E-ISSN: 2676-6167 | P-ISSN: 2538-5100

Journal of Applied Research on Industrial Engineering

www.journal-aprie.com

J. Appl. Res. Ind. Eng. Vol. 8, Spec. Issue. (2021) 1–10.

Paper Type: Research Paper

# Ranking of Key Resources in the Humanitarian Supply Chain in the Emergency Department of Iranian Hospital: A Real Case Study in COVID-19 Conditions

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**Citation:**

Jahangiri, Sh., Abolghasemian, M., Pourghader Chobar, A., Nadaffard, A., & Mottaghi, V. (2021). Ranking of key resources in the humanitarian supply chain in the emergency department of iranian hospital: a real case study in COVID-19 conditions. *Journal of applied research on industrial engineering, 8*(Spec. Issue), 1-10.

Received: 26/02/2021 Reviewed: 29/03/2021 Revised: 21/06/2021 Accepted: 04/08/2021

## Abstract

China introduces a new strain of coronavirus as a causative of a new respiratory disease after several people contracted an unusual pneumonia in December 2019. The World Health Organization stated that the outbreak of the virus resulted in public health emergencies around the world. Humanitarian supply chain management is concerned with managing the efficient flow of aid materials, information and services and aim to reduce the impact of disaster on human lives. In this paper, provides a ranking for key resources in the humanitarian supply chain in the emergency department of Iranian hospital using hybrid decision-making method under COVID-19 conditions. According to the obtain results, nurses in RK 1, receptionists RK 2, general surgeon RK 3, heart residents RK 4 and pulmonologist RK 5. Hybrid decision-making method in this paper is an invaluable contribution to the emergency department and medical managers for evaluates of current situation Emergency Department when crisis occur.

**Keywords:** Humanitarian supply chain, Decision-Making, Emergency department.

## 1 | Introduction



The COVID-19 pandemic which started in Wuhan China at the end of 2019 has spread worldwide by 2020 [1] and [2]. Initially and long time the only answer was lockdown and social distancing. The collateral damage was bigger than the direct impact of corona. Covid-19 tests still were not readily available for the broad general world population by July 2020 [3]. The same holds true for a vaccine, which is still under development and may be ready by 2021. Normal supply chains were interrupted and altered. Borders were closed even between neighboring countries like Iran and Turkey. Crisis management during corona times certainly had its fair share of scandals in all countries.

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http://dx.doi.org/10.22105/jarie.2021.275255.1263

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Modes of transportation were changed as passenger flights were cancelled and container ships delayed to reach its shipping capacity. The first Humanitarian Logistics (HL) efforts were shipments of surgical masks and protective gear and equipment to countries. Critical corona patients were transported to another country in March 2020 [2]. HL is helping the poor as the poor get poorer during the corona crisis and the collateral damage greater than that from the virus [4]. The natural and human-made disasters have been increased vulnerability in the global population. Increasing vulnerability calls for quick and effective responses from Humanitarian organizations and other stakeholders such as military, local government, logistics and supply chain practitioners to provide the required relief and development programs to the affected population by coordination of resources including supplies of food, shelter, and medical facilities [5]. Comparing with healthcare scenario, where every minute is important to treat a critically ill patient; similar is the case when organizations are dealing with disasters and human suffering caused due to catastrophic events affecting lives of few hundreds to thousands of populations. Additionally, catastrophic events or natural disasters have the potential to significantly disrupt the supply chain operations of organizations and thus impact on their balance sheet [6]. All the aforementioned challenges created by catastrophic events such as COVID-19 pandemic requires coordination at the macro level between government, industry, academia, and other humanitarian aid organizations to stabilize the health and economy across the globe. The 'Global Humanitarian Response Plan COVID-19 was outlined by the United Nations (2020) to facilitate the auctioning of a successful response implementation plan for a large-scale COVID-19 pandemic. Therefore, in this paper presented a ranking for effective resources in the hospital's humanitarian supply chain in response to coronavirus using a hybrid decision-making method.

