Decision Location and Resource Requirement for Relief Goods Assembly

Glenda Minguito, Jenith Banluta

Abstract**—**One of the critical aspects of humanitarian operations is the distribution of relief goods to an affected community. The common assumption is that relief goods are prepositioned during disasters which are not applicable in developing countries like the Philippines. During disasters, the on-the-ground government agencies and responders have to procure, sort, weigh and pack the relief goods. There is a need to review the relief goods preparation as it seriously affects the delivery of necessary aid for human survival. This study also identifies the ideal location of the assembly hub to minimize the distance to the affected community. This paper reveals that location and resources are dependent on the type of disasters encountered at the local level. The Center-of-Gravity method and Multiple Activity Chart were applied in the analysis.

Keywords**—**Humanitarian supply chain, location decision, resource allocation, local level

I. Introduction

HUMANITARIAN supply chain management (HSCM) is crucial as it deals with the delivery of necessary aid to the affected community during disasters. HSCM involves processes such as shortage, transport, and distribution. Philippines, which is recorded as the third vulnerable country in the world [1]-[3], encounters several logistical issues in humanitarian operations. One of the disturbing issues is the management of relief goods. Food packs are essential commodities during a disaster. However, the relief goods are delayed during disasters such as 2013 typhoon Yolanda, 2014 Mayon volcano eruption, and 2019 Mindanao strong earthquakes, due to logistical issues [4]-[6]. This issue on relief goods management has been further highlighted during COVID-19 pandemic. The lockdowns during pandemic require the local government units to provide relief goods to the affected population. With the overwhelming demand for relief items, the inefficiency in humanitarian supply chain has been exposed. There were many issues regarding the lead time and transportation of relief items to the affected community. There were delays in the distribution of relief items of food (e.g., rice, canned goods, noodles) and non-food items (e.g., hygiene kit, medicine) [7]. There is a “slow down” in the relief good distribution due to limited volunteers in the repacking of relief items [8]. There were also transport shortages due to huge quantity of food supplies for the affected community.

The two dominant research topics in HSCM are the determination of facility location and prepositioned inventory. The decision in choosing the location is typically influenced by the cost. This cost involves operational warehouse cost, inventory cost and transportation cost [9]-[13]. One the other hand, inventory decision is usually affected by the cost incurred such as replenishment cost, holding cost, penalty cost [14]-[16]. This proves that research on HSCM usually considers as prepositioned inventory of relief supplies. Having a storage facility and prepositioned emergency items greatly helps in the disaster response. The immediate availability of relief supplies during disaster impacts the response time. However, this assumption of having readily available relief items is not always applicable. The local government units which have limited disaster funds do not invest on prepositioned inventory. The uncertainty in the frequency of disasters makes the local government unit hesitant to acquire storage supplies prior to a disaster. It is during calamity that the local agency only procures and packs the relief goods. If there is no systematic process, the relief goods, which is essential for human survival, will be delayed. Hence, it is important to consider the relief preparation or kit assembly in HSCM. Literature considers the assembly process of relief kits in delivering relief supplies during a natural disaster [17]. The facility location varies depending on the type of disaster. The flood prone areas are different from landslide prone areas, therefore, there is a need to identify the location of relief assembly based on the type of disasters. Second, relief goods assembly process has not been examined. The assumption of having a stored inventory that is instantly available to be distributed after a disaster is not always realistic. There are times when organization has to sort, weigh, and pack the relief goods before distributing it to the affected community. There is a need to examine preparation of relief items because it has a significant impact on the response time during disaster. It is necessary to determine the required resources which includes number of workers or volunteers and the packing equipment. The availability of these resources impacts the relief production capacity and the response time.

Considering these gaps, the paper aims to identify location of relief kits assembly hub, and the resource requirement for the relief kits assembly. This study considers the type of disaster, demand, location of affected communities, and the resources needed for the relief preparation. It uses the Center-of-Gravity method to identity the ideal location for relief kits assembly hub. It also applies the Multiple-Activity-Chart in presenting the ratio of machine and workforce requirement in relief preparation.

This study contributes to the humanitarian supply chain perspective within the context of resiliency and flexibility. With

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the bottom-up approach, this research will serve as a baseline study in redesigning logistical infrastructure for relief kits assembly that can adapt to climate change and pandemic setting. Insights on temporary hub location and resource allocation can help government agencies and humanitarian organizations manage the assembly or preparation of relief goods at the onset of disasters.

