICSES, 2007), mentioned that telephone based warning system may be inoperable during floods and may not have updated contact numbers to disseminate message to the public. This study also highlighted the use of personal notifications or flood wardens to supplement the warning dissemination.

Public behaviour during emergency and social communication networks

In order to use the public as informants of warning message, it is essential to understand their behaviour during emergencies. There are widespread misconceptions that: public panic on receiving warning message (Fritz and Williams, 1957; Quarantelli 1988), behave as victims, highly dependent on officials resources and are helpless (Fritz and

Williams, 1957; Dynes 1990). There are various studies refuting such views, which also caution for developing emergency plans with these assumptions (Fritz and Williams, 1957; Quarantelli 1988; Dynes 1990; Sorensen 2000; Maxwell 2003).

Dynes (1990) emphasised the need for building capacity around ‘social units – the community’, by viewing them as a resource for problem solving rather than a victim or a problem during emergency. Various ‘local preparedness programmes' are based on the ‘community as resource’ strategy (Lichterman, 2000). This study cited various programmes that used the public as supplementary resources in various functions including search and rescue, fire fighting, emergency communication, neighbourhood response teams, etc. Community could also be viewed as ‘social capital’ for disaster response (Dynes, 2002; Buckland and Rahman, 2005), and could mobilised to make them resilient.

Parker and Handmer (1998) explicitly addressed the importance of unofficial communication (including personal network and direct observation) during floods. The personal networks (friends, neighbours and relatives) are used to share and interpret the message, increasing the understanding of the contents, aiding in the informed decision making. A survey conducted by the US ‘Centre for Disease Control’, found that about 40% of the respondents to the survey received emergency message from informal channels – friend or relative, either in person, or through telephone (Sorensen, 1992). Another study conducted by Sorensen (2000) specified that informal notification among the public plays an important role in warning dissemination in most emergencies. A tsunami warning study in Mauritius showed that about 15.4% public received face-to-face warning (Perry, 2007). In this study, the significance of face-to-face communication was third behind TV and radio. Werrity et al. (2007) conducted a questionnaire survey among the residents of Scottish flood plain region to understand the social impacts of flooding. The study found that, among the surveyed households, 32% received the warning message from neighbours and about 51% of the flooded households actually received the message from official channels. The empirical evidence shows the significance of informal communication channel, and also the possibility of significant proportion (about 49% in this case) of residents not receiving timely information from official sources.

The role of youth and children, as potential informants within emergency communication network is highly underestimated (Mitchell et al, 2008) and not directly accounted in the theoretical models of risk communication. Mitchell et al. (2008) investigated community initiatives in El Salvador and New Orleans, and demonstrated the possibility of using youth and children as trusted informants. The children and youth were imparted training in school clubs, and found to posses high understanding of local risk, communicate warning message and even state the actions for reducing risks.

Not all the families or individuals respond in the same way during emergencies (Kreps, 1984), which leads to uncertainty in the behaviour of the public as potential informants. Moreover, as each individual takes different time period to assimilate (receive, understand and react) the warning message, there is a possibility of longer time taken for disseminating to public when solely relied on informal communication (McLuckie, 1970). The reliability of a warning system is likely to be increased when there are multiple channels of communication, rather than relaying on a single channel. These studies corroborate the observation of rational and active community behaviour, and also that the public could be potential informants for disseminating emergency message. The behaviour of public as informal channel needs to be modelled along with the official channels.

Behavioural simulation Modelling

Public as the 'informants' of warning message requires understanding about their behaviour and the way the message is disseminated among them. Kimber (1986) in probabilistic analysis of rumour spreading, adopted classification of individuals into three types, namely, *ignorant* (who have not heard rumour), *spreader* (who heard the rumour and spreads it further) and *stiflers* (who have heard rumour but do not spread it). Parallels could be drawn between rumour progression and using human as informants during emergency communication. Rumour, a means of information diffusion through social networks is generally used in a negative connotation due to the distortion in the transmitted message. The same three classifications hold true depending on behavioural trait of the individual household namely *uncovered* houses (who have not received warning message), *covered* houses (who have received message and also transmit) and *defaulter* houses (who have received message but do not transmit to others). There is also lack of control over the message content when conveyed through informal sources (Sorensen, 1992). It is highly undesirable for warning message to get distorted during transmission, which can be avoided by directing the receivers back to official channel (say Television) and maintaining consistent message across channels.

