MULTICRITERIA ANALYSIS APPROACH FOR HUMANITARIAN PREPAREDNESS OPERATIONS

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Abstract: *Strategic, tactical and operational decisions in humanitarian logistics require the simultaneous consideration of a number of usually mutually conflicting criteria in order to come up with optimal decisions. Our work aims to present a conceptual approach based on multicriteria analysis for the selection of the optimal location for the development of a humanitarian logistics depot. In this light, decision-makers are provided with a decision support system towards optimal preparedness for facilitating secure relief to the victims of natural disasters in a timely and reliable way. The proposed framework is implemented for the case of a specific type of natural disaster (earthquake). However, the procedure could be easily adopted in order to come up with optimal decisions in respect to types of natural disasters other than the one examined in the present analysis*

Keywords*: Location of logistics depot; relief operations management; multicriteria analysis; decision support system*

1. INTRODUCTION

The management of humanitarian logistics is a critical factor for facilitating secure relief to the victims of natural or man-made (e.g. terrorist attack) disasters in a timely and reliable way. Humanitarian logistics management is a complicated issue dealing with different situations, times and responses (Kovacs and Spens, 2007). In contrast to commercial logistics where numerous analytical optimization models have been constructed, humanitarian logistics constitute a rather unexplored field. Depending on the type of disaster, different ways of treatment need to be planned and implemented, making disaster relief management a case-specific approach with high levels of uncertainty and risk. This paper presents a multicriteria-based strategic approach towards optimal location for the development of a humanitarian logistics depot. The aim is to provide an easy-to-use decision support system that simultaneously accounts social, technical and economic concerns. The rest of the paper is organized as follows. Section 2 accommodates the proposed methodology, while in Section 3, a case study is provided. Finally, in Section 4 we provide the main conclusions of the paper.

2. METHODOLOGICAL FRAMEWORK

Strategic, tactical and operational decisions in humanitarian logistics often, if not always, require simultaneous consideration of a number of usually mutually conflicting criteria in order to decide the optimal alternative. In practice, decision-makers aim towards the best compromise between available alternatives. Towards this direction, a number of Multi-Criteria Decision Aid (MCDA) techniques have been proposed to assist decision-makers not taking decisions based only on personal thoughts, views or experiences, but on a robust and rational approach. The proposed methodological framework is divided into two phases; before (Phase I) and after the disaster strikes (Phase II). As a primary step of Phase I, potential locations for the development of a humanitarian logistics depot need to be identified. Such depots can alternatively be built within army camps or other public owned infrastructure. The methodology continues with its Phase II, which commences exactly after the disaster occurs. Operational criteria are determined according the nature and the special characteristics of the incident. It should be underlined that the exact number of both strategic (Phase I) and operational criteria (Phase II) depends on the decision-maker. Performances of all potential sites on those criteria need to be qualitatively or quantitatively quantified. Quantified performances of alternative sites over the selected criteria are entered into a performance matrix. Then the quantified parameters are preferably scaled in order to facilitate monitoring and direct comparison between individual criteria. As a last step before the formation of the mathematical model, weighting factors need to be determined for the selected criteria. This step allows the incorporation of specific strategic goals according to the decision-makers philosophy to the decision-making process. Weighting factors of the selected criteria are case specific, based on the type of incident and the severity of its impacts. However, due to the humanitarian nature of the problem under study, weightings of criteria usually "favor" social parameters followed by technical or economic concerns. The methodology concludes with the model runs and the determination of the humanitarian depot's optimal location. This is further reinforced by a sensitivity analysis which enables the decision-maker to identify the robustness of the calculated ranking, as well as which are the parameters that mostly influence the optimal selection. A critical turning point in the decision-making process is the choice of the multicriteria analysis technique to be employed. The literature lists a large number of multicriteria analysis techniques. There are no universally preferable multicriteria analysis techniques, but some techniques are more or less appropriate according to the problem under study and its specific characteristics. In the proposed method, the EliminationEtChoixTraduisant la REalité III technique (Roy, 1978), commonly referred to as ELECTRE III, is used. ELECTRE III requires the determination of three thresholds; preference threshold (p), indifference threshold (q) and veto threshold (v). With the inclusion of the three aforementioned thresholds, ELECTRE III is considered to be well-adapted for uncertainties. The technique uses three pseudo-criteria to represent all aspects of a problem, and it begins by comparing the alternatives' criteria scores. The results are aggregated, and a model of the fuzzy outranking relation, according to the notion of concordance and discordance, is built. The method, in the second phase of the fuzzy relation exploitation, constructs two classifications (complete pre-orders) through descending and ascending distillation procedures. A final classification consists of the intersection of the two complete pre-orders. A sensitivity analysis tests the result by varying the values of the main parameters and observing the effects on the final outcome.

