The Development of Agent Based Modeling Framework For Simulating Disaster Response Teamwork.

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Abstract- The humans and their environmental health safety has always become the most important aspect in human life’s especially in towards the issues of the effects/threats of vulnerable risk, which causes devastation/destruction to humans health and their ecological regions such as disaster which is a hazard. A disaster is a consequences combination of a natural or artificial hazards and as well human factors that were vulnerable to be caused by the lack of in appropriate disaster management plans, which yield as well leads to financial, infrastructural, economical, social and human damages or destructions. Teamwork has always becoming massively important in the organizations due to its beneficial outcomes. Although a team performance levels were been determined by the complexity of interactions between the attributes of its individual members, the communication and dynamics between team’s members, the working environment, and the team’s working tasks. As the organizations evolved, so too does their interactive nature of the team working. During the past two decades, the field development in some agencies and organizations has become increasingly been undertaken by the integrated product unit teams. Such increasing complexity means that the interactive nature of the research methods for studying teamwork must also evolved as a good research area of study. Accordingly, this paper highlight and proposes the used of an agent-based modeling (ABS) concept of approach for simulating teamwork within a disaster environment, this informed by the research conducted on organizational units and their simulating agents. The model parameters concept includes the number of agent variables behavior at each levels, i.e individual level (competency, motivation, availability, response rate), team level (communication, shared mental models, trust), and task level (difficulty, workflow), which jointly determine teamwork performance (quality, time to complete the task, time spent working on the task). However, this paper will also discusses and elaborate the ABS model, and the current practice in which the model is predominantly used to manage/control disaster management. In resolving the issues identified, an ABS approach to agent-parameters behavior is been proposed to modeled the emergence cases of team working simulation, where the team members work cooperatively depends on the communication of agents in the simulation environment known as agents or parameters. It then analyses the processes by behavior of these parameters as intelligent agent’s entities, which were going to be used in development of the ABS model.

Keywords- Disaster Management; Disaster/Emergency Response; Agent Based Model(ABS); Teamwork Simulation; Agent Parameters.

1. INTRODUCTION

Team working has continues to be a key role topic in the organizational research study environment and has been extensively studied across number of field’s such as psychology, disaster management, engineering, and computer science related areas. Indeed, teams have been shown massively to offer organizations many advantages over individual working, and effective team working is related to a number of desirable outcomes such as an organizational efficiency, saving of time/speed and improved quality. Fundamentally, teamwork can simulate the network behavior in several ways that individuals cannot, also can enable the organizations to develop high quality ideas/products efficiently and effectively. However, the common lapses of team working together in disaster/emergency management cases, the communities, units, agencies and organizations find so much difficulties in communication and interactive behaviors to identify the solutions to their existing problems and vulnerabilities especially when performing some tasks as a teamwork. Disaster and emergency teams, units, engineers, architecture and other volunteers organizations always been having some interaction complexities and difficulties in communication (coordination) to respond in teamwork ineffectively and inefficiently to speed up the time duration in disaster response situation. However, most of the existing systems simulation models (SSM) were
insufficiently in addressing the disaster teamwork coordination and communication for teams, units, organization and agencies interaction. This research paper has been focusing mainly on the use of agent based simulation model (ABS) analysis as the way to look in deeper into the system complexity and examines the agent objects parameters coordination behavior in a teamwork. Therefore, these problems stated were been classified into three categories as a). What is the proper system simulation model (SSM) should be chosen by the organizations/agencies/teams to solve the vulnerabilities of emergency and disaster responses? b). How the units, groups and agency can coordinate and communicate with different emergency units/teams to control disaster response simulations? c). How can agent based model (ABS) simulate the emergency/disaster response situation? Therefore, the paper aimed at to developed an agent-based model simulation (ABS) framework for disaster response teamwork in a disaster crisis situation. And also motivate the ready to see clear view on how ABS model can enhance and improve the use of agent parameters communication & coordination of teamwork behavior concept of approach in simulating disaster/emergency response environment.

This paper is organized as follows: Section 2 described about literature review which consist of the need and what is agent base modeling (ABS) simulation in disaster management including the disaster/emergency response, communication and coordination in disaster response teamwork, disaster management in construction industry (BIM). Section 3 explains about the ABS conceptual framework development with the agent parameters, section 4 describes about how the framework works and as well as how it helps in investigating emergency response teamwork simulations. Section 5 discuss about the conclusion of this study.

