

# Agent-based Modeling Approach in Understanding Behavior during Disasters: Measuring Response and Rescue in *eBayanihan* Disaster Management Platform

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**Abstract.** Development of a disaster management system is as complex as the environment it mimics. In 2015, the *eBayanihan* disaster management platform was launched in Metro Manila, Philippines. It is designed to be an integrated multidimensional and multi-platform system that can be used in managing the flow of information during disaster events. Since its development, usage of the system varies depending on the agent who uses the system and which area is affected by what type of disaster. As a complex problem, behavior of disaster agents, such as official responders, volunteers, regular citizens, is best understood if the system can capture, model, and visualize behavior over time. This study presents the development and implementation of an agent-based approach in understanding disaster response and rescue by automatically capturing agent behavior in the *eBayanihan* Disaster Management Platform. All user activities are logged and converted into behavior matrices that can be saved and imported into the Organizational Risk Analyzer (ORA) tool. ORA is used to generate the agent-based model which can be viewed in the *eBayanihan* platform. Actual behavior (ABehM) is compared against perceived (PBM) and expected behavior (EBM) during rescue and response. Results show that EBM networks are fully connected while PBM during rescue and response are granular and vast. Both however show centrality at the provincial and municipal level. ABehM on the other hand shows concentration only at the municipal level with more interactions with ordinary volunteers and citizens.

**Keywords:** agent-based models, behavioral analysis, disaster informatics

## 1 Introduction

In 2015, the *eBayanihan* disaster management platform, a government funded project developed at the Ateneo Social Computing Science Laboratory, was

launched in the Philippines as a free web and mobile tool that will capture and manage the flow of information between and among rescue and response clusters and the public. The development of the platform was highly influenced by the noticeable increase of Twitter posts from citizens during disaster events. As a new source of valuable information, there was a need to provide emergency response clusters from the National level down to the Local Government level with an organized view of verified social media reports. Aside from social media data, there was also a need to create a public platform that can be used by the general public in reporting real time disaster related incidents.

The end goal of *eBayanihan* is to provide a top down and bottom up coordinated communication platform for information sharing during emergency events between rescue and response agencies as well as with the public. Registered users from response clusters as well as the public provide basic demographic information including skills and resources that can be volunteered or performed during emergency events. Each user is also required to select the most appropriate role based on the community organizational chart. The idea behind the role assignment is to be able to keep track of actual behavior during simulated and actual disaster events.

However, understanding the behavior of disaster agents, namely: response cluster agencies, volunteers as well as the public, require capturing movements and interactions between and among users of the system. (eBayanihan) captures user activities and interactions which can automatically be converted to behavior matrices. The system makes use of Organizational Risk Analyzer (ORA), a meta-network organizational analysis tool developed at the Center for Computational Analysis of Social and Organizational Systems (CASOS), as an extension to the *eBayanihan* platform. System logs can be automatically translated to behavior matrices that are uploaded in ORA for social network analysis. Results generated in ORA can be viewed in the (eBayanihan) platform. Having this feature allows for the understanding of the complexity of behavior of agents during disaster events. The system allows for the visualization of social network behavior: who interacts with whom, who is knowledgeable on specific tasks, who performs what task, in relation to disaster management and mitigation. Actual behavior is compared to expected and perceived behavior to gain a better understanding of which coordination activities are relevant or become deterrent to saving lives.

## 2 Literature Review

### 2.1 Agent-based Modeling in Understanding Behaviors during Disaster and Emergency Events

Agent-based modeling (ABM) is an approach to evaluate complex systems where independent and interacting agents make up its domain [6]. As examples, ABM was used to simulate crowd evacuation [4, 5, 7], to aid flood management incident [2], for evaluating positioning during outbreaks [3], earthquake and tsunami evacuation simulation [4, 5], preventing fire and flood [7] and for disaster man-

agement[1]. ABM is also used in studies that focused on human behavior during earthquake [4] and tsunami [5].