Agent based simulation modelling

Agent based simulation is defined as a technique used to modelling the human social and organisational behaviour to study the social interactions, group behaviour (Macal and North, 2005). Agents are defined as basic unit/component capable of making independent decisions based on the specified behavioural rules (Jain and McLean, 2003; Macal and North, 2005). These rules could be just simple reactive decision rules to complex adaptive intelligence. Agents have various features like uniquely identifiable, location, goal-directed, autonomous and adaptive learning.

Agent-based Modelling is highly suitable for modelling inter-dependencies among various classes of agents with respective behaviour (Macal and North, 2005). Agent-based modelling and simulation (ABMS) has applications in wide areas like epidemiological modelling (e.g. Bird flu spreading), economics, military applications (e.g. war-game simulation), supply chain management, ecological networks, biological systems, (e.g. Bird flocking system), social and behaviour systems.

A number of applications of information dissemination have been built using simulation approach. Lawson and Butts (2004) developed a simulation model for studying information transmission through human informants based on the principle of rumour propagation. The study focused on developing models for understanding information distortion. Hiu et al. (2008) proposed an agent based simulation model for the warning message diffusion among community members. This study adopted concept of trust as behavioural factor for diffusion of warning message. They identified the need for studying effect of multiple sources along with informal communication to determine overall effectiveness. When there are multiple sources of warning message communications, simultaneously functioning with varied efficiency, the information reaching each household unit is not deterministic but uncertain. This uncertainty has not been explicitly modelled in previous studies.

Sorensen (2000) in the study on modelling warning dissemination has accounted for dissemination time via different channels (Sirens, tone-alert, telephone, media). The study also specified that time spend by people to respond to warning is an S-shaped curve and also depends on the perceived threat. Family size, community involvement and number of channels are important among the 32 factors identified in this study.

When a household receives a consistent message from various sources, the credibility of message is increased, leading to favourable response to the message. At a macro level, for the community or the city, the metrics would involve observing the time series of proportion of area (or house hold units) covered. Drawing parallels to the rumour model of Chattopadhyay and Gupta (2007), the metrics like expected coverage rate, probability of receiving message from a particular source, etc would also be appropriate to measure efficiency of mass communication through multiple sources. Applying ABMS to warning message simulation would involve specifying behaviour of agents (individual households) as informants along with formal communication channels (as hidden agents).

The trust due to relationship between the sender and receiver of the warning message would influence the dissemination of the message through informal channels. Hiu et al (2008) studied the dissemination of warning message through informal channel with the concept of trust between two groups. This study has proposed an agent based simulation model for dissemination of warning message by factoring the behaviour of the public using four axioms.

Apart from designing the emergency message format (including the wordings), the policy maker for warning and informing is also bound to select various communication channels for dissemination of the message. The competent authority is also responsible for arriving at reasonable time estimate between time to initiate the warning message and expecting pre-mediated response from the public (McLuckie, 1970). Sorensen (2000) in the review of warning system identified that, officials are slow in making decision. The underlying reason could be the inability to integrate and quantify the effects of operational policy decisions on the effectiveness of warning system. This entails a need for developing a tool to aid decision makers.

MODEL DEVELOPMENT

The proposed model adopts an axiomatic approach to account for the behaviour of the public in disseminating the warning message. There are four axioms proposed by Hiu et al. (2008), namely, information loss axiom, source union axiom, value min-max axiom and threshold utility axiom. ‘Information Loss axiom’ states that the information value of the message is non-increasing and is a function of social relationship between sender and receiver. ‘Source union axiom’ explains by a procedure to update the information value from the same source. This ensures that, the messages from the same source are accounted only once. ‘Value min-max axiom’ gives a method for determining the information value when the message is received from multiple sources. ‘Threshold utility axiom’ defines a procedure for ascertaining the state of a particular household based on the combined information value and threshold value. The proposed method is implemented in ‘Agent based simulation’ software called NetLogo. The warning message dissemination model consists of a hypothetical city with 1000 houses. The unit of analysis is individual house which is modelled as agents in the model. Each agent has attributes like identification number, media channels available (for example TV, Radio, etc), defaulter variable (are they willing to communicate the message?) and state variable (informed, uninformed, disbelief). The level of analysis in the proposed model is for the whole city.

