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ANALYSIS 1

Location of humanitarian logistics support facilities with multicriteria model

Author: Luiz Octávio Gavião ***Co-author:*** Sergio Kostin

1. Introduction

The flow of essential supplies to populations affected by disasters is a key issue in humanitarian logistics [1-3]. Any delay in the arrival of medications, blood plasma, water, food, human resources, among others, negatively impacts emergency care. In this context, the road network linking possible points in the humanitarian supply chain is essential to ensure the flow of personnel and material for assistance [4-7]. These points may include command posts, logistics support areas, distribution centers or field hospitals to configure the disaster management support network [8, 9]. In this case, the identification of appropriate points can assist in planning and, consequently, in the efficient execution of logistic support [10].

The Network Analysis presents interesting characteristics for the identification of these points of support. This method allows mapping relationships between different points, called "nodes", being connected by "arcs" to create networks [11]. There are mathematical indicators that reflect the relative importance of each node in a network. These measures are called "centralities", being the most studied metrics [11, 12].

Several studies have associated the measures of centrality with multi-criteria methods to classify the most influential nodes of a network [13-17]. The literature reveals that the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is one of the most widely used multi-criteria decision support methods [18-20]. Its algorithm orders coefficients to indicate the alternative that is closer to the ideal solution and more distant from the anti-ideal one.

Network Analysis is adaptable to typical problems in humanitarian assistance [12]. Some studies have applied this methodology with simulations of emergency response [21, 22], with Indonesia's response after the Sumatra earthquake and tsunami [23] and with the earthquake in Nepal in 2015 [24].

This article aims to present a model, capable of identifying the most influential nodes in the supply chains in disaster management, to assist Humanitarian Organization managers and advisors to Force Chiefs engaged in this type of operation, at the time of planning that precedes the displacement of means to assemble the emergency supply chain.

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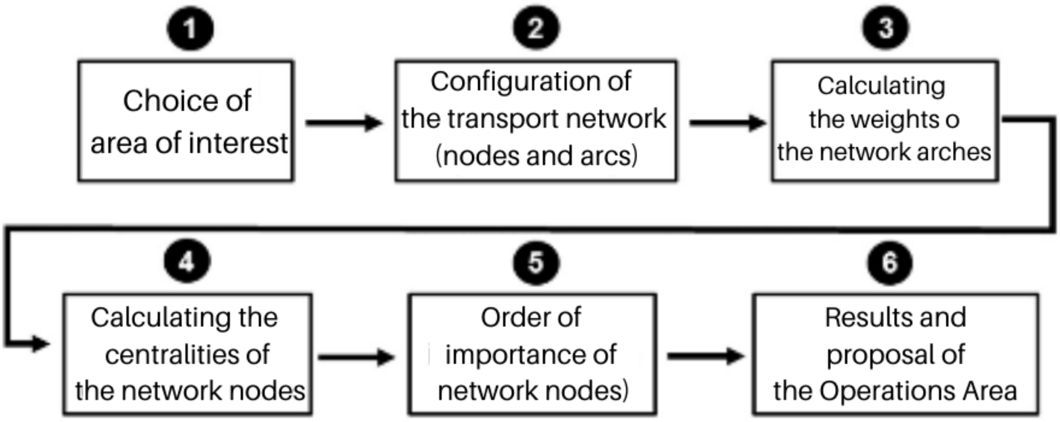
2. Methodology

The problem was modeled in six steps, as shown in Fig. 1 Stages.



Source: adapted from [25].

In Step 1 it is necessary to configure the Area of Interest, which includes, within its limits, the region affected by the disaster and the regions capable of receiving logistics facilities for the coordination of humanitarian assistance. These regions, in general, can be cities or small municipalities with large, urban or even rural areas, capable of receiving mobile infrastructure, typical of humanitarian and military organizations (containers, tents, temporary shelters, among others).

In Step 2 the locations and their connections are gathered to create a nondirected and weighted network of nodes and arches around Marco Zero.

In Step 3 weights are established to qualify the links between the locations. Among the criteria to be considered, it is suggested to evaluate the distances between the nodes, the quality of the transport route according to its characteristics and the degree of damage that the disaster caused to the conditions of use of the highway or road. In this context, the best arc is the one that connects the shortest distances, by transport routes with better paving and less damage caused by the disaster.

In Step 4 the centrality measurements of each network node are calculated. These measures identify the most important vertices in a network. The literature indicates that there are more than 50 types of measures of centrality [26]. However, depending on the resources of the network, some centralities do not present good results in terms of node discrimination. Therefore, it is suggested to reduce the dimensionality of the problem, selecting the centralities that presented the best results. Principal Component Analysis (PCA) is a useful and frequent method for this case.

In Step 5, after selecting the main measures of centrality, a decision matrix is composed of the network nodes and their most relevant measures of centrality. This matrix is the initial database for the application of a multi-criteria decision support method, to sort nodes by degree of importance.

