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SIMULATION MODEL AND SIMULATION-BASED SERIOUS GAMING IN HUMANITARIAN LOGISTICS

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ABSTRACT

Humanitarian logistics has recently gained increasing attention from both academics and practitioners. Although various research groups have addressed theoretical and technical developments in humanitarian logistics, only a limited number of those can actually be generalized, extended, accessed, and understood by non-technical practitioners. To tackle these challenges, we develop a simulation model for humanitarian logistics preparedness and a simulation-based serious game to raise awareness and provide accessibility on humanitarian logistics research to a wider audience. The simulation model aims to optimize the network configuration for prepositioning stocks of life-saving goods in Indonesia, while the game aims to provide a risk-free environment where players can craft various strategies to plan and deploy effective humanitarian operations.

1 INTRODUCTION

With the high number of natural disasters recorded worldwide, there is increasing need for enhanced efficiency in the provision of humanitarian assistance, especially in terms of transportation and distribution of relief goods. For this reason, in the recent past, scholars and practitioners have started to focus their research efforts in the humanitarian logistics field (Balcik and Beamon 2008) to increase the efficiency and effectiveness of relief goods flows. Although various research groups have addressed theoretical and technical developments in humanitarian logistics preparedness (Timperio et al. 2017; Balcik and Beamon 2008; Roh et al. 2013; Horner and Downs 2010; Rezaei-Malek et al. 2016; Duran et al. 2011; Qing et al. 2013), only a limited number of those can actually be generalized and extended to other disasters in different areas.

Simulation models can be used to generalize and extend the humanitarian logistics preparedness. It would model a particular scenario using real data and simulate the real situation. It would widen the spectrum of practical usability for the developed contents. The main benefit of computer simulation lies on the fact that it allows for evaluation of supply chain performance in a virtual environment, hence mitigating the risk of costly mistakes prior the actual implementation (Thierry et al. 2008). Supply chain simulation has been extensively used for supply chain design decisions as well as evaluation of supply chain policies. Several simulation techniques that used to address key issues in humanitarian logistics include System Dynamics (SD) (Besiou et al. 2011; Costa et al. 2015), Discrete Event Simulation (DES) (Iakovou et al. 2014; Noreña et al. 2011) and Agent Based Simulation (ABS) (Grimm and Railsback 2004; Horner and Widener 2011). The simulation model may require certain technical skill sets to comprehend its intended outcome. This would probably limit its access to non-technical practitioners.

To further extend the accessibility of humanitarian logistics contents to a wider audience, including non-technical practitioners and youth in a simplified format that's easy to understand, a simulation-based serious game can be developed. Serious games have been around for many years and have recently gained increased popularity (Ritterfeld et al. 2009). Game provides the players with a safe environment to practice their skills without the threat of real-world consequences, increases interactivity between players and allows them to learn at their own time (Winn 2002). By providing different scenarios with different level of difficulties, game can help to maintain players' interest and motivation, compared to traditional simulation software tools (Hou 2015).

In this paper, we focus on developing a simulation model for humanitarian logistics and a simulation-based serious game for humanitarian logistics, titled Disaster Relief. A real-case simulation model is developed to optimize the network configuration for prepositioning stocks of life-saving goods. It produces a network configuration that allows a potential cost saving of 15% as compared to the configuration prospected by preliminary discussions with several experts.

The Disaster Relief game is based on our simulation model in humanitarian logistics. This Disaster Relief game is motivated by the real need to develop a tool to raise awareness and provide accessibility on humanitarian logistics research contents to a wider audience, and by the potential gain that such tool can bring into practice in the domain of humanitarian logistics. Different disaster scenarios with different challenges based on real and various natural disaster scenarios in different areas are simulated and introduced in the game to improve the players' awareness and understanding of humanitarian logistics best practices. To evaluate the Disaster Relief game, we conducted an interactive session with senior government officials in humanitarian and disaster relief from several countries. Although the players were working in the humanitarian and disaster relief area, most of them had a limited knowledge regarding humanitarian logistics specifically. From the conducted workshop, we gained evidences that serious games have the capabilities to deepen the players' understanding about humanitarian logistics by providing an easy to play hands-on and actual experiences to apply and experiment on the concepts.

