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Decision Modeling for Appraising Material Handling Equipments under Qualitative Indices

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Abstract
Material handling equipments (MHEs) are the important part of every manufacturing and industrial firms, which remains involved during the process of manufacturing, distribution, consumption, disposal etc. Assessing the importance of MHE is crucial and it can influence the profit of the concerned firm. Thus, in this work, the authors responded towards MHE characteristics and equipped an assessment platform for appraising MHE indices, which can be utilized in defining the status of the indices relating the MHE. A Multi-Criterion Decision Making (MCDM) framework under the arena of Material Handling Equipment (MHE) is developed by the authors and a decision support model is presented by the authors to describe the level of the indices pertaining to the selection of MHE. Modeling based on Generalized Interval-Valued Trapezoidal Fuzzy Numbers (GIVTFNs) is presented to reciprocate towards the uncertainty and impreciseness of the MHE indices. A single level hierarchy platform is presented by the authors for demonstrating the scientific realization of the projected work. A fuzzy performance important index framework for MHE indices is discussed in this study to recognize the strong and ill MHE indices. In this study, the authors presented a decision support framework, which can clutch the subjective views of the decision makers. In this study, the chief objective of the authors is to distribute methodological way for determining the importance of distinguishes MHE indices.

Keywords- Material Handling Equipment, Generalized Interval-Valued Trapezoidal, Fuzzy Numbers (GIVTFNs) Modeling, Decision Support Framework, Assessment.

1. Introduction

The majority of the manufacturing sectors own material handling equipments. In present manufacturing organizations a wide variety of material handling equipments are used for specific purposes (Chakraborty and Banik, 2006). These equipments are the significant element of approximate all manufacturing and industrial firms. These equipments are utilized during the process of manufacturing, distribution, consumption, disposal etc. Characterizing and assessing the significant MHEs is important to capture the profitability into the firms. (Sahu et al., 2017) familiarized the readers with the various material handling system and their technologies and also supplied few universal guidelines for opting a particular technology for a particular application. (Karande and Chakraborty, 2013) advised the companies to prefer the load capacity, energy consumption, reliability, cost, etc. as quantitative criteria and environmental hazard, flexibility, performance, environmental performance, safety, load shape, load type, etc as qualitative criteria for constructing the practical valid multi criteria

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decision making module for material handling system evaluation perspective. (Deb et al., 2002) used a fuzzy based multi criteria decision making method to materialize the suitable ratings disperse by decision makers against indices relating the environmental performance of Material Handling Equipment. Egbelu and Tanchoco (1984) explained that Automatic Guided Vehicles (AGVs) widely dispatches the goods. Therefore, automatic guided vehicle can be considered as a great AMHS (Automatic Material Handling System) for job shop manufacturing. Chakraborty and Banik (2006) have found that the selection of suitable material handling equipment for typical conditions requiring the application of an effective and efficient multi-criteria decision making tool. They designed a MHE selection model using AHP (Analytical Hierarchy Process), which efficiently yielded results in many multi-criteria decision making arena. The area of MHEs is needed to be widely studied by the researchers, which should highlight the significant MHEs indices for better ecological saving, firm performance and survival. In this study, the authors responded towards conceptualizing MHEs characteristics and prepared an estimation platform for appraising MHEs indices. The present work can be utilized in defining the status of the MHEs indices. The authors offered a single level hierarchy podium which is relating MHEs for representing the methodical easiness of the projected work. The authors responded towards the momentous MHEs indices in this study to model a MHEs framework based on GIVTFNs.

2. Methodology

Chakraborty and Banik (2006) have found unstructured selection procedure, which have accompanied the zone of MHEs and he characterized the requirement of dependent knowledge to allow easier and more logical selections of MHEs. Thus, a decision support model is presented by the authors to describe the level of the indices pertaining to the selection of MHE. In this study, the authors offered a decision support framework for modeling MHEs indices under subjective arena and utilized Generalized Interval-Valued Trapezoidal Fuzzy Numbers (GIVTFNs) to represent decision result. Modeling based on GIVTFNs is presented to reciprocate towards the uncertainty and impreciseness of the MHE indices. Fuzzy sets theory is a powerful mathematical tool, which can be effectively used by the researchers for modeling uncertainty and vagueness in the systems (Zadeh, 1965; Zadeh, 1975; Chen, 2000). Fuzzy sets theory can be effectively utilize in decision situations; where the captured information possess uncertainty and vagueness (Sahu et al., 2015a; 2015b). Thus, fuzzy sets theory is used in this study. (Maniya and Bhatt, 2011) used Analytic Hierarchy Process (AHP) to disperse the relative importance to their chosen criteria relating the AGV as material handling equipment. They used Extended Grey Relational Analysis (E-GRA) approach to determine the overall index values of AGV alternatives. Their selection is carried out in accordance with greater score of AGV to capture first rank.