## 2.2 Organizational Chart of the Philippine Rescue and Response Cluster

The Philippines makes use of a decentralized approach in the management of disaster and emergency events. At the regional and national level, the Office of Civil Defense (OCD) has formed the National Disaster Risk Reduction and Management Council (NDRRMC). At the provincial level, the elected Governor provides a team under the Provincial Disaster Risk Reduction and Management Council (PDRRMC). At the local level, Local Government Units (LGUs) led by the elected Mayor forms its own Municipal Disaster Risk Reduction and Management Council (MDRRMC). Following the 2005 Humanitarian Reform Agenda of the United Nations (UN), the formation of the council members at each level all follow the cluster approach allowing for coordination and management of humanitarian needs including: food security, health, shelter, telecommunications, rescue and response, to name a few.

## 2.3 *eBayanihan* as a Social Networking Platform for Disaster Management

*eBayanihan* stems from the Filipino root word *bayan*, which means country. The word *bayanihan* is a social representation of the collective helping behavior of Filipinos where an individual or a family in need of assistance becomes a concern of the community. The community then crowdsources and provides possible solutions. The *eBayanihan* disaster management system was therefore designed as an online social networking platform to allow crowdsourcing of information from the public as well as provide avenue to manage response and rescue by line agencies during disaster events.

As part of the user registry, *eBayanihan* requires a user to select a role from a list that represents each cluster role based on duties and responsibilities assigned during disaster events as well as a volunteer or an ordinary citizen for users that do not have official roles. Table 1 shows an aggregated listing of roles and corresponding descriptions.

Table 1: User Roles and Descriptions

User Role	Description
PDRRMC and MDRRMC	oversees rescue and response, submits reports
Barangay DRRM Council (BDRRMC)	produces barangay profile, views reports and requests
Line Agencies (Police, Fire, Health)	safety, security, response and rescue
Official Volunteers	shelter, response and rescue
Ordinary Volunteers	report incidents, verify and validate incidents

*eBayanihan* includes features for viewing reports by location through a timeline which can be filtered by location or viewed on a map. Community leaders are recommended to submit community profiles. Data in this form are used for risk assessment and serve as guide for understanding community-based protocols during disaster events. Official volunteers, such as shelter managers, can profile and update status of evacuation sites in real-time. Lastly, ordinary citizens can submit real-time reports on disaster incidents as they experience it.

### 3 Methodology

An *eBayanihan* training session was conducted to capture actual behavior of disaster agents during a simulated disaster event. Participants were grouped according to designated work titles. The study compares interactions of individual agents in three ways: 1) as it is perceived by the users, 2) as expected based on mandatory disaster protocols and 3) actual behavior captured and measured by the system. The Perceived Behavior Model(PBM) is generated by creating a behavior matrix from results of a survey asking two questions: *Who do you work with before/during a disaster?* which captures Agent  $\times$  Agent Network and *What tasks are assigned to you?* which captures Agent  $\times$  Task. The Expected Model (EBM) is constructed by generating a behavior matrix from the roles and responsibilities stated in the standard local disaster management contingency protocols. The Actual Behavior Model (ABehM) is obtained from the behavior matrix that is generated by *eBayanihan*. Matrix comparison and standard network analysis were performed on the datasets.