The remainder of the paper is structured as follows. Section 2 sets the background of the research by focusing on humanitarian logistics and simulation-based serious games in supply chain and logistics. Section 3 illustrates a real-case simulation model in humanitarian logistics preparedness. Section 4 describes the Disaster Relief game. Section 5 summarizes the paper and presents the future extensions.

2 LITERATURE REVIEW

In this section, relevant literature in the areas of humanitarian logistics, computer simulation applied to humanitarian logistics and simulation-based serious games in this domain are reviewed.

2.1 Humanitarian Logistics

Between 1994 and 2013, 6,873 natural disasters were recorded worldwide, which claimed 1.35 million lives and affected an average of 218 million people yearly (ReliefWeb 2015). In 2017 alone, 301 catastrophes worldwide were registered, of which 183 were natural, and 118 were man-made (Swiss Re 2018). In terms of human lives, 2017 disaster events caused more than 11,000 people dead or missing, coupled with an estimated economic loss of nearly USD 337 billion. This was close to double the USD 180 billion by 2016, and well above the average USD 190 billion per year (inflation-adjusted) in the period 2005-2015 (Swiss Re 2018).

In a global context characterized by a progressive need of humanitarian assistance in concurrence with the shrinking of resources, there is increasing need for enhanced efficiency in the provision of humanitarian assistance, especially in terms of transportation and distribution of relief goods. Humanitarian logistics is defined as the activity of "planning, implementing and controlling the efficient, cost-effective flow of and storage of goods and materials as well as related information, from point of origin to point of consumption for the purpose of alleviating the suffering of vulnerable people" (Thomas and Kopczak 2005).

Humanitarian supply chains are demanded to be simultaneously agile, cost effective, and time responsive. Typically, disaster relief operations are run in highly chaotic and dynamic environment, whereby logistics requirements and operating environment are in continuous and rapid change. Demand (Beneficiaries' needs), and status of logistics infrastructures change drastically throughout the various phases of the emergency response, therefore highlighting the need high supply chain agility. The scarcity of resources such as supplies, people, funds, and technology (Balcik and Beamon 2008; Nahleh et al. 2013), will instead demand for streamlined logistics processes and cost - effective supply chains. The urgent need of life-saving supplies – especially in the so called golden window (72 hours after the disaster) - brings instead upon the additional challenge of short lead times to be met, demanding for time responsive supply chains.

According to Van Wassenhove (2006) between 60% and 80% of humanitarian expenditures account for logistics. Therefore, to gain concurrently time responsiveness, cost effectiveness, and agility, the approach towards humanitarian logistics cannot longer be purely reactive, but there is a clear need to plan for relief operations prior disasters strike (Hermitte et al. 2016; Timperio et al. 2017). In emergency response, both supply chain arcs and nodes play crucial roles. While logistics infrastructures for sea, air, and land transportation (arcs) facilitate material flows in between the various nodes of the supply chain as well as allow distribution of relief items to affected zones, practical experience suggests that also storage facilities (nodes), and their locations, greatly affect both speed and sustainability of logistics operations (Timperio et al. 2017; Balcik and Beamon 2008; Roh et al. 2013; Horner and Downs 2010).

2.2 Simulation-Based Serious Gaming

Serious games have been used as an education gaming tool to increase awareness in specific concepts and knowledge, with notable implementation in education and training (Johnson et al. 2005; Graafland et al. 2012), healthcare (Garcia-Ruiz et al. 2011), military applications (Lim and Jung 2013), and city planning (Gómez-Rodríguez et al. 2011). It provides learning engagement and motivations (Ma et al. 2011; de Freitas and Liarokapis 2011; Riedel and Hauge 2011) as well as give hands-on experience learning specific topics based on the learning objectives of the game. There are many genres of serious games available, for example action, adventure, sports, puzzle, and simulation. This paper will focus on simulation-based games.

