DSS Framework: A Proposal for Disaster Logistic Support System for the Province of Laguna

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Abstract

The Philippines' location within the Pacific Ring of Fire brings enormous threat to its people. Intervention and innovation are to be in place for survival and growth, since nothing can be done about its geographic location and the threats that come with it. This study aims to create a framework for developing a decision support system, a mobile and web application for the efficient implementation of the disaster logistics support system. The study will utilize Agile Methodology for the software development in the proposed framework. This proposed framework exhibits the features of the system such as identifying location, affected families, supplies, reports, management of inventory, vehicle outsourcing, and monitoring. The system framework can be a helpful tool for the efficient and speedy delivery of needed help and an effective approach to disaster supply chain issues.

Keywords: ICT-based logistic, logistics, decision tree models, provincial and municipal disaster risk reduction management

1.0 Introduction

The study of Nahleh, et. al. (2014) noted that the number of disasters worldwide has increased fourfold in the last thirty years. Researchers also reported that disasters have affected around 6.1 billion people and caused an estimated damage of 2.3 trillion dollars. The importance of disaster risk reduction and response management cannot be underscored enough. Proper planning for emergency situations in areas hit by disasters is crucial, given the uncertainty of the circumstances surrounding the event. For example, the delivery of much-needed personnel and supplies to an affected area will be difficult for the disaster response team of a town with limited means of transportation.

Decisions made by disaster response managers are thus critical in ensuring the fast and efficient delivery of aid to disaster victims. This is because the emergency supply chain differs markedly from the normal supply chain in a number of ways. During disasters the supply demand is greater and made at short notice, transportation is hampered by blocked or damaged roadways and infrastructures, communication channels may be unavailable due to power outage and

damaged lines, and the efficiency of delivering the needed goods and services may be compromised. Consequently, the success of relief operations and therefore the survival of disaster victims rely critically on continued and effective logistics processes, despite the odds (Bastosa, Camposa, & Bandeira, 2014).

Researchers have recognized the great potential of the use of analytical tools, in particular those that employ information technology (IT) methods and techniques, in improving disaster-related operations (A-Iryani, & Gassin, 2005). However, D'Uffizi, et. al. (2015) noted that no tool for forecasting emergency logistics planning for humanitarian relief organizations has been developed yet, despite the availability of natural disaster-related time series data for the last 110 years. They also remarked that logistics in emergency situations such as natural disasters is affected by uncertainty, due to the highly volatile nature of such situations characterized by a spike in the number of relief requests and the limited availability of relief resources.

Businesses involved in logistics and supply chain operations worldwide have adopted cutting-edge information technologies to improve the performance of their processes. Research in this area (e.g., Ndonye, 2014; Azmi, Hamid, Hussin, & Ibtishamiah, 2017) has indicated improvement in logistics management, business performance, and customer satisfaction, as well as significant positive relationships between logistics performance and IT components such as information flow, logistics integration, inventory management system, and fleet management system. Through these technologies, the implementation and control of the operational management of logistics and the supply chain are efficiently and effectively conceptualized to better manage resources (Li, 2014).

Governments in many countries play a vital role in the development of the logistics supply chain industry by providing opportunities for collaboration between researchers (Van Dyk, Marais, and Ittmann, 2008). In India, private consultancy services are well connected with government agencies thus giving them high industry connections with logistics corporations. Logistics also has a very important role in the economic development and increased cooperativeness of countries in Africa (Thaller, et al., 2012).

The authors of this paper hoped to apply the same principles of utilizing information technology tools and analysis methods in improving logistics and supply chain management for the disaster suppliers in the Philippines, in particular the branches of government that are on the forefront during disasters. For this purpose, the authors paid a visit to the Provincial Disaster Risk Reduction Management Office (PDRRMO) of the province of Laguna, the province is exposed to a number of natural calamities like typhoons, floods, landslides, and recently, the eruption of Taal Volcano in the nearby province of Batangas.