The article is structured as follows: Section II presents the role of local government in relief distribution, Section III presents the location of the relief assembly hub, and Section IV presents the machine and manpower requirement. The final section concludes the article.

II. Relief Kits Assembly at the Local Level

The authority in dealing with disaster activities shifted from the central government towards decentralizing power [18]. This means that the local government unit (LGU) is responsible for implementing disaster management at the ground or community level [19]. The crucial role of LGU is to deliver immediate relief aid to the affected community [20], [21]. Despite the training and protocols established by the higher-level government, many local government bodies are struggling in providing the relief aid in a speedy manner. The local actors and volunteers are overwhelmed by the calamity and the unsystematic humanitarian operations. This inadequate capability in dealing with disasters is reflected on the late delivery of relief items to the affected population. In addition, literature presents that there is insufficient attention to local government agencies in some emerging countries [22].

The Republic Act 10121 or the Philippine Disaster Risk Reduction and Management Act of 2010 stipulates that one of the responsibilities of the LGUs is to provide immediate relief assistance at the first instance of disaster occurrence. Most of the local government prepares the relief goods manually. This process requires volunteers to sort, weigh, and pack the food packs. The manual method may result in extended processing time, inaccurate quantity, and late delivery. The local government usually calls for volunteers to speed up the packing of relief goods [6], [23]. In times of disasters, there are only a few volunteers because they themselves are victims of calamities. The pandemic further gives rise to human resource shortage due to public fear and home quarantines. There are times when fire-fighters and police personnel serve as food packers instead of focusing on the peace and order situation [24], [25]. Despite some of these efforts, the volunteers cannot catch up with the distribution [26]. This study proposed to utilize a semi-automated rice dispensing machine for repacking. It can increase production capacity, reduce human resources, ensure quantity, and deliver relief goods to the affected community faster. The preparation of relief goods is not typically considered in humanitarian literature as it assumes prepositioned inventory. This assumption is not applicable in most of the LGUs in the Philippines. In October 2015, the Philippine government installed rice bagging machines, a conveyor system, and a pallet racking system at the National Resource Operations Center in Pasay City as solution to the late delivery of relief goods during Yolanda [27]. The requirement for volunteers drastically reduced with the new system. This mechanized production system, however, is managed by the national government. During disasters, the LGUs, primary responders, continue to do the manual process in preparing the relief goods. If the repacking of rice is semi-automated, it will result in a speedy delivery of relief goods, correct quantity, and reduced workforce. The risk of having not enough food packers during disaster is addressed with this semi-automated rice bagging equipment.

This case study was conducted in the city of Tacurong, which is located in Mindanao, Philippines. Aside from the COVID-19 pandemic, the people are susceptible to flood, landslide, earthquake, bombing, and drought. At the onset of the COVID-19 pandemic, the national government provide a Bayanihan Fund/Grant to all LDUs nationwide. The Tacurong LGU utilized the grant for relief goods of affected households (64.16%), procurement of equipment and supplies for hospitals and isolation centers (10.16%), procurement of medicine and vitamins (9.81%), and construction of isolation centers (9.54%) [28]. The percentages reveal that most of the efforts of the LGU are dedicated to the relief operation.

The city of Tacurong is located at the geographical coordinates of 6°41'42.583"N latitude, 124°40'29.818"E longitude. The city has a total land area 15,340 hectares [32], with 20 barangays as presented in Fig. 1. Barangay refers to the smallest political unit in the Philippines. Around 84% of the land area is flat with slope of 0-30% while the remaining 16% has a slope of 15-30% which are mainly located in barangay New Passi and Kalandagan [29]. The plain area is drained by a number of streams mostly running from north to south direction.

Fig. 1 Map of Tacurong [30]

The city is generally affected by the floods based on the hazard maps provided by the Mines and Geoscience Bureau (MGB) and Project of the Philippines. The Kapingkong River traverses in three barangays of the city. The overflowing of the river during heavy rainfall causes flooding which leads to damage of some properties of the residents, especially those who settled along the river banks. The three barangays that are highly susceptible to flooding are barangay Rajahmuda, Baras, and EJC Montilla as shown in Fig. 2. The other 13 barangays in which some portion of their area is traversing and located along the river are moderately affected by flooding. Aside from flooding due to the overflowing of the rivers, the city has experienced flooding due to heavy rains because of the absence and poor maintenance of drainage system and overflowing of river.

