Allocation of Relief Centre for Flood Victims Using Location Set Covering Problem (LSCP)

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Abstract. The frequency of natural disaster has been increasing over the years, resulting in loss of life, damage to properties and destruction of the environment. Compared to other natural disaster, floods are the most significant natural hazard in Malaysia that affect thousands of people. It becomes of great concern especially, during these recent floods, several relief centers were experiencing problems when most of the flood’s victims needed to move to the other relief centers after the existing shelters were also affected by flood water. Furthermore, the relief centers were congested due to the large number of flood evacuees that were over the capacity provided. This study attempts to adapt an advance mathematical location-allocation models in making decision to locate and allocate flood victims during flood event. The Location Set Covering Problem (LSCP), with capacitated constraint is considered and solved using Excel Solver. The determination of safe locations for relief centres with respect to prone area is proposed by adding three new constraints which are the distance from river, elevation from sea level and rainfall amount. A flood case of Kuala Kuantan, Pahang in 2013 was used as the main study area for the analysis as well as the whole Kuantan district. Two scenarios of split and non-split allowed were tested for allocation process and result showed that the percentage allocation and number of relief centers involved increases when the distance increases accordingly. Hence, the model can be considered for better evacuation plan.

Keywords: Flood victims, location allocation model, natural disaster, relief center,

1. Introduction
Humanitarian logistics play an important role in preparing for, responding to, and recovering from sudden-onset disasters and addressing long-term development issues. On the other hand, humanitarian logistics focuses on the personal welfare of the affected people following the disasters to alleviate the suffering caused by the lack of relief materials or services. To achieve efficient and effective humanitarian relief, it is essential for humanitarian organizations to have their warehouses located in appropriate locations. The locations of these warehouses have a direct influence on the response time of the humanitarian organizations [1][2]. When a disaster strikes, basic items such as sufficient source of food and water need to be distributed as fast as possible to cover initial needs. In addition, hygiene kits and sanitary supplies as well as medications are important in the early response phase due to the risk of the outbreak of various diseases
[3]. [4] conducted their study on the basis of different needs of disaster victims, whereby shelter was divided into two types which were basic life and psychological medical service guarantee. It was mentioned that the location model of refugee facilities often ignored the diversion of shelter from the perspective of humanitarian logistics and the need of victims. At the same time, [5] presented their study on shelter location allocation model to efficiency response to relief logistics. The model was tested with two scenarios which were capacitated shelter and un-capacitated shelter, then compared with the existing location allocation plan. This study was conducted in Thailand to demonstrate the application of the proposed model. The finding of this study indicated that this proposed model clearly outperformed the current plan. [6] conducted their study in selecting the locations of shelters to be established as a preparation step for possible natural disasters. On the other study, [7] conducted their study on multi-objective decision model focused on the principle of humanitarian logistics for the selection and special location of community or collective temporary shelters. It is concluded that safety of facility, cultural and location accessibility are the most valuable criteria. Meanwhile, [8] conducted their study in selecting the locations of shelters to be established as a preparation step for possible natural disasters. There were few locations involved in this study, where location A was identified as the optimal warehouse location, with location D and E being relatively closed. However, the organization operated at Location A due to the national stability and government incentives such as land costs and customs exemption. It is concluded that through this research, it was found that natural stability was considered the most important factors for warehouse selection followed by cooperation of the organization in most countries.

Location analysis is referred as the process of analyzing the topography or terrain, infrastructure, population density, elevation, facilities of an observed area. In this study, the number of flood-prone areas is referred to the number of villages that are affected by flood in Malaysia. This is a crucial concern for the preparation of evacuation process in order to determine the number of relief centers that should be set up for the flood victims. The distance between the flood-prone areas and relief centers needs to also be taken into account in order to determine the nearest optimal shelter to transfer the flood victims. Moreover, the capacity of relief centers needs to be observed to avoid excess number of evacuees over the capacity of the relief centers available [9]. In [9], capacitated maximal covering location model was used however, the model emphasized on the maximum coverage possible within limited budget. However, when evacuation plan for flood victim is concerned, a hundred percent coverage is needed. Therefore, the number of populations in the study area is equally important and a model that incorporates all of these factors are needed. These listed factors should be considered to determine the set-up of relief centers during the evacuation process.