The Multi-Criteria Decision-Making (MCDM) are frequently used to solve real world Problem with multiple, conflicting and commensurate criteria. MCDM problems are generally categorized as continuous or discrete, depending on the domain of alternatives. Ehrgott and Wiecek [7], have classified the MCDM into two categories: Multi-Objective Decision-Making (MODM) and Multi-Attribute Decision-Making (MADM). MODM has been widely studied by means of mathematics programming methods with well-formulated theoretical frameworks. MODM methods have decision variable values that are determined in a continuous or integer domain with either an infinitive or a large number of alternative choices, the best of which should satisfy the DM Constraints and preference priorities. MADM methods, on other hand, have been used to solve problems with discrete decision spaces and a predetermined or limited number of alternative choices. MADM methods are used for circumstances that necessitate the consideration of different options that cannot be measured in a single dimension. Each method provides a different approach for selecting the best among several pre-selected alternatives. The MADM methods help DMs learn about the issues they face, the value system of their own and other parties and the organizational value and objectives that will consequently guide them identifying a preferred course of action.

The remainder of this paper is organized as follows: Section 2 shows the Literature review, Section 3 shows Humanitarian supply chain, Section 4 provides the hybrid decision-making method and finally, presents the conclusion.

## 2 | Literature Review

Recently, many authors studied on new management policy to provide healthcare managers, and increase efficiency in the hospital performance. For example, Yousefi et al. [8], presented a systematic review to progress made on the subject while showing possible complexities in Emergency Department (ED). Bal et al. [9], proposed a hybrid methodology combined of lean techniques and Discrete Event Simulation (DES) models. The goal of this paper was to improve the efficiency of ED by reducing the overcrowding and patient waiting times. Duguay and Chetouane [10], developed a DES model of an ED in Canada. The purpose of their research is to minimize the waiting time of patients and to increase total service delivery and system flow. Ahmed and Alkhamis [11], provided a policy for the operational design of ED at a Kuwaiti public hospital. The policy provided by them can reduce waiting time of patients by 40%

and increase patient throughput by 20%. Abo-Hamad and Arisha [12], presented a Decision Support System (DSS) framework for medical center system improvement. Results show that the unblocking of ED flow using bed allocation is more effective than increasing the ED personnel. Kadri et al. [13], developed a DSS to prevent and predict strain situations in an ED in order to increase their management ability of the healthcare system. Also, a DES model was built to evaluate the strain situations, examine the relationship between the strain situations and propose corrective actions. Findings shown the importance of anticipation and management of strain situation in the ED. Zeinali et al. [14], presented a mathematically model in the ED by meta-modelling approach. Results shown the total waiting time of patients is decrease by 48%. Feng et al. [15], presented a Multi-Objective (MO) programming by a Non-Dominated Sorting Genetic Algorithm II (NSGA II) and Multi-Objective Computing Budget Allocation (MOCBA) medical for key resources configuration in the ED according to patients flow or ED output. Traoré et al. [16], presented a framework for mathematical modeling and simulation model to create a DSS tool for evaluation of medical systems. Daldoul et al. [17], presented a stochastic model to minimize patient waiting time in an ED. The objective of this study was to optimize the human and material resources required to decrease the average total patient waiting time. Chen et al. [18], developed a simulated-annealing-based algorithm to find a resources configuration to solve the randomly constrained model using optimization problem. Results demonstrated that proposed algorithm had an increase of 38.28% in the main efficiency compared to the current resources configuration. Aghapour et al. [19], proposed a Multi objective optimization for capacity planning and reconfiguration for disaster-resilient health infrastructure and an unplanned capacity planning in disaster. Ordu et al. [20], proposed a model that linked each and every service and specialty such as out-patient and in-patient services, with the purpose of predicting demand for all the specialties, capturing all the uncertainties of patient flow within a medical center setting by DES model, and building a linear programming solution to approximate the number of beds and required resources of a health care system in England. Results showed a varied view to decision-making with a DSS tool for short and long term policies in order to build a rational and realistic pattern. Pegoraro et al. [21], presented a DSS framework for ED decision management using DES model and MCDM. Pegoraro et al. [22], provided a hybrid MCDM method such as DEMATEL and PROMETHEE II to help ED managers design improvement actions and make decisions that reduce overcrowding. Jahangiri et al. [23], a surrogate model is presented to define the optimal combination of the ED key resources under COVID-19 conditions to minimize the arriving patients total waiting time in an ED in the Iranian public hospital subject to resource capacity and budget constraints. Yang et al. [24], introduced a hybrid multiple-criteria decision portfolio with the resource constraints model of a smart healthcare management system for public medical centers. Ghorui et al. [25], identification dominant risk factor involved in spread of COVID-19 using hesitant fuzzy MCDM methodology.