Numerous researchers have fruitfully explored the arena of GIVTFNs and presented the concepts properties, operational rules pertaining to GIVTFNs (Chen, 1995; Wei and Chen, 2009; Secundo et al., 2017). Various arithmetic operations between GIVFTNs as presented by

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(Sahu et al., 2016b) are utilized in this study to model a decision support framework. Datta et al. (2013) uncovered a resourceful decision support system for evaluating material handling equipment (robot) operated under fiscal and environmental related criterions. MCDM approach is coupled with MULTI-MOORA (Multi Objective Optimization by Ration Analysis) method in their work for selecting the best material handling equipment. The authors utilized the conception of (Liu and Jin, 2012) to define the relative distance between GIVTFNs in this modeling.

3. Fuzzy Performance Index (FPI) and Fuzzy Performance Importance Index (FPII)

In this study, the authors presented a decision support framework, which can clutch the subjective views of the decision-makers $(\partial k_{i,....,p})$. Fuzzy sets theory can assist in the evaluation of the indices and is an important tool to be used for modeling system information. Fuzzy Performance Index and Fuzzy Performance Importance Index based on GIVTFNs as presented by Equations 1 & 2; is utilized in this study to recognize the strong and weak MHE indices. (Sahu et al., 2016a) projected a revised ranking approach escorting fuzzy performance important index to categorize the barriers in Agile Supply Chain Management. The Fuzzy Performance Index characterizes the performance coverage of the indices, which are under consideration and can be utilized by the management for comparison.

$$FPI = \frac{\sum \alpha_i \otimes \beta_i}{\sum \beta_i} \tag{1}$$

Here, α_i is the aggregated fuzzy rating and β_i is the aggregated fuzzy weight against MHEs indices allocated by decision maker. The computed FPI is found as [(0.378,0.495,0.856,1.091,0.800);(0.378,0.495,0.856,1.091,1.000)] in this study. Fuzzy Performance Importance Index is used in this study to classify the strong and weak MHE indices (Lin et al., 2006).

$$FPII = \beta_i^{\Psi} \otimes \alpha_i \tag{2}$$

$$FPII = \left\{ \left[\left\{ (1,1,1,1;1),(1,1,1,1;1) \right\} - \beta_i \right] \otimes \alpha_i \right\} \tag{3}$$

$$\beta_i^{\Psi} = \left[\left\{ (1,1,1,1;1),(1,1,1,1;1) \right\} - \beta_i \right]$$

(4)

4. Discussions

Performance evaluation has constantly been documented by the firms and important strategies to increase the performance are implemented by the firms time to time; in order to achieve an efficient and effective performance. Assessing the importance of MHE is crucial and it can influence the profit of the concerned firm. It is always required to define the strength and weakness of every system for taking appropriate decisions. Thus, the authors discussed a fuzzy performance important index framework for MHE indices in this study to recognize the

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strong and weak MHE indices. In this study, the authors acted towards the MHEs characteristics and delivered a MHEs assessment decision support system, which can be utilized by the mangers of the manufacturing and industrial firms for assessing the significant MHEs indices. In this study, the authors offered an approach for measuring and appraising the performance of the MHEs indices by defining the strong and weak indices. (Mohsen and Hassan, 2010) constructed a support structure after conducting the literature survey in the zone of material handling system. Their developed structure carries the financial and green aspects of material handling equipments. They proposed a structure to the managers of firms for benchmarking and selecting the material handling equipments. Their proposed structure handled the expert's insight and aids to choose the paramount material handling system.

The performance measurement dilemma usually surrounded with multiple subjective indices in a decision making problem. It also engrosses inherent vagueness, inconsistency and incompleteness because of the engagement of multiple subjective indices. Thus, the authors build decision support framework to assist the managers of manufacturing firms to model performance assessment tool pertaining to MHEs selection and evaluation in their decision making. Chakraborty and Banik (2006) implemented Analytic Hierarchy Process (AHP) model for opting the feasible indices pertaining to material handling equipment selection.