Each household unit has an attribute called state variable indicating the status of warning message. This state variable has different possible values namely uninformed, informed, disbelieved and defaulter. Figure – 1 is a flow chart showing various states of the public from receiving warning message to response. When the public received the warning message they move from ‘uninformed’ to ‘informed’. The public would require some time between receiving the warning message to the response for assimilation of the message content

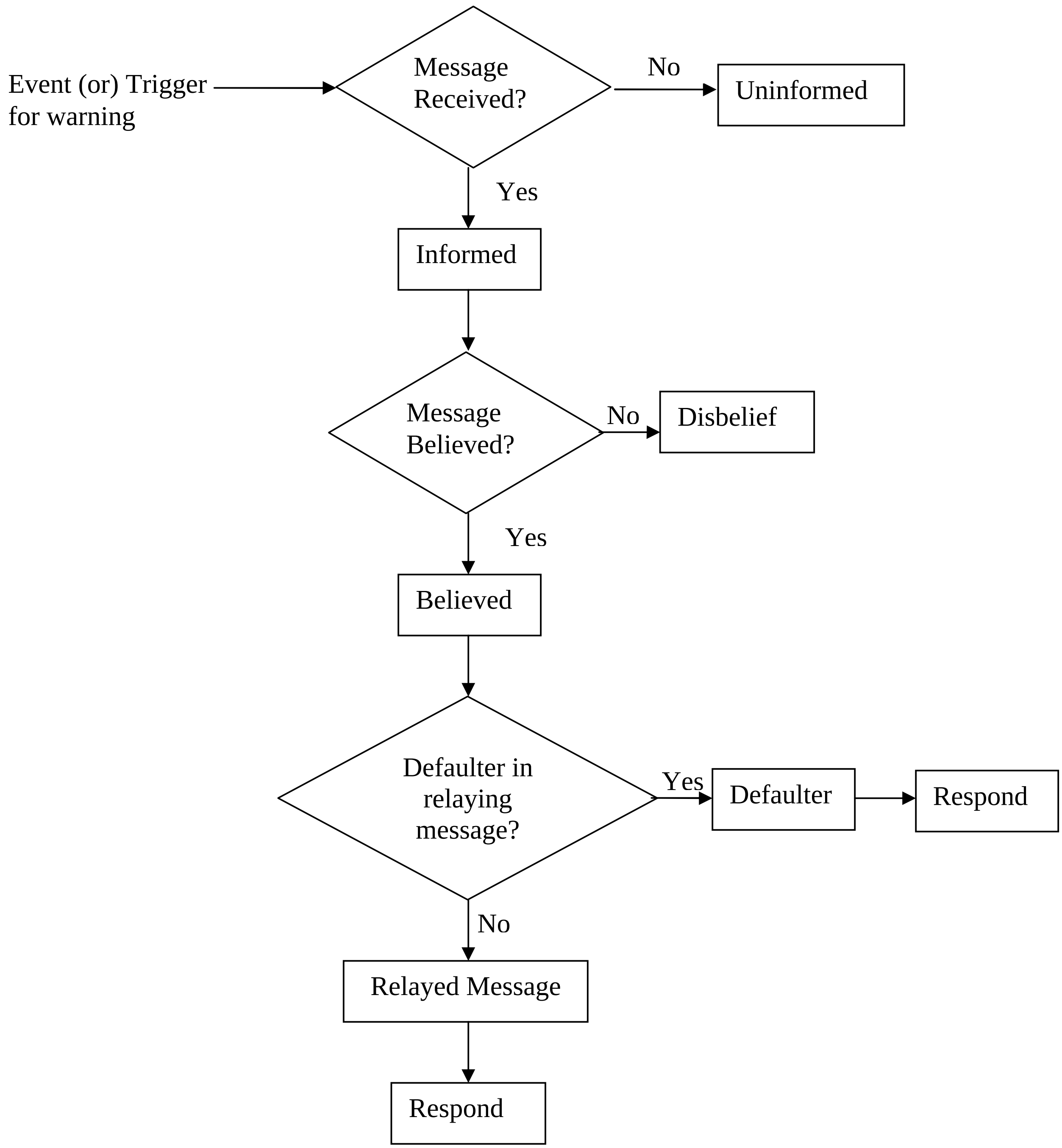
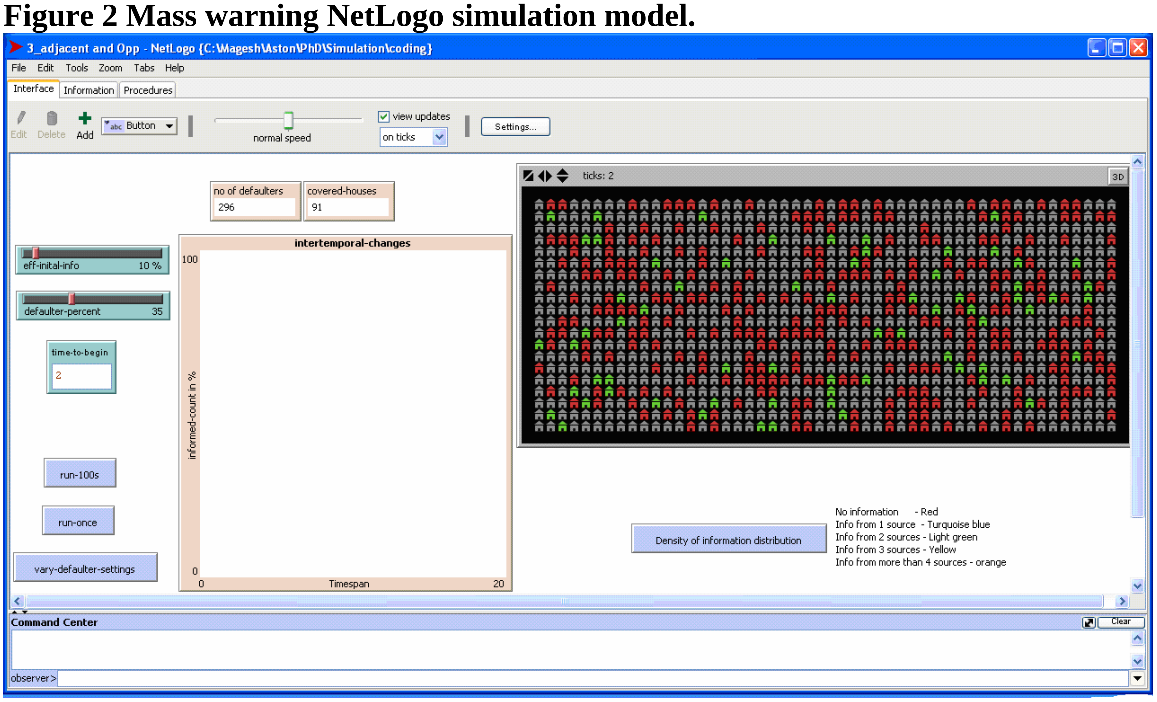