According to the literature review mentioned above, aim of paper is propose the hybrid decision making method to identify the key resources in the ED for reducing the waiting time of patients in the ED under COVID-19 conditions. Also, we show how hybrid decision making method is useful to create the suitable decision for healthcare managers.

## 3 | Humanitarian Supply Chain

Generally a supply chain is the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products or services in the hands of the ultimate consumer [26]. Supply chain management is the management across a network of upstream and downstream organizations of material, information and resource flows that lead to the creation of value in the form of products or services [27]. However, the humanitarian supply chain encompasses the planning and management of all activities related to material, information and financial flows in disaster relief. Importantly, it also includes co-ordination and collaboration with supply chain members, third party service providers and among humanitarian organizations. It does not include the development aid aspect of HL [28]. Further, humanitarian supply chain management is concerned with managing the efficient flow of aid materials, information and services and aim to reduce the impact of disaster on human lives [29]. Humanitarian supply chains play a central role in several phases of a disaster relief concept such as preparedness, immediate response, reconstruction and recovery phase. In this paper, Imam-Ali hospital public medical center that located in the shar-e-kord city in Iran is considered. The Imam-Ali hospital ED is open 24 hours a day. According to data collected from recorded archive, an average of patients is 44000 in a year. The infectious ward of Imam-Ali hospital has been assigned for patients with coronavirus. The Imam-Ali hospital ED has three sub units, Chest Pain Unit (CPU), for patients with acute chest pain or any other heart problems and Intensive Care Unit (ICU), for patients with major trauma, severe burns, respiratory failure and cardiothoracic surgery and surgery unit, for patients that need surgery. According to the data collected, 40% of patient entries to the ED are in critical condition. Therefore, it is necessary patients receive medical care as soon as possible. Since minimize the total waiting time is vital, we decided to consider this section in our problem of resource planning. The important resources in the ED are receptionists $(X_1)$, nurses $(X_2)$, heart residents $(X_3)$, general surgeons $(X_4)$ and beds $(X_5)$. In its current situation, the ED has three receptionists, four nurses, one heart resident, one general surgeon and eight beds. Patient entry process at the ED is shown in *Fig. 1*. According to the Emergency Severity Index (ESI) standard, arriving patients are divided to five levels, designated from 1 to 5 (e.g. patients with ESI 1 are highest priority and the patients with ESI 5 are lowest priority).