2. Methodology

A study area with critical flood occurrence is selected. It is in Kuala Kuantan, Pahang, Malaysia where there are 29 relief centers serving 27088 people from 24 prone areas. The overall capacity for the existing 29 relief centers is 25410 people only, which is lower than the number of potential evacuees, the total population volume for the area. Hence, it can be foreseen that, in the case of flood occurrence, not all evacuees can be transferred to the safe place due to capacity constraint. Meanwhile, the location of prone areas can be located into three categories, which are inland, river and coastal. The criteria for inland area are the average elevation of 16.31m, the rainfall amount of 65mm and around 6m distance from the river. Meanwhile, for river area, the average elevation for relief center recorded is 10.51m, the average rainfall amount is 55m and the distance from river is 0.57m. For a relief center at coastal area, the average elevation is 7.0m, the average rainfall amount is 45mm and the distance from coastal is 0.67m. The division of each relief center area has been described based on figure 1. For inland area, the elevation of relief center is in between 10.52m to 16.31m. The distance from river is in between 0.1m to 6.0m and rainfall amount is 65mm. Meanwhile, for River area the elevation recorded in between 7.1m to 10.51m. The distance from river is in between 0.1m to 0.57m. The rainfall amount recorded is 55m. For coastal area, the elevation is in between 1.0m to 7.0m and the distance from river in between 0.61m to 0.67m. The rainfall amount recorded is 45mm.
As discussed before, Kuala Kuantan was hit by severe flood due to its location which is near to Sungai Kuantan and Sungai Belat. The Department of Drainage and Irrigation further emphasized that the level of river water functions as an indicator to inform if certain areas will experience flooding and whether the process of evacuation should be carried out. The levels of water can be classified based on four colour coded indicators, which are blue representing the actual water level, green for normal level, orange for alert level and red representing danger level. According to the Department of Drainages and Irrigation, when the water level approaches the red line, evacuation process should be conducted by relevant authorities and the affected area will be declared as a flood prone area such as IPD Kuantan, Majlis Keselamatan Negara (MKN), Rela, Majlis Daerah Kuantan, Pejabat Daerah Kuantan, Tenaga Nasional Berhad (TNB), BOMBA, Jabatan Kerja Raya (JKR) and Jabatan Perkhidmatan Awam Malaysia (JPAM).

2.1 Model
Figure 2 shows the flow chart for evacuation flow. In the initial stage, the number of populations for prone area is identified, followed by identifying the capacity of each existing relief center. In stage three the distance between prone area and relief center are calculated and ranked in order. For stage four, the evacuees are assigned to the closest relief center. However, before allocating the evacuees, the capacity is checked for its availability. In stage six, if the closest relief center is no longer available, thus the allocation process is referred back to stage three and the process needs to be repeated. In stage 8, the number of populations being allocated to a certain relief center is calculated and updated by multiplying the allocated number of populations with the distance. Next stage is to update the available capacity of relief center that is allocated. In stage 10, the remaining needed population at the prone center is updated. For stage 11, if all the needed populations are allocated, thus the whole allocation process is completed. In this study, there are 24 prone areas at Kuala Kuantan, hence, in the allocation process is repeated until all evacuees from the 24 prone areas are allocated. The number of prone areas is used as the counter for tracking the process.
In order to analyse for suitability of the allocation process, several models have been considered such as deterministic, dynamic and stochastic facility location problem models. Before selecting the allocation model, the prone areas are identified. The villages were declared as flood-prone areas when they are located at elevation levels between 5 to 25 meters as reported by the Department of Drainage and Irrigation, Kuantan. These areas were hit by a severe flood event in December 2013 due to the high volume of rainfall, which was 1.8 times more than the average level of the monthly rainfall reading in the areas. The rainfall volumes for the years 2011, 2012, 2013 at Station Balok are shown in figure 3. The value of rainfall distribution in December 2013 is found to be the highest compared to other months. During this period, the sea level increased to 3.6 meters due to the severity of the flood in the area. According to the Department of Meteorology Malaysia, the Balok station recorded the highest values of rainfall distribution throughout December 2013.
The information about the flood-prone areas and relief centers were retrieved from the Department of Drainage and Irrigation Kuantan. As mentioned earlier, 24 villages were declared as flood-prone zones and 29 relief centers were set up for flood victims. The identified relief centers include schools, community halls, townhalls and mosques. Since the area of study was chosen randomly, it was observed that the district involved include Kuala Kuantan and Beserah.