3. CASE STUDY

3.1The incident

The applicability of the proposed methodology is demonstrated with its implementation in a virtual case study for the development of a humanitarian logistics depot after an 8.4 magnitude earthquake in Pella, Greece. The epicenter of the earthquake is located at Kromni in Mount

Paiko, 3.2 kilometers below ground, 60kilometers north east from the city of Thessaloniki. Alternative sites that are available for the development of the humanitarian logistics depot are operational army camps in Goumenisa, Giannitsa, Edessa and Skidra, and schoolyards in Aridea, Exaplatanos and Aravisos, respectively.

3.2 Determination of criteria

After identifying all alternative potential sites, the criteria to be taken into account need to be decided upon. In any study concerning site locations, the most important question is defining the criteria to be considered. In this light, a critical number of relevant stakeholders, all experts on the thematic area under study, were personally interviewed in order to decide which criteria to use in the virtual case study. As already stated in the methodological framework, those criteria can be either strategic or operational. On a strategic basis, the selected criteria included; (CS1) local population, (CS2) distance from centralized warehouse, (CS3) quality of infrastructure, (CS4) distance from closest port, (CS5) distance from closest airport,(CS6) distance from closest heliport and (CS7) local hospital capacity. As already mentioned in the previous section, all above criteria can be quantified before the incident occurs in order to come up with timely decisions in the case an event strikes in the area. Performances of the seven alternative logistics depots' sites are summarized in Table 1. References for the data is also depicted. It should be mentioned that quality of infrastructure is measured in a 1 – 10 scale, based on experts' opinions. Value "1" refers to totally inappropriate infrastructure, while "10" refers to infrastructure equipped with state-of-the-art facilities.

Table 1: Alternative sites' performance on strategic criteria

Alternative site	Population (C_{S1})	Distance from centralized warehouse (C_{S2})	Quality of infrastructure (C_{S3})	Distance from closest port (C_{S4})	Distance from closest airport (C_{S5})	Distance from closest heliport (C_{S6})	Hospital capacity (C_{S7})
	(#)	(km)	(1-10)	(km)	(km)	(km)	(# of beds)
Reference	*HSA, 2012*	*Google, 2012*	*HGSCP, 2012*	*Google, 2012*	*Google, 2012*	*Google, 2012*	*TCG, 2010*
Edessa	25,729	40	2	91	56	7	150
Aridea	19,970	60	4	98	67	13	18
Exaplatanos	8,852	63	4	91	60	24	-
Aravisos	7,509	47	8	64	33	6	-
Skidra	15,633	32	6	75	38	12	32
Goumenisa	6,677	82	9	70	42	7	-
Giannitsa	31,782	39	5	52	21	9	248

Similarly, more criteria need to be defined on an operational basis. To that end, the following operational criteria were selected; (CO1) distance from the earthquake's epicenter, (CO2) condition of local infrastructure after the earthquake,(CO3) number of missing people, (CO4) number of homeless people and (CO5) number of wounded people (Table 2). Those criteria need to be quantified after the event, thus those cannot be quantified in advance similarly to the strategic criteria. It should be mentioned that the performances of the operational criteria are based on virtual case study and are not representing real life data. As regards the condition of the infrastructure after the earthquake (CO2), in the present work this is characterized on a 1 – 4 scale with "1" referring to totally destroyed local infrastructure and "4" referring to local infrastructure in good condition and/or fully operational. The values "2" and "3" refer to major and minor destructions in the local infrastructure, respectively. Moreover, as regards the criterion referring to the number of wounded people (CO5), this is further divided into severity of wounds with Cat I to represent the number of slightly wounded citizens, while Cat III to represent the number of heavily wounded ones. Last but not least, quantification of values for criterion CS7 is based on hospital beds capacities of General Hospital of Edessa, General Hospital of Giannitsa, Medical Centre of Aridea and Medical Centre of Skidra, respectively (TCG, 2010).