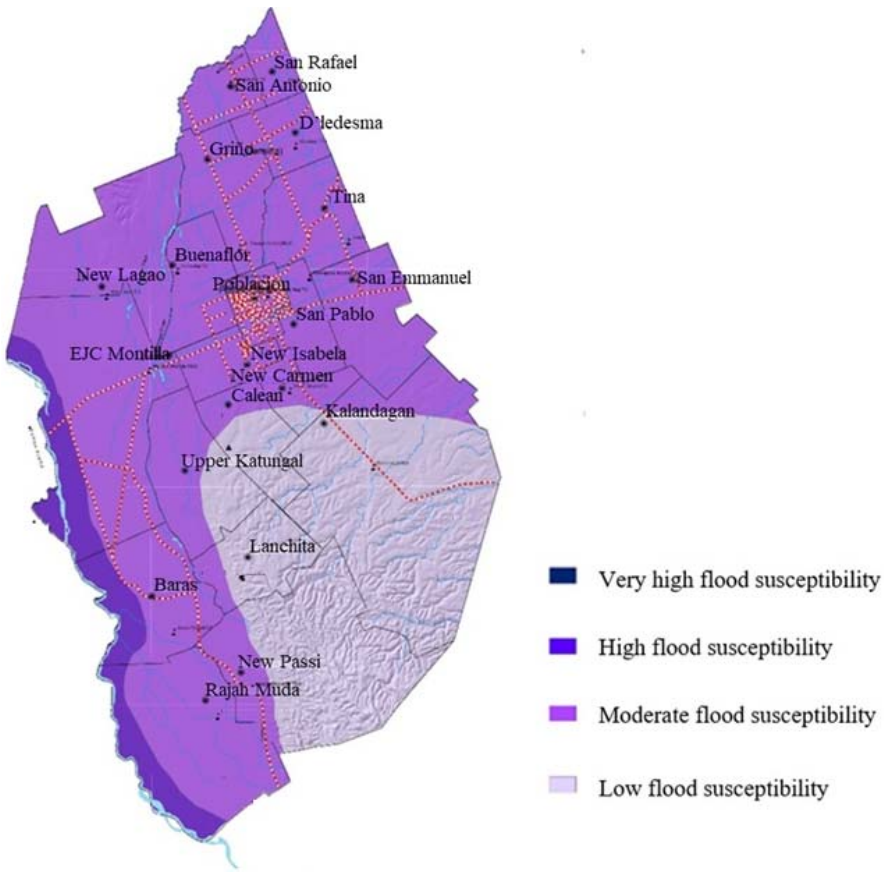

Fig. 2 Flood Hazard Map [31]

Some areas of the city have rolling hills which are prone to landslides as illustrated in Fig. 3. These landslides are generally caused by heavy rains. The barangay of Lancheta is highly susceptible to landslide. There are four barangays that would be moderately affected by landslide: Lancheta, Kalandagan, Calean and Upper Katungal. The rest of the barangays have low susceptibility to landslide.

With the struggles in providing the relief goods in a speedy manner, and the diverse disasters in the city, this study will identify the location of the assembly hub and the necessary resources. The assembly hub is a facility where relief goods will be packed and ready for distribution. The approach is to identify the ideal location which is at the center of the susceptible barangays. The study proposes a semi-automated packing machine. The required resources in terms of the number of volunteers and the number of equipment needed during disasters are be determined.

III. Location of Assembly Hubs

The location of the relief goods assembly hub is important because it affects the humanitarian response time. In this study, a Center-of-gravity method is used to identify the single facility location. This method considers the volume of relief goods and distance of the affected barangay to the assembly hub. It seeks to minimize the distance travelled needed to deliver the emergency items. There are two steps to achieve this. First is to determine the relief goods requirement of each of the affected barangay during a disaster. Second is to find out the x and y coordinates of the ideal assembly hub location by getting the weighted average of the latitude and longitude coordinates of the barangays.