In simulation-based games, the learning and awareness would occur through a process of hypothesizing, probing, and reflection upon the simulated world within the game (Hamari et al. 2016). It combines appropriate story scenarios based on the specific concepts and knowledge, such as supply chain management and humanitarian logistics, where the players can be more involved in solving a particular task or challenge in the game by repeatedly performing manipulation in the experiment and reflecting on its consequences, thus promoting players' motivation and learning transfer in a subsequent realistic context (Hou 2015). This would promote players' awareness as well as replace decision making ability when they encounter events in the real world. Previous studies show that these kind of games advanced players' awareness and learning in scientific knowledge (Hou 2015; Ma et al. 2011).

A number of simulation-based games have been introduced to facilitate teaching and learning in Supply Chain Management (SCM) concepts (Riedel and Hauge 2011), among which are the famous Beer Distribution Game (Wisner et al. 2014; Sterman 1989; Jacobs 2000), and Mortgage Service Game (Anderson and Morrice 2000). There are also several simulation-based games developed to create awareness in humanitarian scenarios (disaster relief), such as Passages (United Nations High Commissioner for Refugees 2005) that describes difficulties experienced by refugees as they flee their homes and countries towards an uncertain future; Against All Odds (United Nations High Commissioner for Refugees 2005), a web-based game which aims to give young people an insight into what it is like to be a refugee; and Darfur is Dying (Vargas 2006; Games for Change 2006) to increase public awareness of the crisis in Darfur. Although there are many simulation-based games for humanitarian scenarios available, none of these discuss or describe strategic planning and implementation of humanitarian logistics. The summary and comparison of two SCM games, two humanitarian games and our proposed game are presented in Table 1.

Table 1: Games Comparison.

	Beer Distribution Game	Mortgage Service Game	Passages	Darfur is Dying	Disaster Relief Game
Topic	Industrial production and distribution system	Service-oriented SCM	Refugees	Refugees in Darfur	Humanitarian logistics
Type of game	Simulation	Simulation	Simulation	Simulation	Simulation
Objective	Introduce the basic concepts of the bullwhip effect and the benefits of information sharing and lead-time reduction	Introduce bullwhip effect resulting from information and capacity adjustment lags and impact of end-user demand information in the service industry	Create awareness, arouse emotions and encourage participants to take action on behalf of refugees	Raise awareness of the genocide taking place in Darfur and empower college students to help stop the crisis	Raise awareness and provide accessibility on humanitarian logistics research to a wider audience
Type of tasks	Operation activities/tasks	Operation activities/tasks	Operation activities/tasks	Operation activities/tasks	Strategic planning and operation activities/tasks
Playing mode	Paper, computerized and online	Computerized	Computerized	Paper/booklet	Computerized

3 SIMULATION MODEL FOR HUMANITARIAN LOGISTICS

A real-case simulation model is developed to optimize the network configuration for prepositioning stocks of life-saving goods in Indonesia. In this case, the simulation model was developed to choose 6 out of 9 alternative locations as nodes of the national network of emergency response facilities. Particularly, the optimization criteria were minimum transportation cost to distribute relief items to 186 demand points across the nation. Transportation cost from a facility to a demand point was calculated based on the actual distance and fuel cost. For facility-demand point pairs that are not connected by land, a very high unit cost was set to simulate the need for intermodal transportation. It was assumed that each demand point is fulfilled by a single facility and that all facilities are incapacitated.

The simulation result is shown in Figure 1 (The Logistics Institute - Asia Pacific 2018). The network configurations identified by the simulation model (Figure 1(a) and 1(b)) will allow a potential cost saving of 15% as compared to the configuration prospected by preliminary discussions with several experts (Figure 1(c)). The network configuration is further fine-tuned by stress-testing on two parameters, namely: fleet size and inventory. The results are shown in Figure 2. It shows that the solutions identified from the simulation model are able to compute service level values at various levels of fleet and inventories. A good combination could be 70% of Inventory level and 100% of Fleet size. It can produce a high service level and reasonable impact on transportation cost.