Table 2: Alternative sites' performance on operational criteria

Alternative site	Distance from epicenter (C01)	Condition of infrastructure (C02)	Missing people (C03)	Homeless (C04a)	Homeless (C04b)	Wounded Cat I (C05a)	Wounded Cat II (C05b)	Wounded Cat III (C05c)
	(km)	(1-4)	(#)	(#)	(%)	(#)		
Edessa	46	3	87	16,724	65%	5,000	1,000	50
Aridea	47	3	367	15,976	80%	6,000	1,000	40
Exaplatanos	39	1	458	8,409	95%	1,500	200	15
Aravisos	16	2	309	7,134	95%	1,000	90	10
Skidra	34	3	-	13,288	85%	1,000	100	15
Goumenisa	30	2	207	5,675	85%	1,200	90	10
Giannitsa	22	4	4	6,356	20%	2,000	800	30

Towards optimal site location, the values of alternatives on criteria CS1, CS3, CS6, CO2, CO3, CO4 and CO5 need to be maximized, whereas the values of alternatives on criteria CS2, CS4, CS5, CO1 need to be minimized. As discussed in the methodological section, the values of Tables 1 and 2 are scaled in a range from 1 to 10 using the aforementioned Nk(A) index (eq. 1). Scaled performances are depicted in Table 3.

Table 3: Alternative sites' scaled performances

Alternative site	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CO1	CO2	CO3	CO4a	CO4b	CO5a	CO5b	CO5c
Edessa	7,8	2,4	1,0	8,6	7,8	1,5	6,4	9,7	7,0	2,7	10	6,4	8,2	10	10
Aridea	5,8	6,0	3,6	10	10	4,5	1,7	10	7,0	8,2	9,4	8,2	10	10	7,8
Exaplatanos	1,8	6,6	3,6	8,6	8,6	10	1,0	7,7	1,0	10	3,2	10	1,9	2,1	2,1
Aravisos	1,3	3,7	8,7	3,3	3,3	1,0	1,0	1,0	4,0	7,1	2,2	10	1,0	1,0	1,0
Skidra	4,2	1,0	6,1	5,5	4,3	4,0	2,2	6,2	7,0	1,0	7,2	8,8	1,0	1,1	2,1
Goumenisa	1,0	10	10	4,5	5,1	1,5	1,0	5,1	4,0	5,1	1,0	8,8	1,4	1,0	1,0
Giannitsa	10	2,3	4,9	1,0	1,0	2,5	10	2,7	10	1,1	1,6	1,0	2,8	8,0	5,5

For the case under consideration, weighting factors, indifference, preference and veto thresholds are presented in Table 4. Weighting factors and veto thresholds are calculated as averages of the corresponding views of the 13 experts that were interviewed. As regards preference and indifference thresholds, those were calculated as follows:

$$p_k = \frac{1}{n}(V_{Ak_{MAX}} - V_{Ak_{MIN}}),\ A \in (A_1, A_2, ..., A_7),\ k \in (C_{S1}, C_{S2}, ..., C_{O5c}) \tag{1}$$

(Haralambopoulos and Polatidis, 2003) and

$$q_k = 0.3 \cdot p_k,\ k \in (C_{S1}, C_{S2}, ..., C_{O5c}) \tag{2}$$

(Kourmpanis et al., 2008), where:

$V_{Ak_{MAX}}$: Maximum performance of alternative Afor criterion k,

$V_{Ak_{MIN}}$: Minimum performance of alternative w for criterion k and

n = number of available alternatives.

In that sense, indifference and preference thresholds are directly linked to the quantified values of the alternatives' performances in the selected criteria. Since values of the performance table (Table 3) are scaled (in a range1-10), indifference and preference thresholds are similar for all criteria. However, those scaled values refer to totally different actual values.