A. Relief Goods Requirement

The volume of relief goods for each barangay is dependent on the type of disaster. This study considers the household population and the percentage exposure of each barangay. Household population refers to the number of households in the city. Based on the National Statistic Office-Census of Population and Housing (NSO CPH) 2015 [32], the total household population of the city is 21814. The barangay of Poblacion, San Pablo, and New Isabela have the highest number of households as reflected in Fig. 4.

The percentage of population at risks of a disaster is taken into consideration in determining the requirement of relief goods in each barangay. Table I illustrates the percentages for flood, landslide, and COVID-19 lockdown. The percentage for

COVID-19 lockdown are those population with income below food threshold. The government provides relief to them because they are greatly affected by lockdowns due to their unavailability to go to work and earn a living.

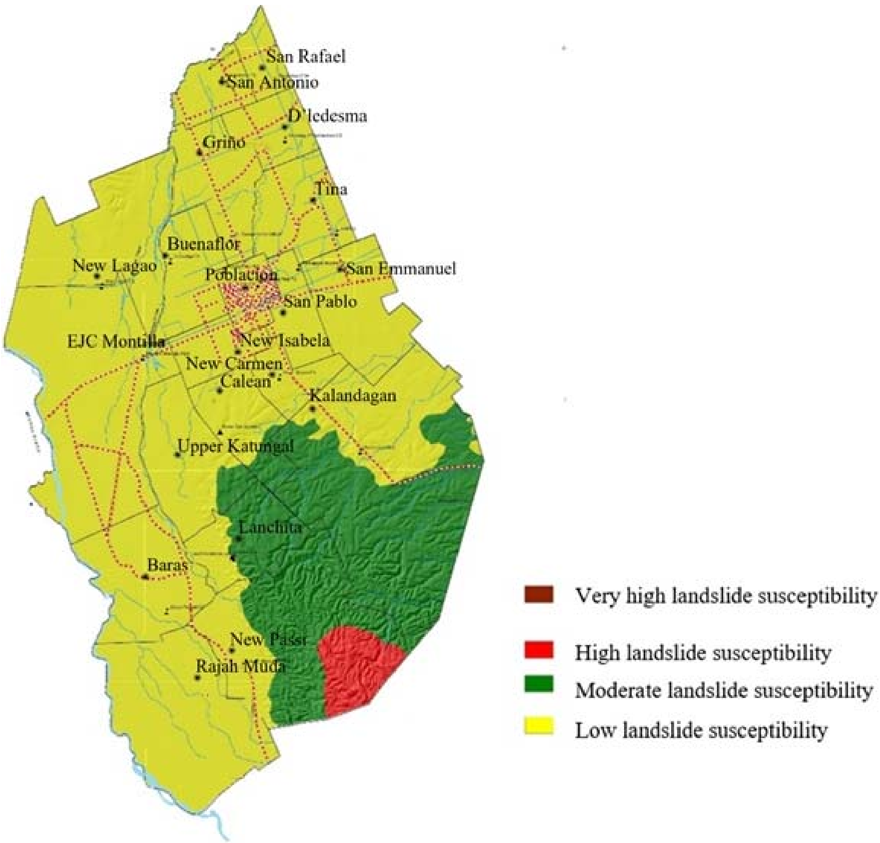

Fig. 3 Landslide Hazard Map [31]

TABLE I
POPULATION AND PERCENTAGE HAZARD EXPOSURE

	Household population	Flood	Landslide	COVID-19 Lockdown
Baras	696	7.21%		40.89%
Buenafor	1333	1.67%		18.71%
Calean	554		1.20%	19.70%
D'ledesma	301	2.58%		23.73%
EJC Montilla	1390	27.00%		16.62%
Grino	1450			29.17%
Kalandagan	541		33.33%	36.33%
Lancheta	276		29.77%	36.53%
New Carmen	749			26.42%
New Isabela	2598			15.51%
New Lagao	620	2.68%		28.63%
New Passi	657		9.72%	38.09%
Poblacion	3594			15.02%
Rajah Muda	858	15.64%		39.80%
San Antonio	290			27.15%
San Emmanuel	1436			29.63%
San Pablo	2823			13.54%
San Rafael	247			46.84%
Tina	572			28.54%
Upper Katungal	829		2.68%	16.62%

Disasters in the city may be single or multiple disasters. Single disaster is when city only focuses on a specific calamity. On the other hand, multiple disasters happen when there is an outbreak of another disaster. For instance, when a city was responding to COVID-19, a flood occurred in some areas. This results to an increase on the number of relief goods (see Table II).