Fig – 1 Flow chart showing various states of the public in receiving the warning message to response.

and understanding the same. This time henceforth called as assimilation time. After the lapse of assimilation time, the public could move into either the 'disbelief' state leading to no-action or 'believed'. The warning message would request for the public to relay the message to neighbours and friends (Red Cross, 2005). Some proportion of the respondent may not be informants in disseminating the message to the neighbours. This behaviour could be due to perceived urgency for self, leading to immediate action, ignoring to inform the neighbours. These households are categorised as ‘defaulters’.

The NetLogo model is provided with effectiveness values of various sources in percentage. The proportion of defaulter houses would be an input into the model. Before the model starts disseminating the message, the defaulter houses are randomly selected to the specified proportion. The defaulter state is indicated as an attribute at the individual household level. The initial warning message is selected randomly based on the effectiveness of each channel. The assimilation time is the time from receiving the message to the state of understanding and confirming the message, is an input to the model based on the estimate from experts. Once the time lapse for the household is equal to the assimilation time, the household would relay the message to the neighbours. The time taken to inform the neighbour is taken as five minutes as adopted by Stern and Sinuary-Stern (1989). On informing the neighbour and reaching the believed state, the household is said to be at the state of ready to respond. Figure – 2 shows the snapshot of the developed NetLogo model.