The disaster risk reduction management agency operates under the mandate of Republic Act no. 10121, entitled "An Act Strengthening the Philippine Disaster Risk Reduction and Management System, Providing for the National Disaster Risk Reduction and Management Framework and Institutionalizing the National Disaster Risk Reduction and Management Plan, Appropriating Funds Therefore and for Other Purposes". The law states that "every local government unit has a basic responsibility to ensure the welfare and safety of its constituents due to the increasing events of calamities caused by

climate change and global warming affecting lives, properties, agricultural productivity, commerce and industry, infrastructure, school buildings and facilities, hampering the normal living condition and quality of life of the people. The need to formulate a contingency plan that will define the systematic procedure on how to effectively prepare for, respond to, face the consequences, capacitate the key actors in time of calamities are valuable steps to be undertaken by every local entity in order to improve the capability and capacity of every constituents for environmental adaptation."

In the event of a disaster the lead agency in handling logistics is the Provincial General Services Office (PGSO), whose member agencies are the Department of Interior and Local Government (DILG), Office of the Laguna Provincial Social Welfare and Development (OPSWD), Armed Forces of the Philippines (AFP), Bureau of Fire Protection (BFP), Philippine National Police (PNP), Provincial Health Office (PHO), Provincial Disaster Risk Reduction Management Office (PDRRMO), Office of the Provincial Agriculture (OPAG), KABALIKAT, Stimulation and Therapeutic Center (STAC), Philippine Board of Orthopedic (PBO), and Laguna Tourism, Culture, Arts and Trade Office (LTCATO). Per the PDDRMO administrator the office does not employ a computerized logistics system to monitor the deployment of logistical support in the province, instead using Microsoft Excel for recording, monitoring and tracking disaster relief operations.

The system framework is a system that takes into consideration the challenges of supply transportation during calamities by integrating features that help lessen travel times through merging reports of the status of roadways to plot the best possible route and facilitate the efficient delivery of the needed supplies and services through a central inventory, especially when there is a huge demand for a certain disaster-hit area. It can especially be useful in providing transportation for disaster relief suppliers in areas with little to no transportation capacity by employing the services of contracted trucking companies.

General Objective:

This study aims to create a framework for developing web application that can be used for a more efficient management of disaster logistics during different disasters especially in determining the location of the evacuees, number of supplies and tracking of available vehicle to deliver the needs of the victims of disaster.

Specific Objectives:

1. To develop a system framework that can offer an all-in-one mobile logistics system that can be used during calamities with the following features:
    a. Disaster Management System
    b. Inventory Management System
    c. Warehouse Management System
    d. Transport Management System
2. To apply the Agile development Model for the creation of the proposed system framework.

Review of Existing System

Table 1 shows a comparison of features between the proposed system framework and a number of mobile applications found in Google Playstore that were developed for disaster response management. It shows that the important features of a disaster management application are lacking on the existing applications. The features listed in the table were included in the system framework based on concepts adapted from the supply chain management theory.

Table 1. *Summary Comparison of Disaster Management Applications*

Application System	Feature Modules				
	Order Management System	Inventory Management System	Warehouse Management System	Transport Management System	Reports
LIGTAS System	✓	✓	✓	✓	✓
PDRMMO System	✗	Manual using excel	Manual using excel	✗	Manual using excel
Disaster Management (Mobile Seva)	✗	✗	✗	✗	✗
Disaster Management (MCGM)	✗	✗	✗	✗	✗
Disaster Management (Softecks)	✗	✗	✗	✗	✗
Disaster Alert (Pacific Disaster Center)	✗	✗	✗	✗	✗
Disaster and Crisis Management (Tototomato)	✗	✗	✗	✗	✗
Emergency Preparedness and Disaster Survival Guide (Summer Rabbit)	✗	✗	✗	✗	✗

The following modules have been integrated into the system framework based on the necessary features:

Order Management System - platform that tracks sales, orders, inventory orders, and fulfilment of delivery.