2. LITERATURE REVIEW

According to the past work been reviewed and done by researchers on disaster and hazards management, during the years of 1960s and 1970s, the geographers studies the vulnerable effect of disasters and threats of event and situations on humans mainly came from the technical and practical aspect. The main idea of approach and concept to disasters is to focused on physical events situation requiring certain scientific and technical solutions (technological view).

Although, Natural and artificial hazards event were experiment in the view approach of simplistic naïve determinism (where real physical operations are determined by the human actions events) and the linear system relationships came from the geophysical situation of events to the vulnerable impacts of human disaster responses. Humans were additionally assumed to be the masters mind of their faith, to a greater extend in percentage or degree than now its seem to be valid. They were expected to live in threats situation due to a inadequate lack of knowledge education.

However, lately 1980s and 1990s researchers in this field and area of natural threats of hazards and disasters events started to criticized/opposed the motion on deterministic, historical and social approach of emergency situation of disasters events and its dependence upon the used of choices of selecting a decision making models (Hewitt 1983; Gardner 2002).

Lastly, Some years ago, the groups, communities and organization has also vital roles to contributes for execution of several technological solutions to enhance the controls of communication on the disaster decision making problems and complexes in disaster management coordination (e.g. earthquakes, hurricanes and threat attacks), (Kanchanasut, et al 2007; Malizia, 2010; Midkiff, 2001; Smith, 2009).

2.1 Communication & Coordination in Disaster Response.

Disaster teamwork decision making coordination and communication were critically/complex issues to be address in every organization especially when it comes to the issue of making a teamwork responsibility. The coordination is usually happening in difference stages, such as follows;

Figure 1: Teams Coordination Diagram

**Intra-Coordination:** This is a type of coordination and communication process within the organizational mobile teamwork (e.g. first aid team member’s, geographical disaster field, and information team members).

**Inter-Coordination:** This refers to a type of coordination and communication in the organization teams which occurs amonge the different type of unit teamworkers (e.g. municipality team and a team of doctors).
2.2. Agent Based Model (ABS).

This is a recently introduced trend concept of approach for simulating system with the interaction of agents as parameters behavior. However, the precise meaning of ABS varies in different fields of study and its application (or even in the same field), the implementations and usages of ABS are similar in concept compared to others system simulation model interactions of objects or parameters (known as agents) to simulate the model you need to identify, produce, generate and design the parameter behaviors. This research case study aimed at focusing on the uses and application of ABS modeling parameter behaviors and numerous works has been completely done in this area over the years ago. Although, the developments of ABS is an introductory tutorials surveys, which could further have some impact of ABS in different fields of applications (Heath, Hill, and Ciarallo 2009; Macal and North 2005, 2006, 2009; Railsback, Lytinen, and Jackson 2006; Wooldridge and Jennings 1995; Zhou, Chan, and Chow 2009). The newly system parameter existing system which provides some examples to demonstrate and clear the application of ABS in simulating of agent parameters behavior. To be self-determine, the paper would explain concepts approach of ABS modeling and make the simulation model more interesting and the demonstration on how a small variation in parameter rules could leads to new agent parameter behaviors.

In general area contest of agent based model idea where used in a technique of modeling in which individuals parameter and their interaction behavior with each other and their environmental nature are explicitly simulated in a program simulation or in other physical entity such as a robot and complex systems. Individuals parameters modeled are for example, people, disaster, groups, teams, and social networks, but they can model agent entities that are more complexes in agencies and organization to make a decision making. It merges the agent parameter and the elements of evolution are been used to introduce complexities. ABS are well known as the individual-based models and the study reviews shows the numerous of literatures on agent-based models and the multi-agent systems illustrating the ABS are mostly been used in the non-computing related areas of scientific study domains including life science, ecology and social sciences. The models simulate a simultaneously agent operations and communication behavior of the multiple agents’ parameters, in an enhancement to simulate and forecast the emergence appearance of the complex system behavior. The simulation process is among the complexes of emergence situation which could be from the lower (micro) level of systems to a higher (macro) level. Therefore, in such a key situation the agent is at simple parameter behavioral rules to generate complex behavior.