Figure 2 Mass warning NetLogo simulation model.



Public response to the warning message is influence by their perception about their threat. The threat perception is also influenced by the distance or proximity of the threat from the public particularly when the threat has epicentre (Sorensen, 2000). This would influence the assimilation time of the public. When the threat has an epicentre, for example a dirty bomb blast or a nuclear release from the plant, the public closer to the incident would perceive a higher threat, hence would take less time to assimilate the warning message and respond quickly. The public farther from the epicentre are likely to have less threat perception leading to longer time for responding to the evacuation warning message. This study assumes that the relationship between distance and threat factor is exponential distribution. The present study has proposed a new axiom, ‘threat proximity factor axiom’ to reflect the effect of threat epicentre location on the dissemination and assimilation of warning message by the public. This factor is given by the following relationship

$$TPF = e^{df*d} \quad (1)$$

Corrected Assimilation time = Assimilation time * TPF

Where,

TPF = threat perception factor (no units)
df = unit distance factor (in per miles)
d = distance from the threat (miles)

The model is developed to facilitate the user to input the values of various parameters like effectiveness of each source, defaulter percentage, assimilation time and time required to inform the neighbours. The user can select on the screen the site where the threat has occurred. Thus the developed model can be customized to account for prevailing conditions in reality including the non-availability of warning channels. The following scenarios were studied using the NetLogo model.

This paper adopts a similar approach to that presented by Sorensen, (1992) and Hiu, et.al, (2008) for the planning of warning message dissemination. Table – 1 contains the list of scenarios studied using the proposed ABMS. Scenario A considers the behaviour of public informing the adjacent houses on left and right side. Scenario B considers the behaviour of public informing the warning message to the adjacent and opposite houses. In scenario C, the neighbourhood is defined by random probability and houses are selected for informing the warning message. Scenario D incorporates the proximity of threat from the public on the warning message dissemination.

Table – 1 Different scenarios used in the simulation model

Scenario	**Informal dissemination scenario**	**Warning channels**	**Threat or Hazard**
Scenario – A	Public disseminate the message to adjacent houses only.	Multiple official sources and Informal notification	Not for specific hazard
Scenario – B	Public disseminate the message to adjacent and opposite house	Multiple official sources and Informal notification	Not for specific hazard
Scenario – C	Public disseminate the message to the neighbours who are selected randomly	Multiple official sources and Informal notification	Not for specific hazard

Scenario – D	Threat perception as a function of distance from the epicentre of the hazard	Multiple official sources and Informal notification	Threat with epicentre – for example dirty bomb blast.

RESULTS AND DISCUSSION

The proposed dynamic simulation model generates the time series of the proportion of public receiving the warning message through official and unofficial channels. Earlier studies (e.g. Stern and Sinuary-Stern, 1989) have adopted the approach of taking the worst-case scenario (for example, late night scenario) for planning the warning message dissemination. For illustration of the model, the effectiveness of the official channel is taken as 10%. The model was run multiple times (100 runs) to avoid bias on the results due to the initial selection of defaulter houses. Fig-3 shows the comparison of average results for scenario A and scenario B. The proportion of the public receiving the message in scenario B was found to be higher than scenario A. This is due to the dissemination happening across the streets leading to the diminishing effect of defaulters. The proposed simulation model enabled to study the dissemination of warning message among the public factoring the perception due to proximity of the threat. The results are also analysed for residual population, defined as the proportion of the public that remain in uninformed or disbelief state at a given point of time. Apart from the estimation of the number of evacuees and proportion of residual population, the result from this model is useful in the planning of subsequent services. For example, the time series of public arriving at the evacuation gathering point is a function of time series of the warning message received. The output of this model could be used in the planning of transport service from evacuation gathering point to shelter locations.

Figure 3. Comparison of residual population between Scenarios A and B.