Table 1. Priority importance of MHE indices

Indices	(C_i)	Weight (β_i)	Group decision making							
			∂m_1	∂m_2	∂m_3	∂m_4	∂m_5	∂m_6	∂m_7	∂m_8
Handling cost	(C_1)	(β_1)	VH	ML	VL	AH	AL	AH	L	AH
Possession cost	(C_2)	(β_2)	L	H	L	L	H	VL	MH	L
Control mechanism	(C_3)	(β_3)	VL	AH	VH	M	L	MH	ML	AH
Logistics	(C_4)	(β_4)	L	M	M	L	VH	AL	ML	ML
Type of movement	(C_4)	(β_5)	M	AL	ML	MH	MH	M	VH	ML
Nature of the movement	(C_6)	(β_6)	VH	MH	ML	ML	H	M	ML	H
Travel arena	(C_7)	(β_7)	AL	MH	VL	AH	MH	VL	AH	L
Quantity of Inventory	(C_8)	(β_8)	ML	H	M	M	ML	MH	AL	L
Inventory characteristics	(C_9)	(β_9)	ML	L	AH	ML	H	VH	M	VL
Type of Inventory	(C_{10})	(β_{10})	MH	MH	MH	VL	L	ML	ML	VL

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Table 2. Appropriateness ratings of MHE indices

Indices	(C_i)	Rating (α_i)	Group decision making ∂m_1	∂m_2	∂m_3	∂m_4	∂m_5	∂m_6	∂m_7	∂m_8
Handling cost	(C_1)	(α_1)	MG	AG	G	MP	VG	MP	G	MP
Possession cost	(C_2)	(α_2)	M	P	M	MG	P	AG	M	VG
Control mechanism	(C_3)	(α_3)	MP	VG	G	VG	G	MP	VG	MG
Logistics	(C_4)	(α_4)	VG	VP	AG	MP	MG	AG	G	AG
Type of movement	(C_5)	(α_5)	AP	VG	P	G	AG	M	M	G
Nature of the movement	(C_6)	(α_6)	G	VP	AP	VG	MP	G	VG	MG
Travel arena	(C_7)	(α_7)	G	AG	AG	M	G	P	MG	G
Quantity of Inventory	(C_8)	(α_8)	VP	VG	G	P	VG	VG	MG	AG
Inventory characteristics	(C_9)	(α_9)	AG	M	MP	MG	M	MP	G	AG
Type of Inventory	(C_{10})	(α_{10})	AP	M	VG	MG	G	MG	M	VP

Table 3. Tabulation of computed FPII

Indices	$FPII_i = \left[\left\{(1,1,1,1;1),(1,1,1,1;1)\right\} - \beta_i\right] \otimes \alpha_i$
(C_1)	[(0.229,0.260,0.331,0.365,0.800); (0.229,0.260,0.331,0.365,1.000)]
(C_2)	[(0.234,0.292,0.414,0.479,0.800); (0.234,0.292,0.414,0.479,1.000)]
(C_3)	[(0.223,0.266,0.364,0.411,0.800); (0.223,0.266,0.364,0.411,1.000)]
(C_4)	[(0.371,0.417,0.530,0.593,0.800); (0.371,0.417,0.530,0.593,1.000)]
(C_5)	[(0.199,0.245,0.364,0.421,0.800); (0.199,0.245,0.364,0.421,1.000)]
(C_6)	[(0.145,0.184,0.295,0.349,0.800); (0.145,0.184,0.295,0.349,1.000)]
(C_7)	[(0.312,0.358,0.458,0.499,0.800); (0.312,0.358,0.458,0.499,1.000)]
(C_8)	[(0.305,0.359,0.484,0.544,0.800); (0.305,0.359,0.484,0.544,1.000)]
(C_9)	[(0.217,0.261,0.375,0.434,0.800); (0.217,0.261,0.375,0.434,1.000)]
(C_{10})	[(0.227,0.280,0.409,0.465,0.800); (0.227,0.280,0.409,0.465,1.000)]

5. Course of Action

A Multi-Criterion Decision Making (MCDM) framework under the arena of Material handling equipments is developed by the authors and a decision support model is presented by the authors to describe the level of the indices pertaining to the selection of MHE. A group of MHEs indices is presented by the authors in this study. It is found that the selection of suitable

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material handling equipment for typical conditions requires the application of an effective and efficient multi-criteria decision making tool. Design and evaluation of a MHE selection model can efficiently yielded results in many multi-criteria decision making arena. In this study; the authors chiefly distributed the methodological way for determining the importance of distinguishes MHEs indices. To identify the weak and strong MHEs performance indices and to furnished the procedural modeling; the fuzzy theory is used in this study. The GIVTFNs as discussed by (Sahu et al., 2016b) is utilized for evaluating and defining the most appropriate MHEs indices and its status.