Inventory Management System – module where inventory processes and warehouse activities are managed and optimized.

Warehouse Management System – module where warehouse operations from the time goods or materials enter a warehouse until they move out are managed.

Transport Management System – the logistics platform that uses technology to help businesses plan, execute, and optimize the physical movement of goods, both incoming and outgoing.

Proposed System Framework

The study proposes a framework for developing a system which is a web-based mobile application that allows the PDRMMO to plan, mobilize, and execute emergency responses. It is also seen to significantly improve the delivery of humanitarian logistics.

The system framework will provide the PDRMMO all information required for the more

efficient and faster delivery of relief supplies. The system framework, as a disaster supply-chain-management system, will provide the PDRMMO the objectives, available choices, possible risks, and other pertinent information needed for disaster relief operations. Figure 1 shows the flow of the disaster logistics system, which includes logistics network, coordination and integration collaborated with the logistics management down to relief priorities. Moreover, the framework also integrated the Decision Tree in which use for management, the choices, risks, objectives, and information needed for relief priorities. The tree is made up of a series of nodes and branches. At the first node on the left, the management has the choice of delivering the relief using the short route or long route. Each branch represents an alternative course of action or decision. At the end of each branch or alternative course is another node representing a chance event—whether or not the road is damaged. Each subsequent alternative course to the right represents an alternative outcome of this chance event.

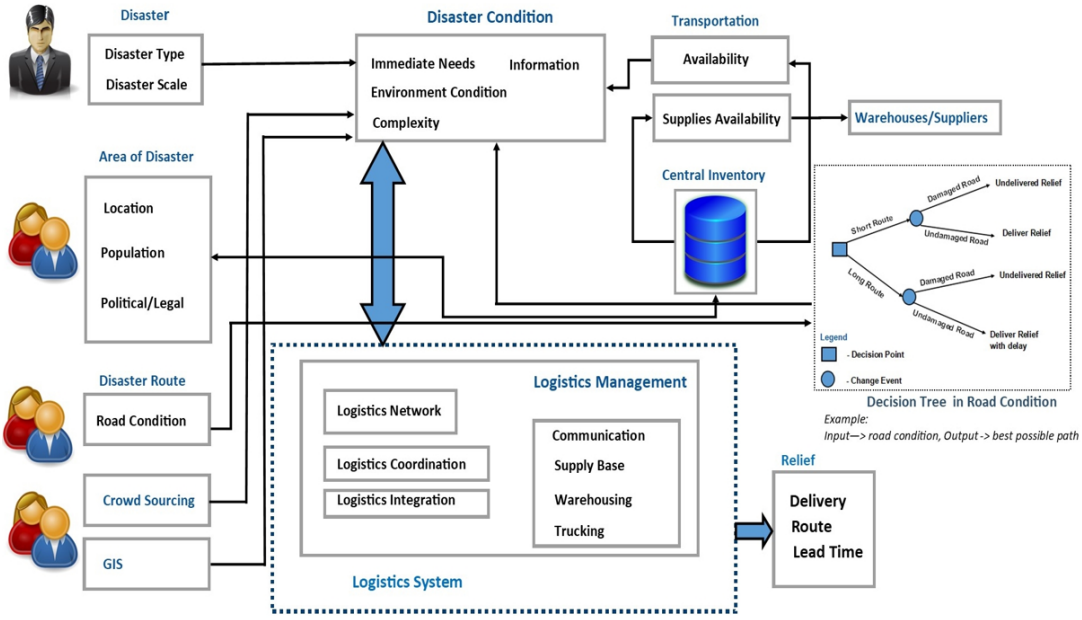


Figure 1. *Conceptual Framework of the Study*

2.0 Methodology

The Agile Methodology will be adopted in managing the software development for the proposed framework. This methodology comprises of several stages like Planning, Requirements Analysis and Design, Implementation, Testing, Evaluation and Deployment. As the system is divided into features that are grouped into milestones, the group of features goes through each of the stages in the methodology forming a cycle of stages. The cycle repeats until a Minimum Viable Product (MVP) is created.