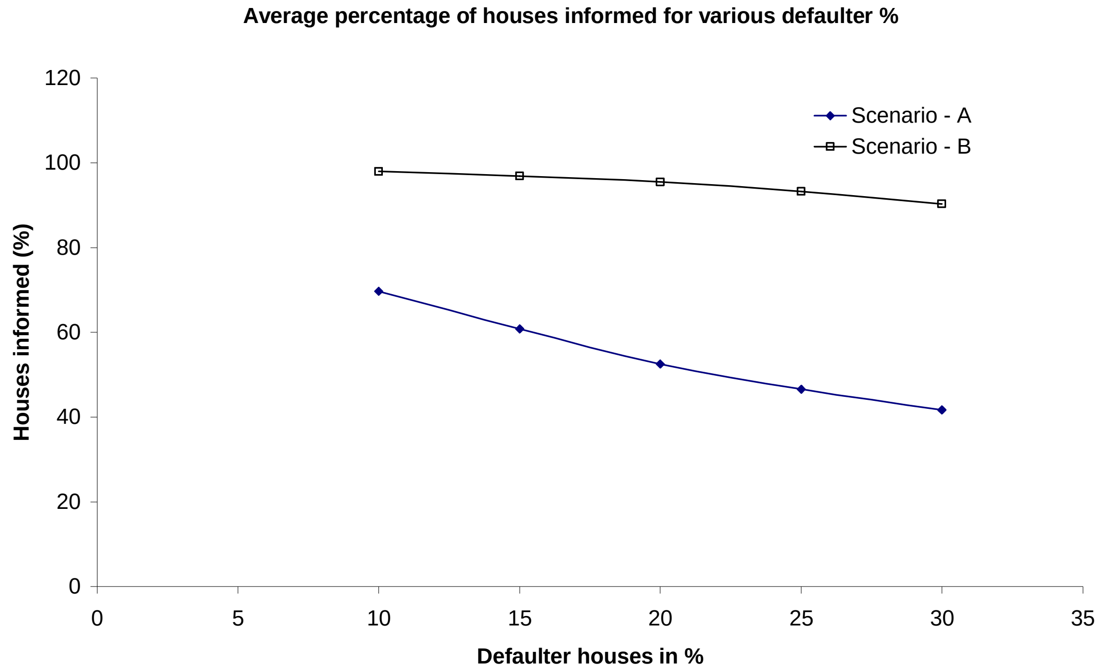


Table – 2 Proportion of residual houses for various % defaulter values for scenario A

Defaulter houses in %	Uninformed houses (Residual population) in %	Proportion of houses receiving message from number of sources (N) (%)			
		N = 1	N = 2	N = 3	N >= 4
10	30.276	12.737	50.118	6.869	0
15	39.162	14.938	39.978	5.922	0
20	47.457	16.176	31.213	5.154	0
25	53.427	16.637	25.6	4.336	0
30	58.288	16.954	20.953	3.805	0

Table – 3 Proportion of residual houses for various % defaulter values for the scenario – B

Defaulter houses in %	Uninformed houses (Residual population) in %	Proportion of houses receiving message from number of sources (N) (%)			
		N = 1	N = 2	N = 3	N >= 4
10	2.086	3.452	24.584	60.523	9.355
15	3.107	6.01	30.273	52.779	7.831
20	4.547	8.939	34.308	45.691	6.515
25	6.786	12.042	36.409	39.364	5.399
30	9.668	15.151	37.566	33.13	4.485

The sensitivity analysis of the defaulter percentage parameter on the proportion of residual population who did not receive the message is given in Tables 2 and 3 for Scenario A and B respectively. The value of uninformed houses has increased by 1.66 times in the scenario A when the defaulter percentage has increased from 10% to 30%.

Likewise, in the scenario B, the value of uninformed house has increased by 4.63 times with increase in defaulter percentage from 10% to 30%. The average value of uninformed houses in scenario A is much higher than scenario B, the sensitiveness of defaulter percentage would have higher error in scenario A. Motivating the public to inform the opposite houses would have considerable impact in the overall average people informed and also reduce the likelihood of houses to be uninformed. The simulation results also estimated the average number of sources per household. This is an important parameter which would indicate the likelihood of a house receiving the warning message. When the warning message is consistent across sources, the higher value of number of sources per household would increase the believability and hence leading to expected response from the public. This is in line with the believability aspect proposed by Sorensen (2000). Zones within the city with lower value of number of sources would require additional deployment of resources (example mobile sirens, door-to-door knocking) to reduce the residual population.