The subjective information pertaining to MHEs indices is evaluated by $\partial k_{i.....p}$ in this study to furnish an assessment platform for appraising MHE indices. Brainstorming sessions are needed to be conducted in this regard. Priority importance and ratings against each performance indices are assigned by the $\partial k_{i.....p}$. The $\partial k_{i.....p}$ provided the subjective information for signifying the performance extent of MHEs indices. A single level hierarchy platform, which is relating MHEs for representing the methodical apprehension, is presented in the projected work. In this study, the authors responded towards conceptualizing MHEs characteristics and prepared an estimation platform for appraising MHEs indices. The present work can be utilized in defining the status of the MHEs indices. Table 1 and 2 furnished the priority importance and ratings against each performance indices assigned by the $\partial k_{i.....p}$. This study adopts the below mentioned procedural steps for modeling the decision support framework in order to assess the significant performance extent indices of MHEs:

(i) Collection of appropriateness priority importance and ratings against each performance MHEs indices
(ii) Approximation and aggregation of priority importance and ratings.
(iii) Determination of Fuzzy Performance Index (FPI)
(iv) Determination of Fuzzy performance important index (FPII)
(v) Estimation of significant MHEs indices via defining the distance amongst fuzzy performance importance indexes.

Table 3 represents the computed values of $FPII$. The presented modeling utilized the concept of Euclidean distance as defined by Liu and Jin (2012) in this study to identify the strong and weak MHEs indices. The raking order incorporates the distance between fuzzy performance importance index of the indices and the ideal fuzzy performance important index, which is shown by Table 4.

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Table 4. Distance measure amongst aggregated and ideal FPII

Indices	$d\left(\tilde{\tilde{A}}, id\tilde{\tilde{e}}al\right)$	Ranking
(C_1)	0.1637	9
(C_2)	0.1110	4
(C_3)	0.1458	7
(C_4)	0.0000	1
(C_5)	0.1535	8
(C_6)	0.2113	10
(C_7)	0.0642	3
(C_8)	0.0495	2
(C_9)	0.1406	6
(C_{10})	0.1196	5

The managers of the manufacturing firms can supplement their firm MHEs presentation by conceptualizing the offered work in their decision making. The projected fuzzy approach imparts significant decision support framework to be adopted by the firm's top management for administering MHEs assessment and selection. Figure 1 indicates the deviation of distance from ideal FPII. The offered work presented the general and momentous MHEs indices and drafted a way to identify the significant indices.

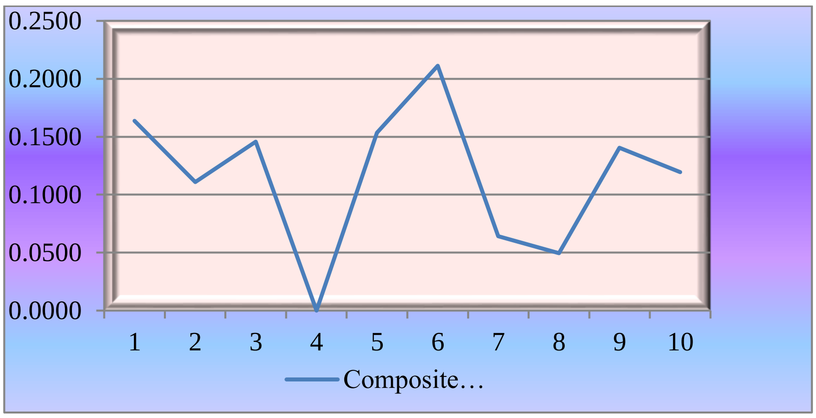

Figure 1. Line chart indicating the deviation of distance from ideal FPII

6. Conclusions

The researchers are attentive in developing the decision support framework accompanying distinguish decision environment. The present work studied the MHEs arena, which highlighted that the significant MHEs indices are accountable for better ecological saving, firm performance and survival. This study presented a fuzzy based mathematical modeling, which is a simple and flexible to be incorporated under MHEs evaluation. The present study offered direction to managers to employ and researchers to relate, expand and devise qualitative and quantitative approaches for implementing significant MHES indices. The preset study can act as a tool and can be use to foster environmentally concerned strategies by an organization. The work can also be functional to any MCDM problems, which engrosses uncertainty and vagueness in the evaluation. The work prepared a performance model, which have amalgamated MHEs indices with Generalized Interval Valued Trapezoidal Fuzzy Numbers (GIVTFNs) theory. The presented work offered a chain of general and momentum MHEs indices, which are responsible to capture the profitability into the firms. The work can assist the managers of the global firm in framing effective decision policies considering MHEs assessment and selection for future sustainability. The exploration of GIVTFNs in combination with the conception of distance measurement is presented in this study to evaluate and assess the weak and strong MHEs indices.

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