The milestones of each system, Disaster Management System (DMS), Inventory

Management System (IMS), Warehouse Management System (WMS) and Logistics Management System (LMS), are organized and divided into sprints, which will identify what group of functionalities should be prioritized and what functionalities should be done before others can be done presented in table 2. The milestones of the DMS, IMS and WMS are recommended to have overlapping sprints because they have functionalities that depend on one another. That way, agencies can ensure that both systems consider the changes as soon as it happens. As early feedback is encouraged in the Agile methodology, the updates in the requirements and design are adapted as soon as it is learned and agreed upon.

The sample roadmap allows the team to divide the functionalities into multiple milestones. In each milestone, the aiming to complete one full-cycle functionality, meaning frontend and backend, in each system for every sprint. The number of sprints will vary according to team size and feature complexity.

In the sample roadmap, Milestone 1 aims to cover the basic features of the DMS, IMS and WMS. Milestone 2 covers the more advanced features of DMS and IMS. LMS development should only start when DMS and IMS have all the basic features implemented because both DMS and IMS are a dependency of LMS.

After formulating and constructing the design and developing the system, the proponents will also conduct tests and evaluations with the help of respondents.

LIGTAS is a cloud-based web application that is written in Java Script which uses open-source libraries and APIs, e.g. Google Map APIs.

The stack technology is Java Script for the Backend; Firebase for the Database Management System (DBMS) and Analytics. HTML5+CSS for the Frontend using ReactJS framework.

The System Architecture is using the fundamentals concept of Web Application Architecture. It is consisting of components like user-interface, application logic and databases. Firebase Database Management System is a real-time database that can store data and sync data at real time. Users can easily access the data in any device whether it is a web or a mobile application as presented in Figure 2.