B. Determination of Temporary Hubs Location

The Center-of-Gravity method is used to identify the location of the facility center for relief preparation. It is an approach that seeks to compute geographic coordinates for a potential single new facility that will minimize the distance travelled. The latitude and longitude coordinates of each barangay are reflected in Table III. The center of these coordinates is the ideal location for the relief kits assembly to lessen the distance travelled, consequently the transportation cost.

Equations (1) and (2) were used to determine the coordinates of the ideal location for relief kits assembly. The latitude C_x and longitude C_y coordinates are computed by considering the volume of relief goods V_i and coordinates of each barangay.

$$C_x = \frac{\sum V_i x_i}{\sum V_i} \quad (1)$$

$$C_y = \frac{\sum V_i y_i}{\sum V_i} \quad (2)$$

TABLE II
RELIEF GOODS REQUIREMENT

	Flood	Land-slide	COVID-19 Lockdowns	Flood and Land-slide	Flood and COVID-19 Lockdowns	Land-slide and COVID-19 Lockdowns
Baras	50		285	50	335	285
Buenafor	22		249	22	272	249
Calean		7	109	7	109	116
D'ledesma	8		71	8	79	71
EJC Montilla	375		231	375	606	231
Grino			423	0	423	423
Kalandagan		180	197	180	197	377
Lancheta		82	101	82	101	183
New Carmen			198	0	198	198
New Isabela			403	0	403	403
New Lagao	17		178	17	194	178
New Passi		64	250	64	250	314
uPoblacion			540	0	540	540
Rajah Muda	134		341	134	476	341
San Antonio			79	0	79	79
San Emmanuel			425	0	425	425
San Pablo			382	0	382	382
San Rafael			116	0	116	116
Tina			163	0	163	163
Upper Katungal		22	138	22	138	160
Total	606	355	4879	961	5485	5234

TABLE III
GEOGRAPHICAL COORDINATES OF THE BARANGAYS

Barangay	latitude coordinate (x-axis)	longitude coordinate (y-axis)
Baras	6.618378164	124.6541834
Buenafor	6.699493429	124.6558591
Calean	6.662584049	124.676845
D'ledesma	6.730304782	124.6840686
EJC Montilla	6.678888379	124.6545806
Grino	6.719459063	124.6628825
Kalandagan	6.662629454	124.6929064
Lancheta	6.638750306	124.6783493
New Carmen	6.677284134	124.6834992
New Isabela	6.679337138	124.6742664
New Lagao	6.708997058	124.6423565
New Passi	6.60236003	124.6731036
Poblacion	6.689140072	124.6787563
Rajah Muda	6.59762529	124.6647218
San Antonio	6.744483642	124.6683052
San Emmanuel	6.697358753	124.6996898
San Pablo	6.687025286	124.6853601
San Rafael	6.742697602	124.6812845
Tina	6.710839094	124.691339
Upper Katungal	6.651081593	124.6604683
Total		

The calculations reveal that the locations of assembly hubs for during flood, landslide and COVID-19 lockdown are barangay Upper Katungal, Calean, and New Isabela, respectively. The common preferred location for multiple disasters is in New Isabela as reflected in Table IV.