2.2 Location Set Coverage Problem Model (LSCP)

The location set covering problem (LSCP) model aims at minimizing the number of facilities required to cover all demands within specific distance, $S$. In this study, the LSCP is applied as the allocation model with the objective to locate the minimum number of relief centers required to “cover” all the evacuees (affected population) within some specific traveled distances which are 3km, 5km and 10km.

Denoting $Z$ as the objective function (1), it is to locate the minimum number of relief centers required to accommodate all of the demands (affected population). The formulation for LSCP is as follows.

Objective function:

$$\text{Min} Z = \sum_{j \in J} Y_j$$

Subject to

$$\sum_{j \in J} a_{ij} Y_j \geq 1 \quad \forall \quad i \in I,$$

where:

- $a_{ij} = 1$ if site $j$ can cover demand $i$
- $a_{ij} = 0$ if not
- $y_j = 1$ if site $j$ is selected for a relief center to open
- $y_j = 0$ if not
\[ Y_j = \{0,1\} \quad \forall \quad j \in J, \quad (3) \]

Constraint (2) ensures that each demand at a prone area is covered by at least one facility. Constraint (3) enforces the yes or no nature of opening a relief center at the location. In this study, three distances are considered for flexibility which are 3km, 5km and 10km between the demand nodes and the relief center. Based on previous study, it was decided that the location of relief center must be within 1 km from prone areas [10]. This situation is to avoid the relief center to be prone during the flood event and also to avoid reallocation from happening.

3. Results and Discussion

The model is run using Excel Solver, based on the following specifications:

i. Assuming the safest distance between the prone area and relief centers are 3km, 5km and 10km

ii. Assuming split is allowed (where a family can be separated and allocated to different relief centers based on its availability)

Table 1 shows the result using capacitated LSCP within 3km with split is allowed procedure. The percentage allocation recorded is 60.4 percent. Based on the table, the flood victims from 7 prone areas (Kg Pandan, Tmn Tanah Putih, Putra Square, Taman Teratai, Tmn Chenderawasih, Kg Sei Damai, Kampung Jawa) are totally unable to be allocated due to the capacity of nearest existing relief centers are already occupied. Meanwhile, all the flood victims from 12 prone areas (total unallocated equals zero) are successfully allocated to the existing relief centers. The number of relief centers involved within 3km allocation is 22. Considering that no split is allowed, the application of capacitated LSCP within 3km recorded only 34.9 percent evacuees being allocated. Meanwhile, only flood victims from 4 prone areas are successfully allocated to existing relief. The number of relief centers involved for no split is allowed within 3km allocation is 14.