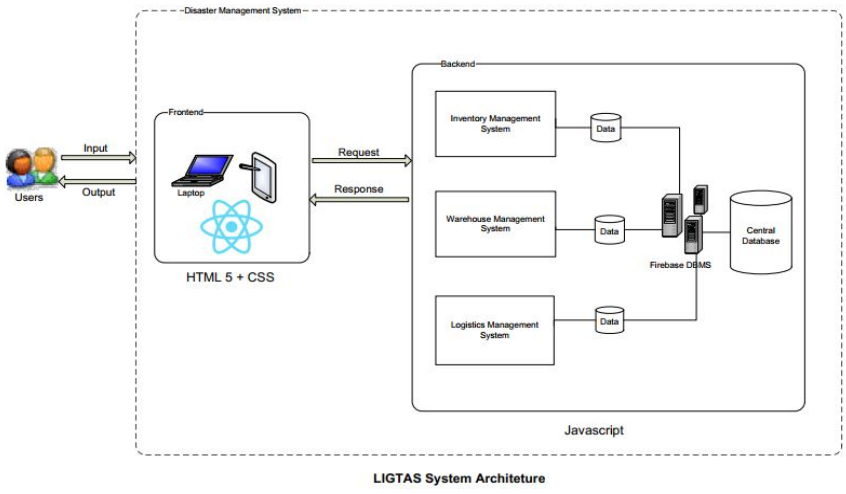
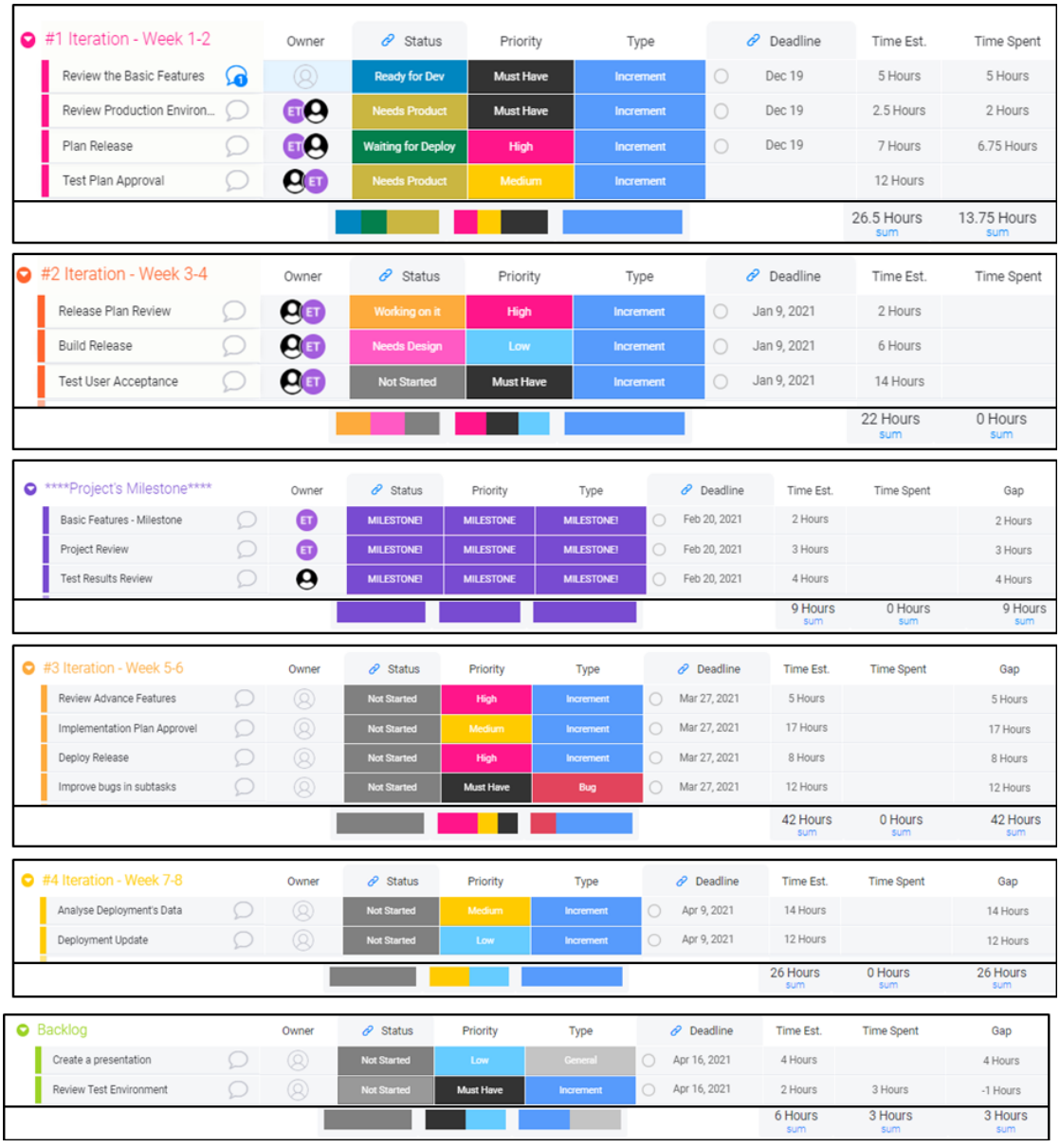


Figure 2. *LIGTAS System Architecture*

Table 2. *Summary Comparison of Disaster Management Applications*



The target number of 300 respondents will be non-randomly selected from Local Government Unit-Disaster Risk Reduction Management (LGU-DRRM) officials of the 30 municipalities and cities in Laguna province. They will be asked to evaluate the system using a survey-questionnaire constructed for this purpose, which will be personally administered and retrieved by the authors. Table 3 below shows the corresponding descriptive ratings of the 5-point Likert-type scale employed in the evaluation questionnaire.