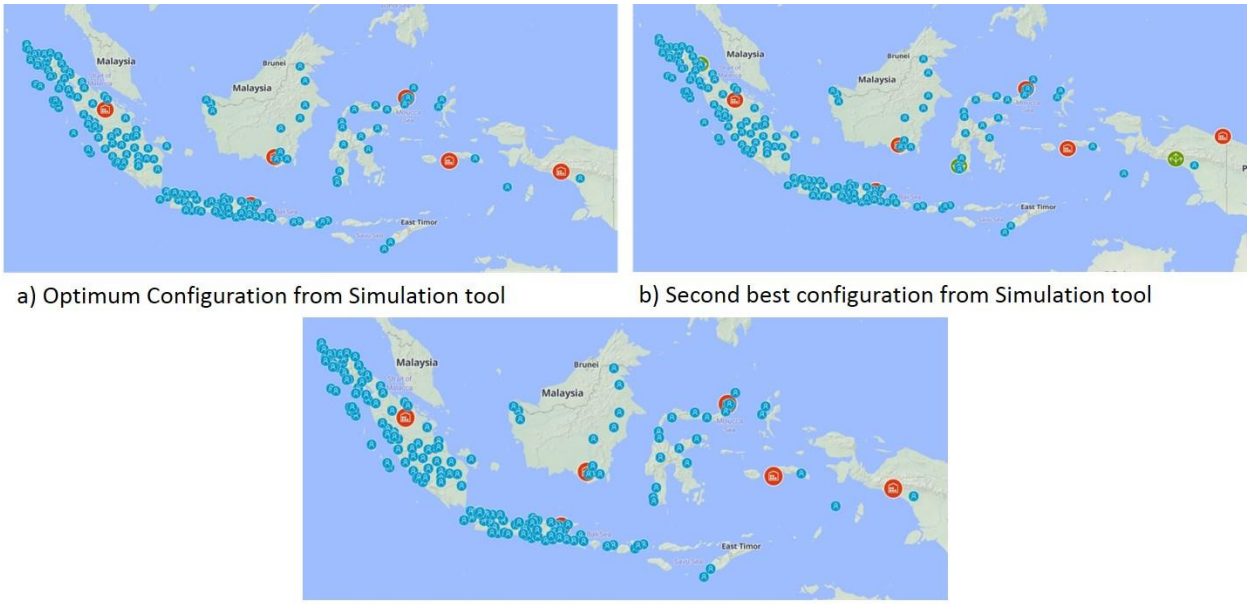

Figure 1: Disaster Relief Model.

Figure 2: Simulation Result for Fine-tuning the Network Configuration on Two Parameters.

4 THE DISASTER RELIEF GAME

4.1 Disaster Relief Game Overview

The Disaster Relief game is a digital single player role-based simulation game whose main objective is to create awareness and understanding of the importance and complexity of supply chain management planning and execution for humanitarian crises. The game interfaces are shown in Figure 3. This game is developed to provide a risk-free environment where players can craft various strategies to develop a rescue

and resource management and allocation plan when a disaster strikes. The game will then execute the plan to simulate its effectiveness and resilient during a disaster. Different disasters in different areas can be simulated, depending on the scenarios. The introduction of random emergency events at this stage will further test the player's ability to think on their feet and their ability to react.