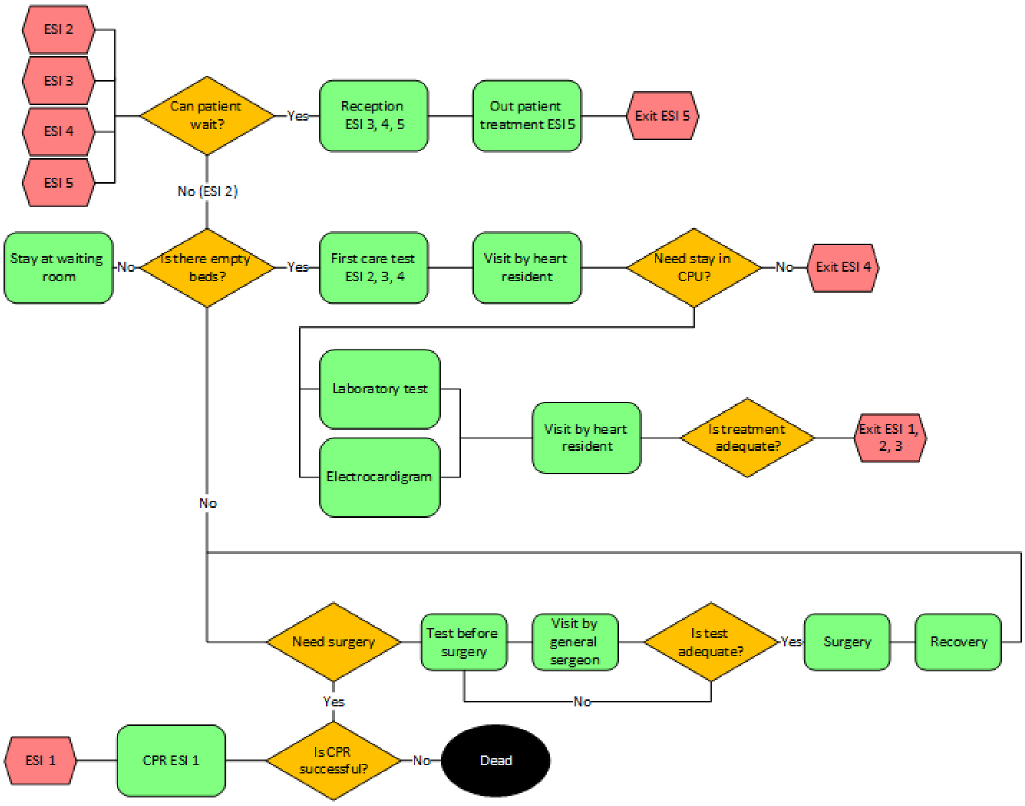


**Fig. 1. Patient entry flow.**

## 4 | Hybrid Decision-Making Method

### 4.1 | Best-Worst Method (BWM)

Here, we briefly describe the steps of Best Worst Method (BWM) that can be used to derive the weights of the criteria. The BWM introduced by Rezaei [30] for first time.

**Step 1.** Determine a set of decision criteria. In this step, the decision-maker identifies n criteria $\{c_1, c_2, ..., c_n\}$ that are used to make a decision.

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**Step 2.** Determine the best (e.g. most desirable most important) and the worst (e.g. least desirable, least important) criteria.

**Step 3.** Determine the preference of the best criterion overall the other criteria, using a number between 1 and 9. The resulting Best-to-Others (BO) vector would be:

$$AB = (a_{B1}, a_{B2}, ..., a_{Bn}).$$

**Step 4.** Determine the preference of all the criteria over the worst criterion, using a number between 1 and 9. The resulting Others-to-Worst (OW) vector would be:

$$AW = (a_{1w}, a_{2w}, ..., a_{nw})^T.$$

**Step 5.** Find the optimal weights. The aim is to determine the optimal weights of the criteria, such that the maximum absolute differences $\frac{W_B}{W_j} = a_{Bj}$ and $\frac{W_j}{W_w} = a_{jw}$ for all j is minimized, which is translated to the following min-max model:

$$\begin{aligned} & \text{MinMax}\{\left|\frac{W_B}{W_j} - a_{Bj}\right| \text{and} \left|\frac{W_j}{W_w} - a_{jw}\right|\}, \\ & \text{s.t} \\ & \sum w_j = 1. \\ & w_j \geq 0, \text{for all j} \end{aligned} \tag{1}$$

*Model (1)* is equivalent to the following model

$$\begin{aligned} & \text{MinMax}\{\left|W_B - a_{Bj}W_j\right|, \left|W_j - a_{jw}W_w\right|\}, \\ & \text{S.t} \\ & \sum W_j = 1. \\ & W_j \geq 0, \text{for all j} \end{aligned} \tag{2}$$

Also, *Model (2)* is equivalent to the following model:

$$\begin{aligned} & \text{Min}\varepsilon \\ & \text{S.t} \\ & \left|W_B - a_{Bj}W_j\right| \leq \varepsilon, \\ & \left|W_j - a_{jw}W_w\right| \leq \varepsilon, \\ & \sum W_j = 1. \\ & W_j \geq 0, \text{for all j} \end{aligned} \tag{3}$$

Solve *Model (3)* calculates the weight of the indicators $(W_j)$ and the consistency rate.