| System Simulation Models | Discrete Event System (DES) | System Dynamic (SD) | Agent Based Model (ABS) |
|--------------------------|-----------------------------|---------------------|-------------------------|
| Application scopes       | Operational, tactical       | Strategic           | Academic, Technological |
| Importance of variable parameter | Higher                     | Lower               | Higher                  |
| Importance tracking of individuals parameters | Higher                     | Lower               | Higher                  |
| Number of entity         | Smaller                     | Larger              | Larger                  |
| Flow of Control          | Holding (queues)            | Rates (flows)       | Simulation (agents)     |
| Timescale                | Short time                  | Long time           | Short time              |
| System Purpose           | Decisions: optimization, prediction & comparison | Policy making: gaining understanding | Interaction, Decision, State making: simulation of agent & objects |
| Human agents             | Decision                    | Policies            | Decision, simulation    |
| Model Type               | Old model                   | Old model           | New model               |
| Approach                 | Sequential approach         | Top-down approach   | Button-up approach      |

2.3 Disaster Management & ABS in Disaster Response.

Disaster management is a process of planning, controlling, organizing, coordinating and implementing plans which are necessary to prepare, response and recovery of emergency cases of disaster risk, damage or any threat that may cause destruction and devastation to human life’s in their organizations or environments. In regards to disaster response operation domain ABS plays a significant role in simulating of emergency responses on the complex systems, such as in crisis, mass evaluation of human in the building collapse, in addition it has been mostly used by agencies & organizations in making decision to accomplished the goal of communication plans to control their teamwork operation, either as individual team or as a group of organizations. The new technological knowledge of computer-artificial intelligent agent-based modeling, have be improved and help to planned for chaos emergency situations; accurate mass evacuation crisis scenarios have been explained the services support of the designer of egress method for the new facilities and modernizations; research service support in the field areas of human behavior in disaster sociology; and model the mass movement between different agents parameter.

There are two methods that have been introduced to control disasters situations, firstly to protect an event from incident and second they have a good emergency response system plan. However, the both natural and
human-made disasters may cause or leads to injuries, deaths and distraction of people life’s and as the result of that situation a proper attention was needed in the organizational structure and to allocate the teams and their resources to control the risk effects of disasters.

2.4 Disaster Management in Building Construction Teamwork.

a. Building/Structural Collapse

This is the sudden destruction or collapsing of a building structures due to human or artificial threat which have yield the result of building collapses, and these reasons includes the foundation concrete mixture percentage ratio was not right, there was not enough planking structure in place to support the evacuations in place, the area spacing was too large or small, the cement reinforcement was not adequate, the contractor was cost price for cutting recommendation concrete mixture was not proper or reducing the mixture amount recommended, in addition of the illegal building structures to approved plans and as well the multitude of other reasons are amongst what is contributed for these infrastructural collapses. However, the engineering and construction teams perspectives, the buildings like all other infrastructures, are been designed and developed to support some certain loads. The loads are the weights of humans, the wind, snow, rainfall, flood and other objects that were occupying the building structure are referred to support life loads, and the weight of the building structure itself, were also referred to as dead loads. The structural engineers are the teams responsible for the engineering design, analysis of support loads and the integrity of the whole structural building system to guides in planning building. However, the buildings are susceptible to infrastructural collapse due to many cases threat of disaster, such as like incorrect structural design plan, faulty or wrong construction and workmanship, poor foundation will leads to failure, extraordinary heavy support loads, unexpected collapse modes of building failure.

b. Building Information Modeling (BIM)

The BIM is a framework currently been used within the building organization and industry as the interoperability issues are becoming more and more important in relative to the quality and productivity of the industry. BIM can be defined as a modeling technology which is associated with the set of processes to develop, communicate, construct and analyze building infrastructures throughout the entire projects lifecycle. Although, there are several bound of benefits that were gained from the BIM application, the local construction industry still reluctant to deploy the technology in delivery to its services. In the past decades of 1990s, the productivity benefits/advantages have being realized in other industries and the construction industries have went globally unaffected. However, much of this was due to the segmentation situation of the industry where the relationship between designer’s team, contractor’s team and subcontractors were experiencing difficulty of communications and team working. This is a BIM framework consisted of three major parts as shown below in a BIM diagram.

Policy Field: This is refers to the field were the building industry planned their policy rules and regulations are been developed and well started to the follow by employees of the industry. However, such policy fields include; Regulation Body, Educational institutes/programs, Research center/project and Insurance companies policies.

Figure 2: BIM Framework Diagram

Technology Field: This is the field that involves the implementation and development of the Information Communication Technology (ICT), the professions have been developed their own construction-related and communication software applications for the ease of their works. This field consisted of software’s (BIM software & communication systems), Hardware’s (model servers & database) and Networking providers (GIS & Equipment’s).