CONCLUSIONS AND FURTHER SCOPE OF RESEARCH

The Planning for warning message dissemination requires due consideration for socio-technical issues and also the behaviour of public as informants. This study has proposed an agent based simulation approach to model the dissemination of warning message through official and unofficial sources. This study has proposed an axiom called 'threat proximity factor axiom' to account for the threat perception due to the distance from the threat on the warning dissemination through informal channel. The proposed model was studied under various scenarios. The sensitivity of defaulter percentage factor on the uninformed population was also studied.

The effect of factors such as number of channels per household from which the message was received and source credibility, on the time series of proportion of public receiving warning message is to be studied further. The credibility of the source is an important factor affecting the believability of the warning message and hence the response (Sorensen, 2000; Hiu et al., 2008). This model could be extended for a real city factoring the geographical features like roads, bridges, etc and then factoring the same in the dissemination of the warning message. Further extension of the model needs to take into account channels such as mobile public announcement (PA) systems. Further research could be done on developing decision support system for the allocation of mobile PA systems. The time series data from the model would serve as an input to the transport planners for making optimal allocation of transport facilities based the demand pattern from the evacuation data.

REFERENCES

Becker, S. M. (2004). Emergency communication and information issues in terrorist events involving radioactive materials. *Biosecurity and Bioterrorism: Biodefense strategy, practice, and science,* Vol. 2, No. 3, pp. 195 – 207

Bernard, E. N., and Milburn, H. B. (1991). Improved Satellite-based emergency alerting system. *Journal of Atmospheric and Oceanic technology*. Vol. 8, December, pp. 879 – 893.

Buckland, J. and Rahman, M. (2005). Community-based disaster management during the 1997 Red river flood in Canada, *Disasters*, Vol. 23, No. 2, pp. 174 – 191

Burnside, R., Miller, D. S., and Rivera, J. D. (2007). The impact of information and risk perception on the hurricane evacuation decision making of greater New Orleans residents, *Sociological Spectrum*, Vol. 27, No. 6, pp. 727 – 740.

Chattopadhyay, A. K., and Gupta, A. (2007). Study on Diffusion of Rumours through Epidemic Models under Non-Identical set-up, *Bulletin of the Calcutta Statistical Association*, Vol. 58, No. 231, pp. 263 – 280

Dynes, R. R. (1990). Community emergency planning: False assumptions and inappropriate analogies, *Disaster Research Center, University of Delaware, Preliminary paper – 145.*

Dynes, R. R. (2002). The importance of social capital in disaster response, *Disaster Research Center, University of Delaware, Preliminary paper – 327*

Fritz, C. E., and Williams, H. B., (1957). The Human Being in Disasters: A Research Perspective, *Annals of the American Academy of Political and Social Science*, Vol. 309, No. 1, pp. 42-51.

Glik, D., Harrison, K., Davoudi, M., and Riopelle, D., (2004) Public Perceptions and Risk Communications for Botulism, *Biosecurity and Bioterrorism: Biodefense strategy, practice, and science*, Vol. 2, No. 3, pp. 216 – 223

Handmer, J. (2001). Improving flood warnings in Europe: a research and policy agenda, Environmental Hazards, Vol. 3, No. 1, pp. 19 – 28

Hiu, C., Goldberg, M., Magdon-Ismail, M., and Wallace, W. A., (2008). Micro-simulation of diffusion of warnings. *Proceedings of the 5th International ISCRAM Conference – Washington, DC, USA*, edited by F. Fiedrich and B. Van de Walle , pp. 424 – 430.