## 4.2 | Technique for Order Performance by Similarity to Ideal Solution (TOPSIS)

The TOPSIS (Technique for order performance by similarity to ideal solution) was first developed by Hwung and Yoon [31]. According to this technique, the best alternative would be the one that is nearest to the positive ideal solution and farthest from the negative ideal solution [32]. The positive ideal solution is a solution that maximizes the benefit criteria and minimizes the cost criteria, whereas the negative ideal solution maximizes the cost criteria and minimizes the benefit criteria [33]. In short, the positive ideal solution is composed of all best values attainable from the criteria, whereas the negative ideal solution consist of all worst values attainable from criteria [33].

The computational steps of the TOPSIS method are presented in the following steps [34] and [35]:

**Step 1.** Establishing a performance decision matrix:

$$X_{ij}=\begin{pmatrix} X_{11} & \cdots & X_{1n} \\ . & & . \\ . & \cdots & . \\ . & & . \\ X_{m1} & \cdots & X_{mn} \end{pmatrix}. \tag{4}$$

**Step 2.** Calculating the normalized decision matrix. The normalized value $(p_{ij})$ is calculated as follows and normalized decision matrix as *Eq. (5)*:

$$P_{ij}=\frac{X_{ij}}{\sqrt{\sum_{i=1}^{m}x_{ij}^{2}}};i=1,\dots,m;j=1,\dots,n.$$

$$p_{ij}=\begin{pmatrix} p_{11} & \cdots & p_{1n} \\ . & & . \\ . & \cdots & . \\ . & & . \\ p_{m1} & \cdots & p_{mn} \end{pmatrix}. \tag{5}$$

**Step 3.** Calculating the weighted normalized decision matrix. The weighted normalized value $(V_{ij})$ is calculated as follows *Eq. (6)*:

$$v_{ij}=p_{ij}\times w_{j}=\begin{pmatrix} v_{11} & \cdots & v_{1n} \\ . & & . \\ . & \cdots & . \\ . & & . \\ v_{m1} & \cdots & v_{mn} \end{pmatrix}. \tag{6}$$

Where $W_j$ is the weight of the $j^{th}$ criterion or attribute and, $\sum W_{x_{ij}}=1$.

**Step 4.** Determining the positive ideal $A_i^+$ and negative ideal $A_i^-$ solutions.

$$A_i^-=\{(\mathrm{Min}\,v_{ij}\mathrm{Max}v_{ij}\,|j\in J'),(J=1,\dots,N)=\{v_1^-,\dots,v_n^-\}.$$

$$A_i^+=\{(\max v_{ij}\,|j\in J),(\mathrm{Min}\,v_{ij}\,|j\in J'),(i=1,\dots,m)=\{v_1^+,\dots,v_m^+\}.$$

Where $J$ and $J'$ are the sets of criteria with positive effect and criteria with negative effect, respectively.

**Step 5.** Calculating the separation measures using the m-dimensional Euclidean distance. The separation measures of each alternative from the positive ideal solution and the negative ideal solution, respectively, are as follows:

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$$D_i^+ = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^+)^2}; i = 1,...,m. \quad (7)$$

$$D_i^- = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^-)^2}; j = 1,...,n. \quad (8)$$

**Step 6.** Calculating the relative closeness to the ideal solution.

$$CC_i^+ = \left[\frac{D_i^+}{D_i^+ + D_i^-}\right]; 0 \le CC_i^+ \le 1; i = 1,...,m. \quad (9)$$

**Step 7.** Ranking preference orders. Choose an alternative with maximum value of $CC_i^+$ or ranking alternatives according to $CC_i^+$ value in descending orders.

## 4.3 | Proposed Hybrid Decision-Making Method

In this paper, presented a hybrid decision-making method using BWM and TOPSIS to ranking of the key resources in the humanitarian supply chain in the ED of Iranian hospital. According to the hybrid decision-making method first, with using BWM calculate the index weight. Second, using TOPSIS prepare ranking of the key resources. In this case, considered Indexes and Alternatives are shown in *Table 1*.