Table 1. Allocation of evacuees using Capacitated LSCP within 3km.

| No | Prone Area           | No of population | Split Allowed | Split Not Allowed |
|----|----------------------|------------------|---------------|-------------------|
|    |                      |                  | Allocate | Unallocated | Allocate | Unallocated |
| 1  | Medan Tok Sira       | 1237             | 1200      | 37          | 1200     | 37          |
| 2  | Taman Tas Jaya       | 800              | 800       | 0           | 500      | 300         |
| 3  | Kg. Pandan I         | 950              | 950       | 0           | 80       | 870         |
| 4  | Kampung Darat Makbar | 1817             | 1817      | 0           | 0        | 1817        |
| 5  | Sg. Isap Perdana     | 1200             | 1200      | 0           | 1200     | 0           |
| 6  | Kampung Tiram        | 361              | 361       | 0           | 350      | 11          |
| 7  | Taman Sekilau        | 993              | 393       | 600         | 0        | 993         |
| 8  | Taman Sri Setongkol  | 1030             | 1030      | 0           | 530      | 500         |
| 9  | Taman Fairmount      | 522              | 522       | 0           | 522      | 0           |
| 10 | Kg Bukit Rangin      | 1402             | 1402      | 0           | 145      | 1257        |
| 11 | Kg Pandan            | 1051             | 0         | 1051        | 0        | 1051        |
| 12 | Jaya Gading          | 670              | 40        | 630         | 40       | 630         |
| 13 | Kg Lubuk Puyu        | 1350             | 1160      | 190         | 580      | 770         |
| 14 | Kg. Belukar          | 850              | 850       | 0           | 850      | 0           |
| No | Prone               | No of population | Split allowed | Split NOT allowed |
|----|---------------------|------------------|---------------|------------------|
|    |                     |                  | Allocate d    | Unallocate d     | Allocate d    | Unallocate d |
| 1  | Medan Tok Sira      | 1237             | 1237          | 0                | 1200          | 37           |
| 2  | Taman Tas Jaya      | 800              | 800           | 0                | 500           | 300          |
| 3  | Kg. Pandan 1 Kampung Darat Makbar | 950         | 950           | 0                | 80            | 870          |
| 4  | Sg. Isap Perdana    | 1817             | 1817          | 0                | 60            | 1757         |
| 5  | Kampung Tiram       | 361              | 361           | 0                | 350           | 11           |
| 6  | Taman Sekilau       | 993              | 993           | 0                | 993           | 0            |
| 7  | Taman Sri Setongkol | 1030             | 1030          | 0                | 530           | 500          |
| 8  | Taman Fairmount     | 522              | 522           | 0                | 522           | 0            |
| 9  | Kg Bukit Rangin     | 1402             | 1402          | 0                | 145           | 1257         |
| 10 | Kg Pandan           | 1051             | 510           | 541              | 250           | 801          |
| 11 | Jaya Gading         | 670              | 670           | 0                | 40            | 630          |
| 12 | Kg Lubuk Puyu       | 1350             | 90            | 1260             | 580           | 770          |

Table 2 shows the result using capacitated LSCP within 5km with split is allowed procedure. The percentage allocation recorded is 75.9 percent which is higher than previous procedure. Based on the table, the number of unallocated flood victims decreases which involved only 1 prone area (Kg Seri Damai). Meanwhile, there are 16 prone areas (total unallocated equals zero) which are successfully allocated to the existing relief centers. The number of relief centers involved within 5km allocation is 24. Table 2 also shows the result using Capacitated LSCP within 5km when split is not allowed. The percentage allocation recorded is only 53.5 percent which is lower than previous procedure. Based on the table, all the flood victims at only 6 prone areas are able to be allocated to the existing relief centers based on its available capacities. The number of relief centers involved within 5km allocation for split is not allowed procedure is 19.
Table 3 shows the result using capacitated LSCP within 10km with split is allowed procedure. The percentage allocation recorded is 93.84 percent with 22 prone areas (total unallocated equals zero) that are successfully being allocated to the existing relief centers. The number of relief centers involved within 10km allocation for split is allowed procedure is 29. Table 3 also shows the result using capacitated LSCP within 10km with split is not allowed procedure which indicates that the result cannot be improve further due to the limited capacity of the existing relief centers. The percentage allocation recorded is 53.5 percent which is similar to that of the previous procedure within 5km. Hence, similarly, there are only 6 prone areas that are successfully allocated to the existing relief centers and the number of relief center involved within 10km allocation for split is not allowed procedure is 19.