In Step 6, the results are analyzed to identify the best locations to establish distribution centers and other logistics facilities that will support humanitarian assistance operations. The best nodes and the Zero Mark are locations to be included in the Area of Operations.

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3. Model Simulation

To illustrate the application of the proposed model, a network of 12 locations, indicated by letters "A" to "L" and interconnected by transport routes, was simulated around a fictitious region, called "Marco Zero". At a preliminary planning moment, these localities around the central point present some potential to provide direct support to the affected population. The possible connections between the localities are indicated by non-directional arcs, as shown in Fig. 2, which is not in scale. The markings in red "X" simulate interruptions in highways or roads after the disaster, which could be identified by aerial or spatial images available to the intelligence sections or similar advisory services of humanitarian organizations.

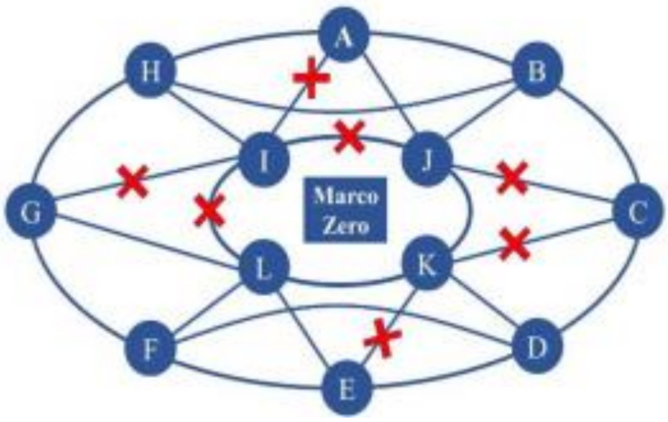

Fig. 2. Diagram of the locations around the "zero mark". Source: [25].

In Network Analysis, arcs can be weighted to indicate the degree of importance between them. These measures are relevant to the problem analyzed here, to indicate that an arc damaged by the disaster hinders or prevents the connection between certain arcs, while other connections remain in normal condition.

Arcs can be weighted in different ways. In the proposed model, this weighting was based on three variables: (1) the class of the highway, (2) the accessibility between the nodes and (3) the distance between them. The highway class was scored from 1 to 7, according to the table used by the National Department of Transportation Infrastructure (DNIT) [27], which uses seven classifications for highways, adapted here to indicate the quality of the connection between the nodes. The accessibility of the road after the disaster, for a stretch between us, was scored from 0 to 1, varying from bad to excellent conditions respectively, and may receive fractioned values. The distance between the nodes was also rated between 0 and 1, which are equivalent to very long and very short distances, respectively, also with fractional variation, by the evaluator.

The products of these three variables provided the weights of the network Adjacency Matrix, as shown in Table 1. This matrix is the initial data base for the calculation of the node centralities in Network Analysis. The null values indicate the absence of connection between the nodes, indicating that there is no road connection between the points.

[Continues]

Table 1. Adjacency Matrix

Nodes	A	B	C	D	E	F	G	H	I	J	K	L
A	0	3,6	0	0	0	0	0	2,7	1,2	2	0	0
B	3,6	0	2,7	0	0	0	0	0	0	2	0	0
C	0	2,7	0	2,7	0	0	0	0	0	0,8	1,4	0
D	0	0	2,7	0	1,8	0	0	0	0	0	1	0
E	0	0	0	1,8	0	3,6	0	0	0	0	0,8	2
F	0	0	0	0	3,6	0	2,7	0	0	0	0	2
G	0	0	0	0	0	2,7	0	3,6	1	0	0	1
H	2,7	0	0	0	0	0	3,6	0	2	0	0	0
I	1,2	0	0	0	0	0	1	2	0	0,2	0	0,2
J	2	2	1,6	0	0	0	0	0	0,2	0	2	0
K	0	0	1,4	2	0,8	0	0	0	0	2	0	1
L	0	0	0	0	3	2	3	0	0,2	0	1	0

Source: adapted from [25].

4. Results and analysis

The calculations were performed in the R software. The centralities have been calculated by the "Central Informative Nodes in Network Analysis (CINNA)" application [26]. The results indicated 47 different measures of node centrality. Through the PCA method, five measures of centrality stood out from the other results because they were more discriminatory than the other indexes. Thus, these best measures were exported to configure the decision matrix in Table 2.

Table 2. Centralities

Nodes	*Weighted vertex degree*	*Eigenvector centralities*	*Kleinberg's authority centrality*	*Kleinberg's hub centrality*	*Cluster rank*
A	9,5	0,6648324	0,6648324	0,6648324	10
B	8,3	0,5743593	0,5743593	0,5743593	10,666667
C	8,4	0,5222619	0,5222619	0,5222619	10
D	6,5	0,47874	0,47874	0,47874	10,666667
E	9,2	0,8851833	0,8851833	0,8851833	10
Nodes	*Weighted vertex degree*	*Eigenvector centralities*	*Kleinberg's authority centrality*	*Kleinberg's hub centrality*	*Cluster rank*
F	8,3	0,9234976	0,9234976	0,9234976	10,666667
G	10,3	1	1	1	10
H	8,3	0,7383063	0,7383063	0,7383063	10,666667
I	4,6	0,4225498	0,4225498	0,4225498	10,4
J	7,8	0,5254835	0,5254835	0,5254835	10,4
K	7,2	0,5214308	0,5214308	0,5214308	10,4
L	9,2	0,9593598	0,9593598	0,9593598	10,4

Then, the TOPSIS method was applied to the decision matrix, to select the most influential nodes in the network. The software "R" and its application "topsis" were used to calculate the results, according to Table 3 [28]. Weights equal to the five centrality measures selected in the PCA were considered.