Table 3. *Likert Scale for Evaluating the Developed System*

Scale	Range	Descriptive Rating
5	4.21 - 5.00	Highly Efficient (HE)
4	3.41 - 4.20	Efficient (E)
3	2.61 - 3.40	Moderately Efficient (ME)
2	1.81 - 2.60	Somewhat Efficient (SE)
1	1.00 - 1.80	Not Efficient (NE)

System Features

This UML in the Figure 3 shows how the user and the system will interact with the following features identifying disaster location, disaster scale, affected families, supplies, generating reports, management of inventory, vehicle outsourcing and fleet monitoring.

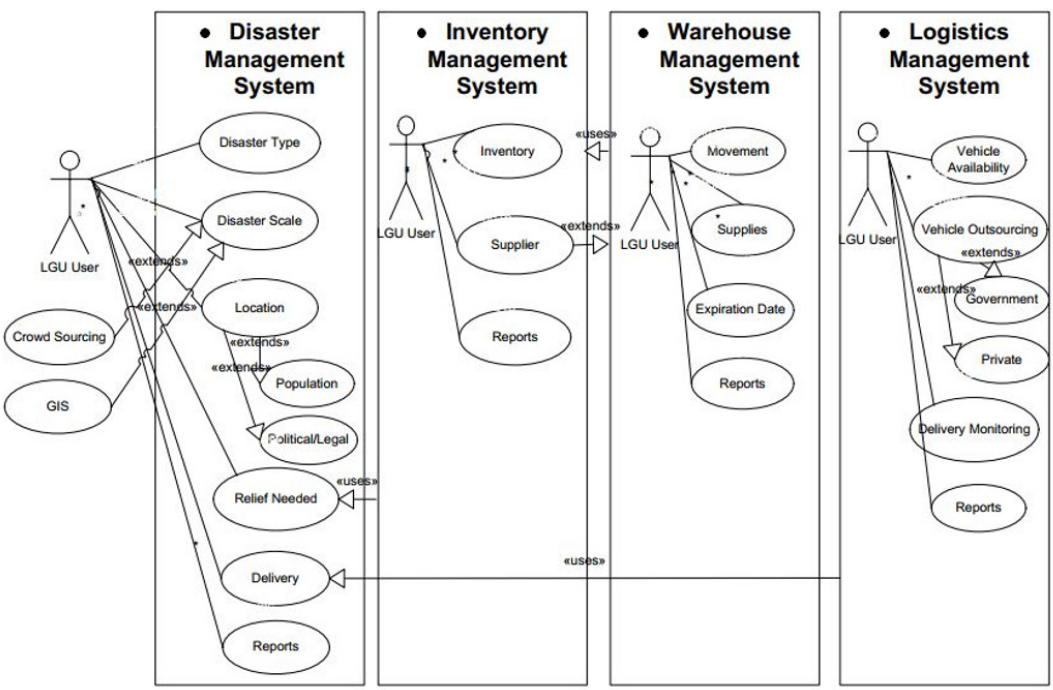


Figure 3. *Case diagram of Proposed System*

Table 4. *Description of Use Cases*

Use case name	Description
Disaster Type	Add and update disaster type
Disaster Scale	Add and Update the Scale of Disaster – Source: Crowd Sourcing/GIS
Location	Add and update disaster location Identifying the Population, Political and Legal Implication
Relief Needed	Add and update number of affected families
Supplies	Add and update supplies needed for the relief
Logistics	Add and update vehicle requirement
Generate Reports	Compile Report
Manage Inventory	Add, update and order supplies
Supplier	Add and update supplier list
First-In First-Out	Add and update delivery stocks list
Stocks	Add and update stocks list
Available Vehicle	Add and update vehicle availability list
Vehicle Outsourcing	Add and update vehicle for outsourcing
Fleet Monitoring	Add and update vehicle status

Sample Proposed User Screen

The study proposes a framework for developing system, a web-based mobile application that allows the PDRMMO to plan, mobilize, and execute emergency responses. It is also seen to significantly improve the delivery of humanitarian logistics.