Jain, S., and McLean, C. (2003). A Framework for Modelling and Simulation for Emergency Response, Proceedings of the 2003 Winter Simulation Conference, S. Chick, P. J. Sánchez, D. Ferrin, and D. J. Morrice, eds , pp. 1068 – 1076

Kimber, A., (1986). Rumours, *Teaching Statistics – An international journal for teachers*, Vol. 8, No. 3, pp. 85 – 90

Kreps, G. A., (1984). Sociological inquiry and Disaster research, *Annual review of sociology*, Vol. 10, No. 1, pp. 309 – 330.

Lawson, G. C., & Butts, C. T. (2004). Information transmission through human informants: Simulation., *Proceeding of NAACSOS 2004*, K. Carley (Ed.). Pittsburgh, PA: Carnegie Mellon University

Lichterman, J. D., (2000). A ‘Community as Resource’ strategy for disaster response, Public health reports, Vol. 115, No. 2-3, pp.262 – 265.

Macal, C. M., and North, M. J., (2005). Tutorial on agent-based modelling and simulation. In *Proceedings of the 2005 Winter Simulation Conference* M. E. Kuhl, N. M. Steiger, F. B. Armstrong, and J. A. Joines (eds), pp 1 – 5.

Maxwell, T. A., (2003). The public need to know: emergencies, government organizations, and public information policies, *Government Information Quarterly*, Vol. 20, pp. 233–258

McLuckie, B. F., (1970). The warning system in disaster situations: A selective analysis, Disaster Research Center, University of Delaware, Report Series – 9.

Mitchell, T., Haynes, K., Hall, N., Choong, W., and Oven, K. (2008). The Roles of Children and Youth in Communicating Disaster Risk, *Children, Youth and Environments*, Vol. 18, No. 1, pp. 254 – 279

Montanari, M., Mehrotra, S., and Venkatasubramanian, N. (2007). Architecture for an Automatic Customized Warning System, *Intelligence and Security Informatics – IEEE*, pp. 32- 39

National Steering Committee on Public Warning and Information - NSCPWI (2003), Third interim report, UK.

Parker, D. J., and Handmer, J. W. (1998). The role of unofficial flood warning system. *Journal of contingencies and crisis management*, Vol. 6, No. 1, pp. 45 – 60.

Perry, S. D., (2007). Tsunami Warning Dissemination in Mauritius, *Journal of Applied Communication Research*, Vol. 35, No. 4, pp. 399 – 417

Quarantelli, E. L., (1990). The warning process and Evacuation behaviour: The research evidence. Disaster Research Center, University of Delaware, Preliminary paper – 148

Quarantelli, E. L., (1997). Ten Criteria for Evaluating the Management of Community Disasters, *Disasters*, Vol. 21, No. 1, pp. 39 – 56.

Red Cross (2005), World Disaster Report, Chapter – 2, Red Cross, Geneva, retrieved on 05-Nov-2008, from http://www.ifrc.org/publicat/wdr2005/chapter2.asp

Reynolds, B., and Seeger, M. W. (2005). Crisis and Emergency Risk Communication as an Integrative Model. *Journal of Health Communication*, Vol. 10, pp. 43–55

Sorensen, J. H. (1992). Assessment of the need for Dual Indoor/Outdoor warning Systems and enhanced Tone alert technologies in the Chemical Stockpile Emergency Preparedness Program, *ORNL TM – 12095*, Oak Ridge National Laboratory, Oak Ridge, US.

Sorensen, J. H. (2000). Hazard warning systems: Review of 20 years of progress. *Natural Hazards Review*, Vol. 1, No. 2, pp. 119–125.

Stern, E., and Sinany-Stern, Z. (1989). A behavioural-based simulation model for urban evacuation, *Papers of the regional science association*, Vol. 66, pp. 87 – 103.

Victoria State Emergency Service - VICSES (2007). Review of SES Role in Flood Warning, *final report, Victoria State Emergency services*, December 2007, retrieved on 10-Nov-2008, from http://www.ses.vic.gov.au/CA256AEA002EBBF1/Lookup/Emergency-Management-Research/$file/Review%20of%20VICSES%20Role%20in%20Flood%20Warning.pdf

Werrity A., Houston D., Ball T., Tavendale A., and Black A. (2007) Exploring the social impacts of flood risk and flooding in Scotland. *School of Social Sciences – Geography. University of Dundee*, Scottish Government.