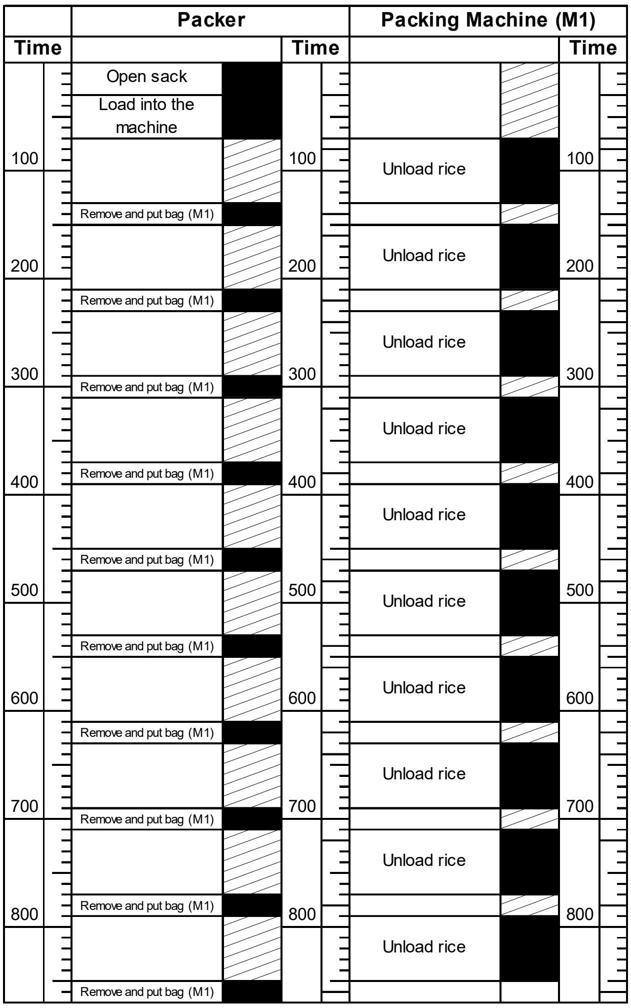

Fig. 4 Multiple Activity Chart for 1 operator - 1 machine

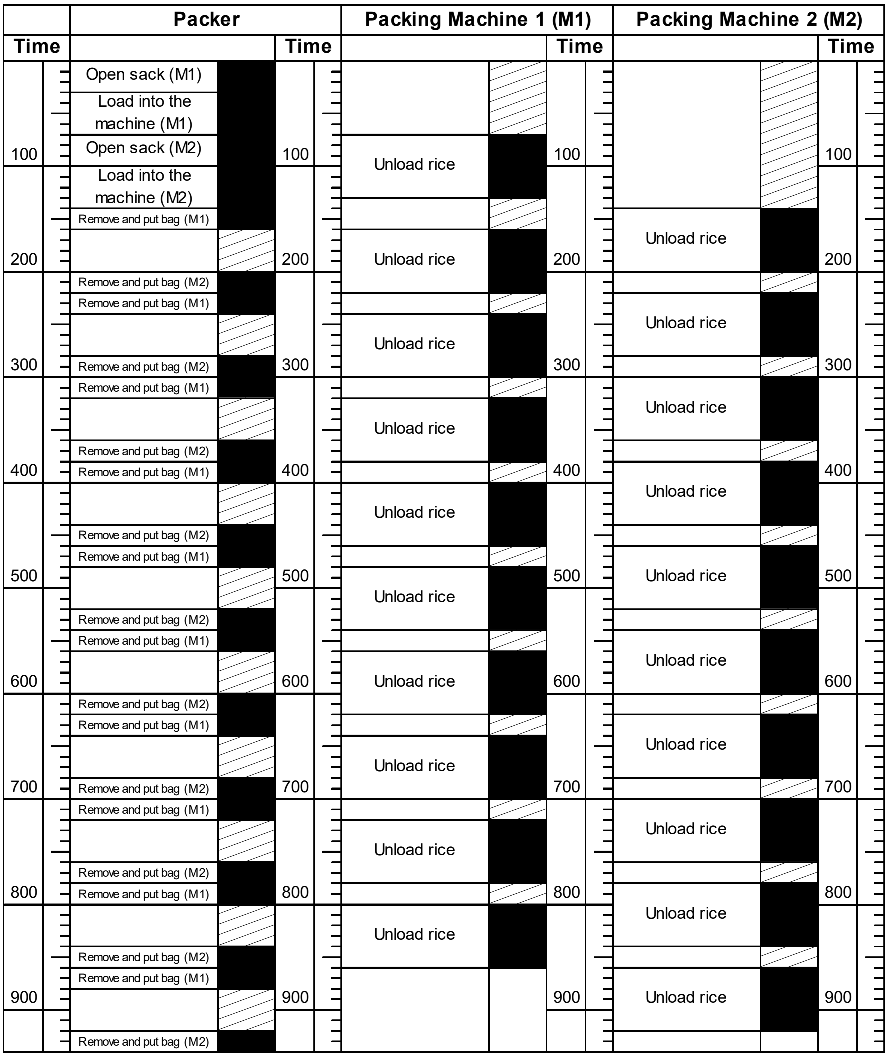

Fig. 5 Multiple Activity Chart for 1 operator - 2 machines

TABLE IV
LOCATION OF FACILITY CENTER

Type of Disaster	x-axis coordinate	y-axis coordinate	Location
Flood	6.658126575	124.6568825	Upper Katungal
Landslide	6.645546988	124.6836528	Calean
COVID-19 lockdown	6.67652227	124.6735923	New Isabela
Flood and Landslide	6.65348169	124.66677205	Upper Katungal
Flood and COVID-19 Lockdown	6.67449222	124.67174534	New Isabela
Landslide and COVID-19 Lockdown	6.67442311	124.67427476	New Isabela