The application is composed of four modules. These are the 1) Disaster management system; 2) Inventory management system; 3) Warehouse management system; and 4) Transport management system.

a. Disaster Management System – this module will show the user how much supply is needed for the relief operations. This information will be predicted based on an analysis of historical data for the specific location affected by the disaster, which have been collected and merged in a database. The number of vehicles needed for transporting the supplies will also be provided. Delivery of the relief goods will be monitored from the warehouse to the destination as shown in figure 4.
b. Inventory Management System – this module will optimize the availability of supplies. This will manage the inventory process using the First-In First-Out (FIFO) concept. Because some disasters cannot be reliably foreseen, an adequate supply must be ensured at all times for disaster logistics. The system will monitor this and will alert managers when stocks need to be replenished, when supplies

are nearing their expiration dates, as well as provide a list of recommended quality vendors presented in figure 5.

c. Warehouse Management System – this module will maximize the efficiency of handling operations of the warehouse. This will track the exact location of supplies for immediate dispatch and loading to delivery trucks.
d. Logistics Management System – this module enables the manager to mobilize the available fleet of trucks, heavy equipment, and fire trucks for deployment. It also allows for the dispatch and receiving of trucks shown in figure 7.

The proposed system framework will provide the PDRMMO all information required for the more efficient and faster delivery of relief supplies. The system, as a disaster supply-chain-management system, will provide the PDRMMO the objectives, available choices, possible risks, and other pertinent information needed for disaster relief operations.