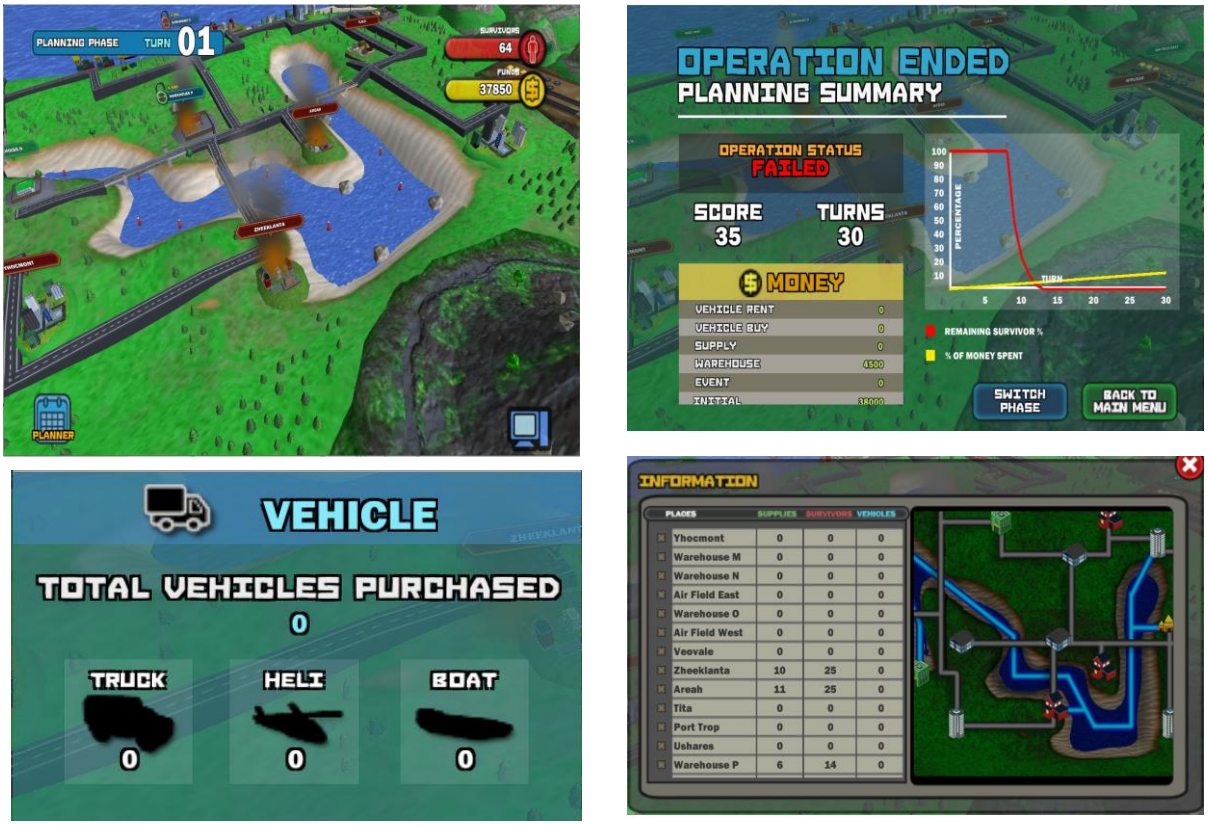

Figure 3: Disaster Relief Game Interfaces.

Using this game, players from interdisciplinary groups which may have limited knowledge about humanitarian logistics can work together for a best-fit plan. The game also acts as a communication medium for better networking among the players. Players can choose to replay the same scenario or choose a different disaster scenario with different challenges, repeatedly. The players are assessed on factors such as usage of available resources and management of limited funds, two variables heavily affected by upstream decision making and relevant to the context we delve in.

Gamification elements are also included in the game such as scoring system given at the end of each gameplay to help motivate and provide immediate feedback. The scoring system also helps to create competitiveness among players to improve in their planning. The instant feedback, for example, gives the player the realism of the urgency. And with the option of mobile play, we are able to extend the learning circle beyond the classroom walls and reach out to a greater audience of all demographics, creating greater awareness among the mass public.The game has two stages, the Planning Phase and the Execution Phase, which simulate the Preparedness and Response stage of the Disaster Management Cycle respectively. During the Planning Phase, the player is given information about an imminent disaster affecting one or more towns on a fictitious island, its projected affected population number, its current state on resource availability, and many more. The player is to plan for the escape routes to possible ‘safe areas’ for the

affected population (or survivors) and its projected number of supplies required to sustain the survivors throughout the gameplay. Once the player is satisfied with his/her plan, he/she may proceed to the Execution Phase, where the disaster will occur and the game will put into action the player's plan. At this stage, the player is unable to make changes to his/her plan, unless some unexpected event occurs, at which the player may wish to make changes to adapt to the new challenges.