| No | Prone                      | No of population | Split allowed | Split NOT allowed |
|----|----------------------------|------------------|---------------|-------------------|
|    |                            |                  | Allocate | Unallocate | Allocate | Unallocate |
| 14 | Kg. Belukar                | 850              | 850       | 0         | 850       | 0         |
| 15 | Kg Gudang Rasau           | 950              | 950       | 0         | 330       | 620       |
| 16 | Telok Mahang              | 1276             | 1276      | 0         | 50        | 1226      |
| 17 | Tmn Tanah putih          | 1050             | 1050      | 0         | 1050      | 0         |
| 18 | Putra Square             | 1645             | 641       | 1004      | 285       | 1360      |
| 19 | Taman Teratai             | 1125             | 300       | 825       | 300       | 825       |
| 20 | Taman Chenderawasih       | 1194             | 334       | 860       | 150       | 1044      |
| 21 | Kg Sri Damai              | 870              | 0         | 870       | 650       | 220       |
| 22 | Kampung Jawa              | 1870             | 1870      | 0         | 1800      | 70        |
| 23 | Kg Anak Air               | 800              | 740       | 60        | 500       | 300       |
| 24 | Kg Paya Besar            | 2075             | 962       | 1113      | 2075      | 0         |
|    | Total                     | 27088            | 20555     | 6533      | 14490     | 12598     |
|    | Coverage %                | 75.9%            | 53.5%     |           |           |           |
15 Kg Gudang Rasau 950 950 0 330 620
16 Telok Mahang 1276 1276 0 50 1226
17 Tmn Tanah putih 1050 1050 0 1050 0
18 Putra Square 1645 1645 0 285 1360
19 Taman Teratai 1125 1125 0 300 825
20 Taman Chenderawasih 1194 1194 0 150 1044
21 Kg Sri Damai 870 870 0 650 220
22 Kampung Jawa 1870 1870 0 1800 70
23 Kg Anak Air 800 800 0 500 300
24 Kg Paya Besar 2075 543 1532 2075 0
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Total 27088 25410 1678 14490 12598

**Coverage %**

| Distance | Coverage % |
|----------|------------|
| 3km      | 93.8%      |
| 5km      | 53.5%      |

Figure 4a summarizes the allocation results for capacitated LSCP within 3km, 5km and 10km with split is allowed procedure. It can be seen that within 3km, the percentage allocation recorded is 60.4 percent and number of relief centers involved is 22. Meanwhile, for 5km, the percentage allocation recorded is 75.9 percent and the total number of relief center involved is 24. Within 10km, the percentage allocation recorded is 93.8 percent and there are 29 number of relief centers involved. It can be concluded that the percentage allocation and number of relief centers involved increases when the distance increases accordingly. Similarly, for split is not allowed procedure in figure 4b., it can be seen that for capacitated LSCP within 3km, the percentage allocation recorded is 34.9 percent and number of relief centers involved is 14. Meanwhile, for 5km and 10km, the percentage allocation and the number of relief centers involved remain at 53.5 percent and 19 relief centers respectively. Hence, it can be concluded that the percentage allocation and number of relief center involved increases when the distance increases accordingly for split is allowed procedure but not for split is not allowed procedure, as the coverage percentage would be saturated unless some improvement like an additional relief center with additional capacity is created.

Figure 4. The relationship between number of relief center, distance and percentage allocation.

4. Conclusion

Based on the analysis above, it can be concluded that the existing relief center is not adequate to allocate all the flood victims from the prone areas. The results show that the existing capacity is unable to allocate...
100 percent of flood victims even the distance is extended to 10 km. Therefore, the capacity of relief centers needs to be upgraded to fulfil the demand. Further analysis in identifying the appropriate capacity is very much needed for future planning of recovery plan during the flood event. It can also be concluded that the adapted LSCP model can give an information on the coverage percentage of flood victim as well as the existing number of usable and occupied relief centers.

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