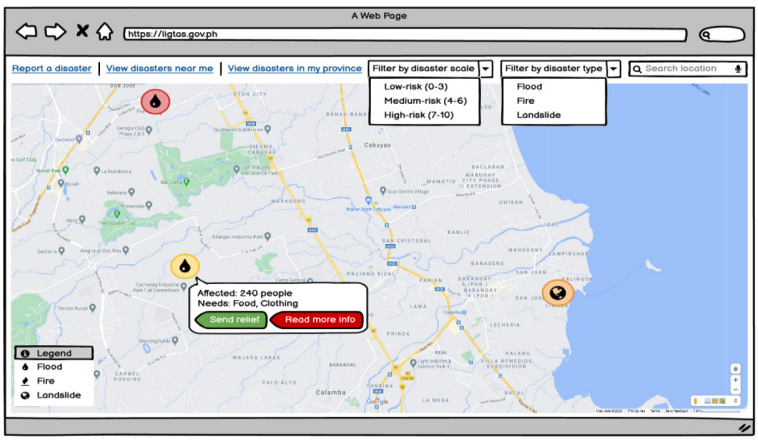


Figure 4. *Disaster management System- Main Interface*

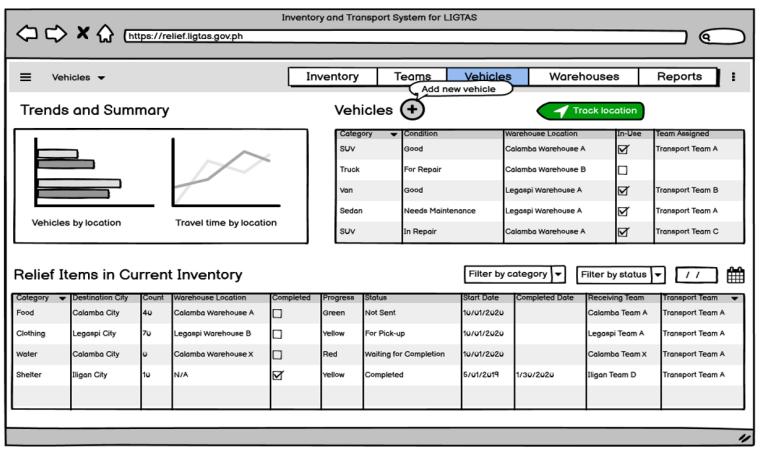


Figure 5. *Inventory Management System – Main Interface*

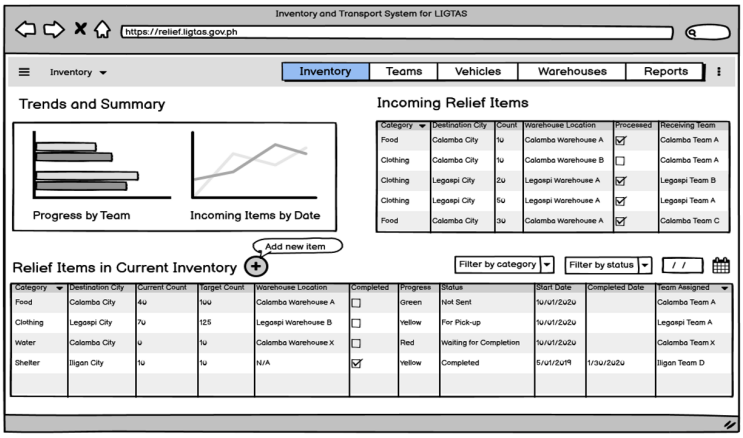


Figure 6. *Logistics Management System – Main Interface*

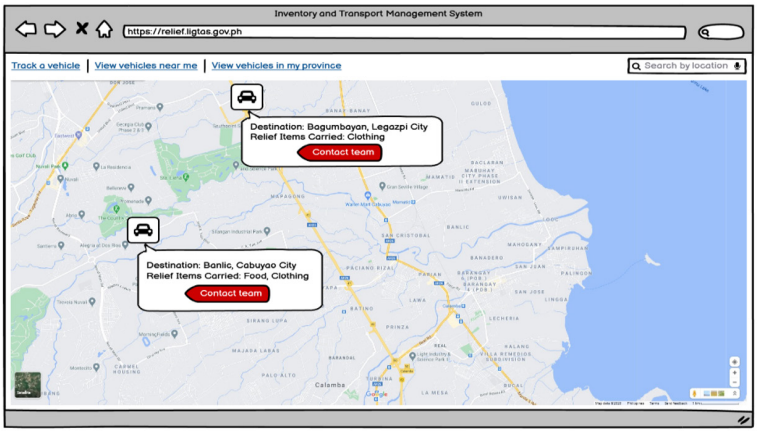


Figure 7. *Fleet Tracking System – Main Interface*

3.0 Conclusion and Future Works

The proposed system framework was developed to address issues in disaster supply chain logistics to help the target client (PDRRMO) in its disaster risk reduction management and relief operations. It has great potential to provide a solution to issues that affect the efficient and speedy delivery of needed help. As other studies show, using a mobile application as a tool for disaster response is beneficial and is seen as an effective approach to disaster supply chain issues. As such, agencies such as the provincial and municipal branches of the disaster risk reduction management office of the government are advised to adopt computer-based logistics systems that use decision tree (DT) models such as the system framework to facilitate its operations in times of emergency. Information on such logistics systems should be promoted and disseminated to disaster suppliers and other related personnel as well. Follow-up studies should be conducted after disasters have happened to further optimize the processes and tools involved in disaster relief operations.

A similar framework for general disaster risk response management is seen as the subject of a future study by the authors. The framework and methodology used in this study will be adopted for such project, including evaluation by IT experts using ISO 25010 guidelines for software development. The acceptability of the system will also be tested by users to assess the effectiveness and usefulness of such tools for improving emergency response operations during times of calamities and disasters.

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