[Continues]

Table 3. TOPSIS Results

Nodes	Coefficient TOPSIS	Ranking
G	0,960456238	1
L	0,894239719	2
F	0,809655068	3
E	0,798907535	4
H	0,566947203	5
A	0,50397959	6
B	0,354724226	7
C	0,304980391	8
J	0,279625031	9
K	0,24561693	10
D	0,169576681	11
I	0.024104389	12

The validity of decision support models can be considered based on the degree of satisfaction of decision makers [29]. Another option to validate a model is to verify its ability to simulate the real system, using statistical methods to compare the results of both [30]. However, the application of the proposed model was simulated, with the purpose of presenting a way to assist managers and staff advisors in real cases. The G, L, F and E nodes form a coherent solution to the hypothetical problem, as they identify a sector of approach to the Zero Mark with less access limitations, as shown in Fig. 3. Here it is assumed that the stakeholders involved in the disaster response would accept this outcome as the most favorable region to support the humanitarian supply chain.

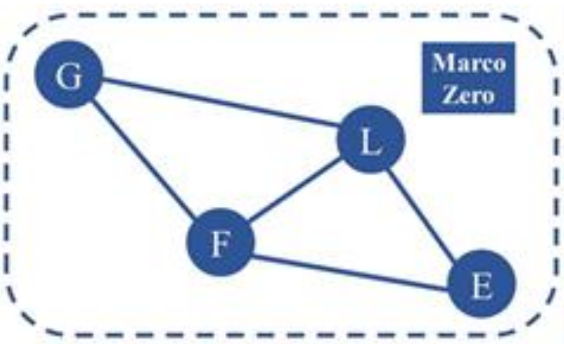

Fig. 3. Proposed sector for Marco Zero support facilities.

[Continues]

5. Conclusion

Disaster management operations require adequate and rapid planning to efficiently serve affected populations. In this context, an Area of Operations should be sized with the main sites capable of receiving command and control facilities, logistics facilities, distribution centers, storage facilities, among others. These sites need to be connected by networks capable of guaranteeing the flow of essential supplies for humanitarian assistance.

This article identified the most influential nodes in disaster management supply chains using Network Analysis and TOPSIS. R software and its specific applications were used to calculate the results. TOPSIS has been applied frequently to decision support issues in a variety of knowledge areas, including Humanitarian Logistics.

Some options for future research are visualized. The establishment of arc weights requires the subjectivity of specialists, being used here three variables considered the most important in the analyzed literature. However, other variables can be considered in order to improve the accuracy of these weights. We also see the possibility of applying the model to other types of networks in disaster management, such as airports and ports, or even interconnecting the different types of nodes.

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News published by OMNIDEF

Brasil de Fato – 20/10/2020

Fórum de Mobilidade Humana debate políticas públicas para migração e refúgio

Com o tema “Migração e Refúgio: desafios e experiências no acesso às Políticas Públicas”, será realizado, entre os dias 20 e 22 de outubro, o 8º Seminário Estadual do Fórum Permanente de Mobilidade Humana do Rio Grande do Sul (FPMH-RS). Por conta da pandemia, a edição deste ano será de forma virtual, com transmissão pelo canal do Fórum no Youtube, sempre das 19h às 22h. Em sua oitava edição, o seminário dará destaque a experiências relacionadas à saúde, à assistência social, à moradia, ao trabalho e renda.

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Aeroin – 28/10/2020

Sideral usará Boeing 737-300 em mais um resgate de refugiados venezuelanos

Está programado para a manhã desta quarta-feira (28), mais um voo especial da empresa Sideral Linhas Aéreas com o objetivo de resgatar refugiados venezuelanos de Roraima e levá-los ao sul do Brasil. Dessa vez, o destino será a cidade de Curitiba. Segundo os dados da Agência Nacional de Aviação Civil (ANAC), a programação do voo prevê decolagem de Boa Vista às 7h da manhã, com pouso no Aeroporto Internacional Afonso Pena às 11h45 locais. O número do voo é o SID-9213 e a aeronave programada é o PR-SDW.

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Center of Strategic Studies

Brazilian War College (ESG)

Fortaleza de São João - Av. João Luiz Alves, s/nº, Urca

Rio de Janeiro - RJ - CEP: 22291-090

Tel.: (21) 3545 9889 / Fax (21) 3545 9971

cee@esg.br

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