Table 4: Weighting factors and thresholds for the development of a humanitarian logistics depot in Pella, Greece

	C_{S1}	C_{S2}	C_{S3}	C_{S4}	C_{S5}	C_{S6}	C_{S7}	C_{O1}	C_{O2}	C_{O3}	C_{O4a}	C_{O4b}	C_{O5a}	C_{O5b}	C_{O5c}
Weighting factor	5.3%	4.1%	6.0%	1.6%	1.8%	4.9%	9.8%	7.7%	7.2%	14.9%	9.7%	1.4%	5.1%	7.8%	12.7%
Threshold of indifference	1.43														
Threshold of preference	0.43														
Veto threshold	-	-	6.1	-	-	-	-	-	5.7	2.8	4.8	-	-	-	5.4

3.3 Results and discussion

As a next step, following the determination of alternative sites and criteria, the mathematical The optimal location (Aravisos) can be interpreted as a result of the specific site's excellent performance in a number of different criteria. More specifically, Aravisos is the site closest to the earthquake's epicenter(CO1) among alternatives, while also the location is one of the closest to port(CS4), airport (CS5)and heliport (CS6)so that resources and human capital can be quicker and more efficiently transported. This is further reinforced by the specific site's excellent quality of infrastructure (CS3), since the specific area corresponds to a newly renovated army camp. In order to overcome subjectivity issues, the sensitivity analysis that follows, as well as the ease to re-calculate optimal solution with modified parameters, provides the decision maker with an easy-to-use tool. Sensitivity analysis is considered as a significant merit of the presented methodological approach on the grounds that in real-world applications, input data originate from estimations which, although assumed constant, are sometimes more or sometimes less reliable. Especially in times of severe incidents as the one herein described, the quality of input data is further questionable. General sources of individual uncertainties could come from data series uncertainties, synergies and idiosyncrasies in the interpretation of ambiguous or incomplete information. In any case it should be underlined that the simultaneous consequences of potential variations of parameter values, decision variables and constraints could be studied by new model runs, since the low computational time gives the opportunity for fast reformed optimal solutions. On this basis, ELECTRE III is preferable, since it is considered to better adapt to uncertainties (Roy and Bouyssou, 1993).In this light, for sensitivity analysis purposes, the problem under study is resettled with modified parameters (weighting factors and thresholds).Together with the "basic" scenario, twelve more parameter-based scenarios with differentiated preference and indifference thresholds were examined. Those scenarios correspond to increase of preference and indifference thresholds by 5%, 10%, 20%, 30%, 40% and 50%, respectively. The rest six investigated scenarios similarly correspond to decrease of preference and indifference thresholds by the same percentages. For all above scenarios, Aravisos appears as the optimal location for the development of the logistics depot, which provides the decision-maker with additional confidence on the robustness of the result. Apart from the aforementioned twelve threshold-based scenarios examined, sensitivity analysis is also conducted with the modification of criteria weighting factors also by 50% (increasing and decreasing). For all weighting factors-based scenarios, Aravisos appears the optimal location.

4. CONCLUSIONS

In cases of earthquakes, floods, volcanoes' explosions, tsunamis, as well as other natural or man-made disasters, timely and efficient organization, planning and execution of all necessary actions towards humanitarian relief is most critical. Notwithstanding the fact that all such different incidents heavily differentiate among each other in terms of the required relief operations, in all cases those operations need to be carefully organized well ahead the incident occurs. In this light, responsible bodies need to be adequately prepared in order to efficiently cope with such disastrous situation. Towards this direction, one of the most strategic decisions is the optimal location of a humanitarian logistics depot to be developed. Such a decision may represent the cornerstone towards humanitarian relief and may further influence all other important strategic, tactical and operational actions that are required. Optimal location of a humanitarian logistics depot involves simultaneous consideration of usually mutually conflicting parameters which may be either related or not to the episode's epicenter. The latter can be assessed well ahead the incident strikes in order the responsible body to be better prepared for rapid response. On the other hand, the decision-maker needs to wait until the disaster actually happens in order to come up with the assessment of the parameters that are directly influenced by the type of disastrous incident and its epicenter. This paper presents an easy-to-use tool that could facilitate secure relief to the victims of disasters in a timely and reliable way. The proposed methodological framework is implemented for the case of a virtual earthquake incident in northern Greece. However, the procedure could be easily adopted, with slight modifications and adjustments to the special requirements of the problem under consideration, in order to surface optimal decisions in respect to types of natural or man-made disasters other than the one examined in the present analysis.

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