### 4 Results

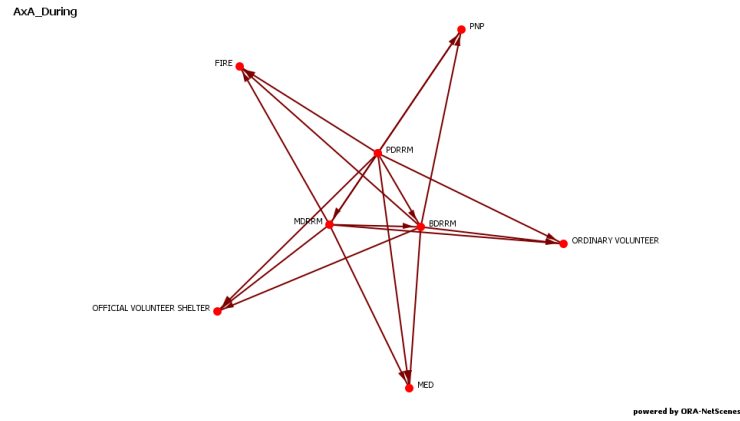


Fig. 1: Expected A  $\times$  A Behavior Model (EBM) During Disaster

The Expected Behavioral Model (EBM) during a disaster show that most of the agents interact directly with one another showing evidence of a strongly connected network as seen in Figure 1.

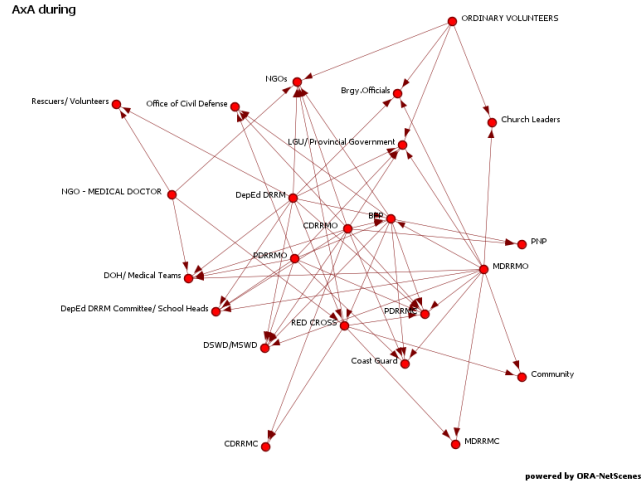


Fig. 2: Perceived  $A \times A$  Behavior Model (PBM) During Disaster

As seen in Figure ??, PBM shows an expanded view detailing coordination between and among LGUs and Non-Government Organizations (NGOs), official and ordinary volunteers. Interactions between and among agents significantly increase. Government agencies receive more requests for services.

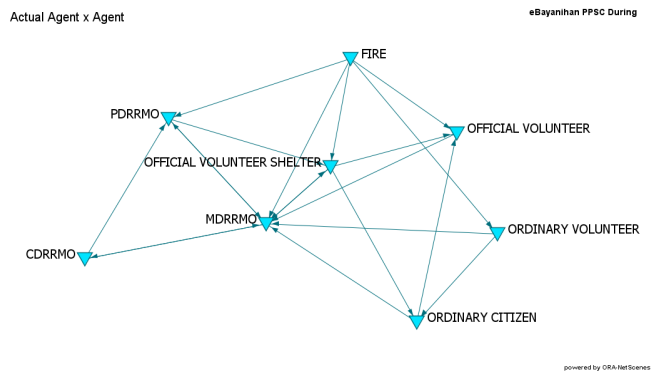


Fig. 3: Actual  $A \times A$  Behavior Model (ABehM) During Disaster

Figure 3 shows the ABehM interaction between and among agents as captured by the *eBayanihan* system during a simulated earthquake event. It shows that there are lesser agents than EBM which indicates lesser use of the system than expected.

## 5 Conclusion

This study contributes findings in understanding behavior during rescue and response by capturing perceived behavior (PBM), expected behavior (EBM) and actual behavior (ABehM) in a disaster information management platform. Expected rescue and response behavior of agents shows a fully connected graph with LGUs at the heart of the operations, consistent to the devolved and cluster approach. However, the EBM does not depict the granularity of coordination that is perceived by disaster agents. Actual behavior shows that not all perceived activities are actually implemented during simulated disaster events. There is a need therefore to revisit disaster coordination protocols to ensure that expected behavior, perceive behavior and actual behavior remain consistent during the different phases of disaster, most especially during critical operations of rescue and response.

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