Process Field: This is the building subsequence step by step process to be followed often carrying out into construction of a building, since from the foundation until it reaches to the rooftop of the building structure. The field consist of the activities like, drawing document & survey(estimators & suppliers), component documents (fabricators, developers & contractors) and models (architect & engineers).

Therefore, BIM can help responders to access critical building information in case of emergencies. This can help in search and rescue operations within the building and its rapid mass evacuation. It can also be used for disaster planning and simulating different emergency scenarios. BIM increases the effectiveness of emergency response by providing the static model information such as floors, stairways, hallways, etc.

2.5 Limitations of BIM in Disaster Communication.

The BIM has the potential limitation and lapses if a genuine planning effort between team member is carefully reviewed and communication been shared. BIM application software’s can break down and provide a better understanding of the construction project, that can be implemented among contractors and other emergency/disaster teams. However, when used appropriately, it can reduce construction time speed, costs, and disasters claim. Therefore, what will happens when a BIM is not carefully shared and explain to all construction members, especially when it comes to the disaster
communication? The important issue when implementing BIM as an integral part of your project is the collaboration and communication access to the model by everyone involved during the construction stages. While Architects teams can use BIM to generate a great building structure, reducing costs and material, if the thought approach when the building is being designed is not transmitted and then claims as well problems will arise.

2.6 Why ABS is good to investigate the Communication.

The teamwork communication within the consultants and the contractors is very important issue to the exent that careful considerations has to be involved since from the beginning root foundation construction of the building, where by the teams coordinate hierarchical sequence order. And the groups and teams are responsible for the entirely construction of the building structure as well as monitoring perspectives. However, the architectural, structural, mechanical & electrical engineers and quantity surveys are refers to as the consultant teams while the contractor will be on the other side of teams to contract the construction of the building infrastructures accordingly.

3. ABS CONCEPTUAL FRAMEWORK DEVELOPMENT.

The model conceptual framework consists of very details explanation of the agent based model and how the simulation process of operation where carry out in this research case study. However, this case study will be using the ABS concept approach which mainly depend on these parameters of team level working together, such agent parameters are coordination, communication, shared metal model, time duration and trust, how they are been used in team operation in regards to disaster/emergency response situation.

Table 2: The different types of ABS Models and their application domain with respect to the parameters.

| Types of ABS                                                                 | Domain                                                                 | Parameters                                                                                     | Outcomes                                                                                     |
|----------------------------------------------------------------------------|------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| 1. The Development of an Agent-Based Modeling Framework for Simulating Engineering Team Work. By (Richard M. Crowder, Mark and rest, 2012). | Agent-based modeling method concept approach for the simulation team work within the engineering team environment, this notified and illustrated by research conducted in two different teams. | -Individual level (competency, motivation, availability and response rate). <br>-Team level (communication, coordination, shared mental model and trust). <br>-Task level (Difficulty and workflow). | -Quality of the task, time duration to complete the task, time period spends on working the task operation. <br>-Efficiency and effective coordination among the organization members. |
| 2. Agent-Based Simulation of Human Movements During Emergency Evacuations of Facilities. By (Joseph L. Smith, PSP) | ABS model is been used during and after any type of extremely situational event of disaster either of natural or man-made hazards, evacuation of people out of the threat situation and to the area of been protection of safety are the main primary objectives. | -Evacuation facilities. <br>-Fast and egress support. <br>-Human movement exercise (fast responders). <br>-Intelligent Agent based evacuation modeling. <br>-Technological equipment’s. <br>-Security personals. | -Successful humans egress evaluation simulation. <br>-Time and the speed which allowed the realistic parameter simulation of various physical and behavioral agent parameters. <br>-Coordination and communication of the evaluation team members.-Agent parameters information (size, position, behavior, speed and response time. |
| 3. Agent-based simulations for disaster rescue using the DEFACTO coordination system. By (Janusz Marecki, Nathan Schurr, Milind Tambe) | This paper describes the method of addressing extreme situational terrorist disaster attacks which requires a special attention to the prevention and protection to respond in the disaster crisis. | -Human situational event awareness. <br>-Human effectiveness towards directing agent teams behavior. <br>-Agent team communication and interaction strategies. <br>-Agent team parameters behavior performance. | -Improving of the human situational awareness and capability to assist agents. <br>- Agent team among the variety of team-level interaction strategies. <br>- Flexibility of agent coordination and communication within the team level. |
| 4. An Agent-Based Disaster Simulation Environment. By (T. L. Hsu & J. W. S. Liu, IEEE Fellow) | Agent-Based Disaster Simulation Environment as a framework that provides model idea of the agent elements and parameter tools to support modeling and simulation of object common types of natural disasters. | -Active objects function of time and space. <br>-Agents movement and their attachment simulation. <br>-Interaction with each other and with their environment. | - Agents and external simulators model elements. <br>-Behaviors and interactions of agent’s coordination. |
a. Agent Variables selection Criteria.
The table below contained the different agent parameters that are needed in ABS Model to be used and selected for the simulation process operations in disaster response teamwork processes. The table diagram of the agent based model variables/parameters is going to show below in the table and explain the parameters behavior of communication relationships in the simulation model.