IV. Machine and Workforce Requirement

The LGU provides relief goods during disaster. Each relief pack contains rice, canned goods, and hygiene kits. However, due to massive requirement of relief aid during pandemic, the LGU focused on the packing of rice which is the basic commodity of the residents. Other relief items were assembled by private suppliers. This paper considers the rice packing of relief goods. It also presents a semi-automated rice packing machine to speed up the relief assembly and to minimize the number of volunteers needed.

TABLE V
PRODUCTION OF EACH LINE

Number of machines	1	2	3
Number of machine operator	1	1	1
Cycle time (sec)	870	940	1010
Packs per cycle	10	20	30
Seconds per pack	87	47	34
Working time (8-hours)	28800	28800	28800
Capacity	331	613	855
Working time (10-hours)	36000	36000	36000
Capacity	414	766	1,069
Working time (12-hours)	43200	43200	43200
Capacity	497	919	1,283

Given the process time from the multiple activity charts, A multiple activity chart was used to determine the resources needed for the packing of rice. The chart deals with the work elements and their time of the worker and the machine. It records on a common time scale interrelationship of operator and machine. Figs. 5-7 present the multiple activity charts of utilizing one for packer to operate one machine, two machines, and three machines, respectively. Handling more machine lowers the idle time of food packer, thus, maximizing the time.

Table IV shows the capacity of having 8-hours, 10-hours, and 12 hours working time of relief personnel.

From the calculated capacity, the machine and manpower requirement for certain type of disasters are illustrated in Figs. 8 and 9, respectively.