This Disaster Relief game helps players refine their thought process of planning and in designing a coordinated and uninterrupted supply chain of life saving relief items to the affected areas including cargo and information flows starting from assessment, sourcing (stocks and procurement), transportation, warehousing up to distribution.

4.2 Game Experience

To evaluate the effectiveness of this game in creating awareness in humanitarian logistics and the overall game experience, we conducted an interactive session with senior government (National Disaster or Management) officials for humanitarian and disaster relief from several countries. Although the players were working in the humanitarian and disaster relief area, most of them had a limited knowledge regarding humanitarian logistics. The session was held in Singapore on November 2017. This session was part of five-day workshop focusing on humanitarian and emergency response.

From this workshop, we gathered two feedbacks. The first feedback is to evaluate the overall game experience. For this purpose, we developed a questionnaire comprising 18 questions focuses on six game criteria, namely: challenges, choices, competition, fantasy, goals and rules. Each question represents either positive or negative experience. The questionnaire used the 5-point Likert scale (5=strongly agrees, 1=strongly disagrees). Thirteen valid responses were received. The results show that the average score for all criteria with positive experience is above 3 and average score for all criteria with negative experience (except for rule criteria) is below 2. This indicates that the players have a good experience with the game. The negative experience in rule criteria is considered quite high, this indicates that the players may need additional time to understand and master the rules of the game.

The second feedback is to evaluate the learning objective by asking each player to list down learning points from the game after they have played the game. We then match it with the intended learning objectives of the game. From their feedback, we found out that their learning points are aligned with the intended learning objectives mentioned in section 3. It confirms that the players were able to absorb the learning objectives of the game and the game helps to increase awareness in humanitarian logistics.

Other than this interactive game session, we have also conducted game sessions for various prestigious conferences, seminars and workshops around the world for this Disaster Relief game. For example at the 3rd Senior Executive Programme in Disaster Management and the 8th Leadership Programme in Disaster Management hosted by the Singapore Civil Defence Academy (Civil Defence Academy 2018), with participants from various international countries senior government officials and policy makers. Our games have also been played at Serious Games Conference 2017, Singapore (Serious Game Association (Singapore) 2017) and training workshops in various parts of Indonesia. The acceptance and learning objective evaluations of the players resonates throughout all of our game sessions.

5 CONCLUSIONS

In this paper, we focused on generalizing and extending the accessibility of humanitarian logistics contents to a wider audience using simulation model and simulation-based serious game. A real-case simulation model to optimize network configuration for prepositioning stocks of life-saving goods in Indonesia has been developed. This simulation model is able to produce a network configuration that allows a potential cost saving of 15% as compared to the configuration prospected by preliminary discussions with several experts.

A simulation-based digital game, named Disaster Relief game, is also developed as an easy-to-use tool to increase awareness in humanitarian logistics for non-technical practitioners. It is able to provide several

scenarios based on real natural disasters in different areas. The game has two stages, the Planning Phase and the Execution Phase, which simulate the Preparedness and Response stage of the Disaster Management Cycle respectively. An interactive session as part of five-day workshop was conducted to evaluate this Disaster Relief game. Our survey from this session shows the use of the Disaster Relief game was well received and has a significant good effect on the players. The learning objective evaluation also showed that the players were able to grasp the learning objectives of the game.

Nonetheless, we see three possible extensions that we would like to study in the near future. First, we would like to integrate the serious game with the actual simulation model. This would provide the players a better feedback according to real simulation result. Second, we would like to include intelligent algorithms to tweak the scenarios and simulations based on the players' behavior. This would increase the challenges and motivate the players to keep playing the game. Third, we would like to evaluate the Disaster Relief game in wider audiences with different ages and different background knowledge related to supply chain and humanitarian logistics. It would provide a more comprehensive result to evaluate the ability of the game to increase awareness in humanitarian logistics.

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