| Parameters              | Types    | Team | Individual | Task |
|-------------------------|----------|------|------------|------|
| Shared mental model     | Process  | ✓    | ✓          | ✓    |
| Communication           | Process  | ✓    |            |      |
| Trust                   | Process  | ✓    |            |      |
| Learning Time           | Process  | ✓    | ✓          | ✓    |
| Availability            | Process  | ✓    | ✓          | ✓    |
| Response Rate           | Process  | ✓    | ✓          | ✓    |
| Motivation              | Process  | ✓    | ✓          | ✓    |
| Competency              | Process  | ✓    |            |      |
| Workflow                | Process  | ✓    |            | ✓    |
| Difficulty              | Process  | ✓    |            | ✓    |
| Quality                 | Performance | ✓ | ✓        | ✓    |
| Working time            | Performance | ✓ | ✓        | ✓    |
| Communication Frequency | Process  | ✓    |            |      |
| Control                 | Process  | ✓    |            |      |
| Completion Time         | Performance | ✓ |            |      |

b. Agent Based Simulation (ABS) Framework.
The diagram below was showing the ABS model conceptual framework of this research study, which will be related to agent teamwork response to disaster and emergency cases operation.

![ABS Conceptual Framework diagram](image-url)
The above conceptual diagram known as the ABS model concept approach was displaying the parameters structures within an individual teamwork known as “Designer Agent”. Therefore, during the simulation process, the workflow should upload the individual subtask requirements to the designer agent in the simulation model, which it will execute as well computes all the agent parameters or variables and controls the entire communication requirements. The rectangular blocks known as “agent parameters” and the interconnecting arrows within and across the simulation model they are representing the implementation of simulation rules. However, in general the diagram illustrated as well describes the agent based model simulation of agent’s parameters in the disaster/emergency response team working environment in regards to the teams/units communication and coordination of their objects (agents) operations. Therefore, the team working was mostly depending on the agent variables parameters to communicate and coordination with one another in the simulation process, because if the agent parameter element violate the correct simulation rules, in which supposed to follow or obey a complex problem could be arise which would lead to something else without been able to achieved the required aims of the teamwork simulation.

4. DISCUSSION

The conceptual framework approach help investigating the teamwork operation and how they are been carried out simultaneously in which depends on the agent parameters needed in coordination and communication within and out of different agents as teamwork. However, the parameter were going to be determined by some expression or equation to the efficiency and effectiveness of the ABS model and disaster response situations mainly depend on how the teamwork speed and fast time response operation in the process of accomplishing or achieving the stated goal of controlling emergency situations of disasters. However, the different types of simulation system models where been analyzed carefully before selecting the ABS model which serves as the case study area of this research.

5. FUTURE WORK

In regards to the future work of this case study, the agent based model (ABS) simulation will serves as guide to the organizations and agencies on making a decision to select a good system simulation model (SSM). Therefore, the framework is going to be apply to a data that will be getting from two separate teams from a certain organization that are working in disaster building construction industry region to tasty the efficiency of the model framework. The teamwork simulation hierarchical sequence from the group engineers, quantity surveys and architects are the teams which are going to be interview as well generate the data to be analyze as the communication agent parameters in the model.

6. CONCLUSION

In summary, the Agent Based Simulation (ABS) model is the best concept of approach other than the System Dynamic (SD) and Discrete Event System (DES) due to the simplicity and the above mention reasons. The Building Information Modeling (BIM) was serves as a guide in the implementation as well as the data collection stage among the teamwork of units, in other to taste and validate the agent’s variable parameters in the ABS conceptual framework. And lastly, this research paper will serves as guide to the organizations and agencies on making a decision to select a good system simulation model (SSM) when it comes to the issue of disaster management situations.

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