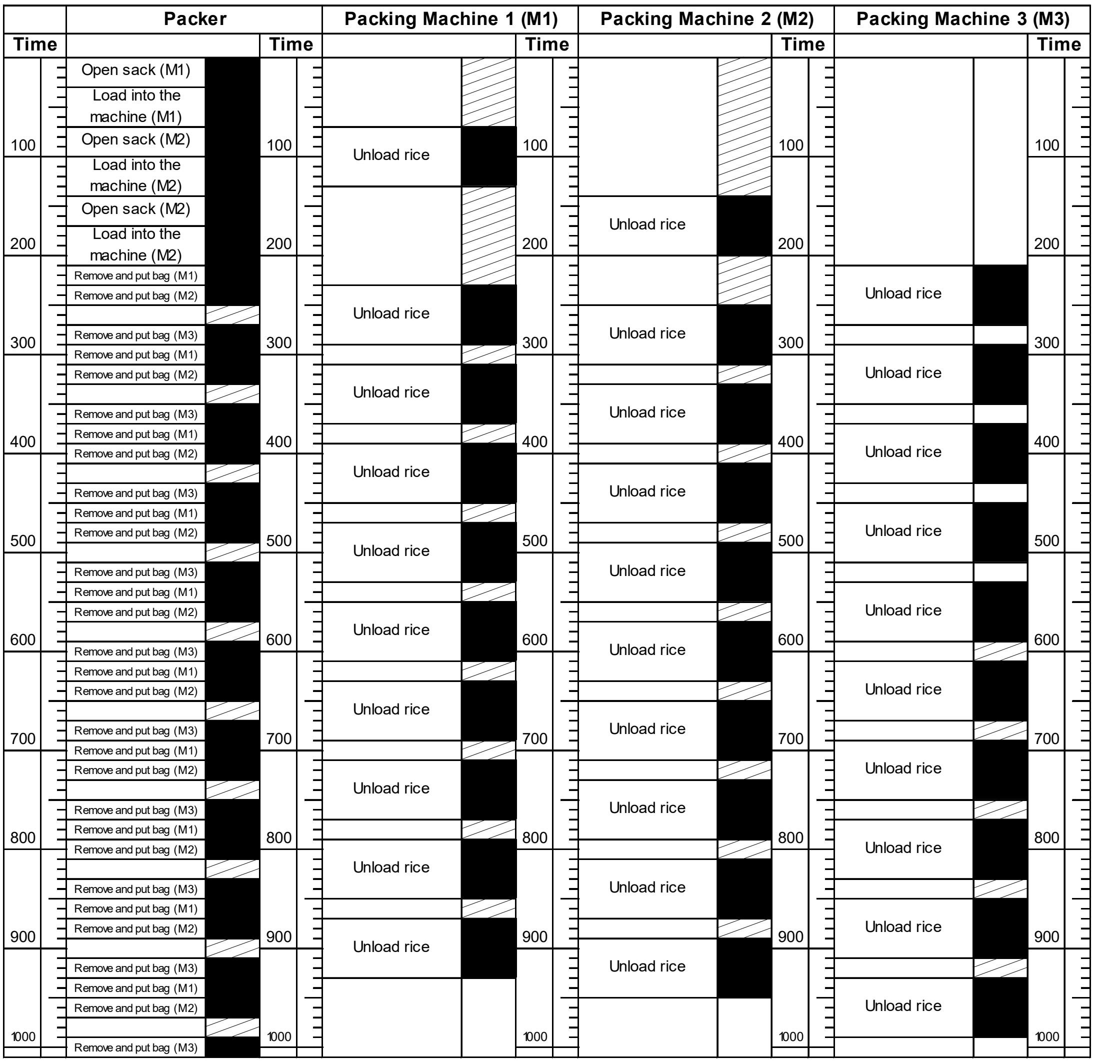

Fig. 6 Multiple Activity Chart for 1 operator - 3 machines

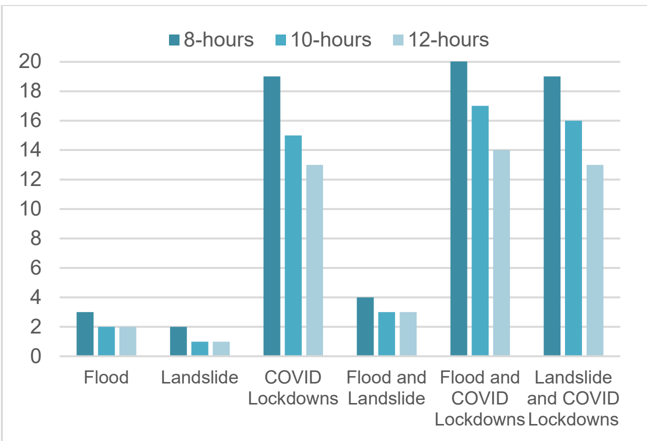

Fig. 7 Machine Requirement

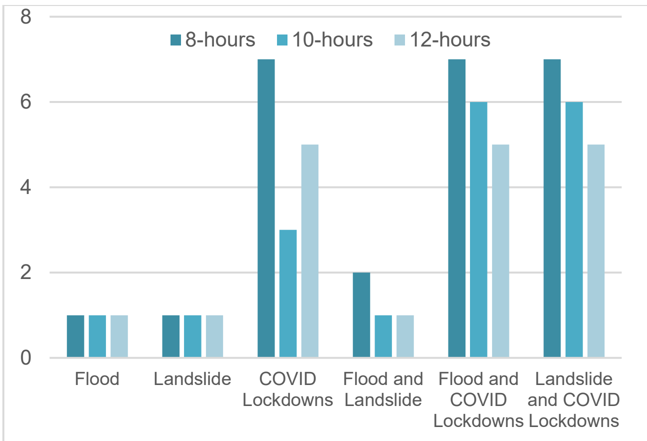

Fig. 8 Workforce Requirement

V. Conclusion

Relief preparation affects the response time of the humanitarian supply chain, thus needs to be examined. Most literature considers a prepositioned inventory during disasters. This assumption is not always applicable to LGUs of a developing country such as the Philippines. The on-the-ground agencies have limited budget and inadequate skills to streamlined process which are necessary in humanitarian operations.

The location of the facility is important to minimize the distance to the affected communities. The determination of the machine and manpower requirement is necessary to prepare the city for a disaster. This research reveals that location of the assembly hub and resource requirement is dependent on the type of disaster. Therefore, it is essential to determine the location and resources according to the disaster encountered by the city.

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