**Table 1. Decision matrix.**

| Index | Alternative |
|---|---|
| Technology Education $(C_1)$ | Receptionists $(A_1)$ |
| Senior Management $(C_2)$ | Nurses $(A_2)$ |
| Human Resource $(C_3)$ | Heart residents $(A_3)$ |
| Quality Management $(C_4)$ | General surgeon $(A_4)$ |
| Organizational Culture $(C_5)$ | Pulmonologist $(A_5)$ |

In this case, BO and OW pairwise comparisons are shown in the *Table 2* and *3*.

**Table 2. BO pairwise comparison.**

| Best other | $(C_1)$ | $(C_2)$ | $(C_3)$ | $(C_4)$ | $(C_5)$ |
|---|---|---|---|---|---|
| Best criterion: $(C_2)$ | 2 | 1 | 4 | 3 | 8 |

**Table 3. OW pairwise comparison.**

| Other worst | Worst Criterion: $(C_5)$ |
|---|---|
| $(C_1)$ | 4 |
| $(C_2)$ | 8 |
| $(C_3)$ | 2 |
| $(C_4)$ | 3 |
| $(C_5)$ | 1 |

When ranking key resources in the ED, manager considers five index Technology Education $(C_1)$, Senior Management $(C_2)$, Human Resource $(C_3)$, Quality Management $(C_4)$, Organizational Culture $(C_5)$. The manager provides the pairwise comparison vectors as shown in *Table 2* and *3*. Solving this problem using *Model (2)* results in $W_1^* = 0.210,\ W_2^* = 0.421,\ W_3^* = 0.105,\ W_4^* = 0.210,\ W_5^* = 0.052$. This comparison system is fully consistent and we have a single solution.

Five types of key resources that are considered in the ED as alternatives. Based on expert's opinion, five index identified for evaluating Humanitarian supply chain. Therefore, considered index for key resources ranking in this study are: Technology Education $(C_1)$, Senior Management $(C_2)$, Human Resource $(C_3)$, Quality Management $(C_4)$, and Organizational Culture $(C_5)$. The decision matrix which is the average of expert's opinions about score of alternatives in each index is shown in *Table 4*. Weights of index shown in the last row of *Table 4*.



**Table 4. Decision matrix.**

| | | | | | |
|---|---|---|---|---|---|
| **($A_1$)** | 3 | 5 | 7 | 7 | 9 |
| **($A_2$)** | 5 | 7 | 9 | 9 | 9 |
| **($A_3$)** | 7 | 7 | 9 | 9 | 9 |
| **($A_4$)** | 9 | 7 | 9 | 9 | 9 |
| **($A_5$)** | 9 | 7 | 9 | 9 | 9 |
| **$W_i$** | 0.210 | 0.421 | 0.105 | 0.210 | 0.052 |

In the next step, for ranking key resources, TOPSIS method is applied. Based on decision matrix (*Table 4*) and weights of criteria, and following step 2-7, ranking of key resources are shown in *Table 5*.

**Table 5. Ranking of key resources.**

| Key Resources (Alternative) | Rank |
|---|---|
| Receptionists ($A_1$) | 2 |
| Nurses ($A_2$) | 1 |
| Heart residents ($A_3$) | 4 |
| General surgeon ($A_4$) | 3 |
| Pulmonologist ($A_5$) | 5 |

## 5 | Conclusion

This paper presented a hybrid decision-making method for ranking of the identified key success factors in the humanitarian supply chains. These are important for an effective management of emergency response measures in the ED under critical condition such as COVID-19. As limitation it can be observed that the boundaries between the objectives of the stakeholders, key success factors and performance measurement metrics are not sufficiently clear. Therefore as a further development the boundaries have to be defined. By a sufficient definition of objectives and key success factors a holistic performance measurement metrics can be developed that matches the humanitarian supply chain environment. The suggested key success factors here have to be translated into measurement metrics and implemented as well as tested in decision making method. Further a performance measurement system and tools can be developed for this sector based on these research results. Using the proposed method, the priority of the identified indicators in the humanitarian supply chain has been obtained. According to the results, nurses in RK 1, receptionists RK 2, general surgeon RK 3, heart residents RK 4 and Pulmonologist RK 5. For future research authors declare to use other hybrid methods such as BWM-VIKOR. Also, compare the findings with the results of this study.

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