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Selection of Automated Guided Vehicle using Single Valued Neutrosophic Entropy Based Novel Multi Attribute Decision Making Technique

Abstract

Selection of material handling equipment for typical conditions and handling environment is one of the multi attribute decision making problem. The objective of the research paper is to implement and validate multi attribute selection of automated guided vehicle for material handling purpose. The present paper proposes a single valued neutrosophic set with entropy weight based multi attribute decision making technique. A proposed technique also works with more uncertainty, imprecise, indeterminate and inconsistent information. The proposed methodology follows with the example for selection and ranking of automated guided vehicle and in validation and sensitivity analysis of the novel multi attribute decision making technique carried out. The result of the study builds assurance in suitability of single valued neutrosophic set entropy based novel multi attribute decision making for selection of automated guided vehicle alternatives.

Keywords

Multi attribute decision making, single valued neutrosophic set, material handling equipment, automated guided vehicle.

1. Introduction

Material Handling Equipment (MHE) is playing a vital role in today's manufacturing system and also improving productivity in the small, medium or large scale manufacturing industries. MHE is a very essential task for the manufacturing sectors because of the considerable capital investment required(Onut, Kara, & Mert, 2009). Saputro et al. (2015)) reviewed 42 papers for MHE selection and established ranking to appropriate MHE for complex selection problems. Right MHE selection and good design of the MHE can increase productivity and reduce investment and operation's costs.

Karande & Chakraborty (2013) investigated the various functions performed by MHE are as follows:

a. Transportation and logistics (for moving material form one point to another, i.e. conveyors, cranes, industrial trucks, etc.)
b. Positioning (for aid machining operation like, robots, index tables, rotary tables, etc.)

c. Unit formation (for holding or carrying purpose pallets, skids, containers, bins, etc.)
d. Storage (For store/ inventory automatic storage and retrieval system (AS/RS), pallets, etc.).

On the real difficulties in developing and using selection methods is due to the natural vagueness associated with the inputs to the model (Deb, Bhattacharyya, & Sorkhel, 2002).

2. Literature Survey

Literature survey is carried out with two elements one for selection methodology for MHE using multi attribute decision making (MADM) and the other for literature on single valued neutrosophic set theory.

1.1 Literature survey of selection methodology used for selection of MHE using MADM techniques

Since last three decades researchers pay more attention in finding and implementing different MADM techniques with different criteria (attributes). Onut et al. (2009) implemented fuzzy Analytic Network Process (ANP) for assigning weights to the attributes for MHE selection and fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is used to ranking solution. Maniya & Bhatt (2011) implemented and validated modified grey relational analysis (M-GRA) method combined with AHP for multi attribute selection of Automated Guided Vehicle (AGV) for the material handling. Sawant et al.(2011) worked on Preference Selection Index (PSI) method for AGV selection in manufacturing environment. Chakraborty & Banik (2006) worked on Analytic Hierarchy Process (AHP) for material handling equipment selection model. Kulak (2005) investigated a fuzzy multi attribute selection of material handling equipment which consist of a database, rule based system and multi attribute fuzzy information axiom approach for selecting MHE. Nguyen et al. (2016) worked for fuzzy AHP and fuzzy additive ratio assessment for conveyor evaluation ranking and selection process. Mirhosseyni & Webb, (2009) presents fuzzy knowledge based expert system and then genetic algorithm (GA) for efficient selection and assignment of MHE. Eko Saputro & Daneshvar Rouyendegh (2016) investigated a hybrid approach for selecting MHE in a ware house by using entropy based hierarchical fuzzy TOPSIS and Multi Objective Mixed Integer Linear Programming (MOMILP) for ranking and selecting best alternatives. Anand et al. (2011) investigated MHE selection with ANP for complex decision making problem. Biswas et al. (2016) proposed TOPSIS approach to SVNS and applied the approach for multi attribute group decision making problem.

1.2 Literature survey of single valued neutrosophic set

In classical MADM approach, input variables are crisp sets but in the real world decision problem input variables are expressed in terms of qualitative information. Qualitative information provided by decision makers (DMs)/experts can be easily expressed by linguistic variables.

Sometimes due to lack of time-pressure, limited knowledge about public domain, decision maker may prefer linguistic variables (Zadeh (1975)) to deal with imprecise data. To cover up the limitation of fuzzy set, Atanassov (1986) proposed the Intuitionistic Fuzzy Set (IFS) by adding truth membership Ta (x) and falsity Membership Fa (x). Further Atanassov (1986) proposed the Interval Valued Intuitionistic Fuzzy Set (IVIFS). However, drawback of IFS and IVIFS is that they cannot handle indeterminate and inconsistent information. In real application, information of input data is often incomplete, indeterminate and inconsistent (Chi & Liu (2013)). The limitation of above sets is covered up with Neutrosophic Set (NS) (Smarandache (2002)) with degree of truth, indeterminacy and falsity, where all membership function is completely independent. Single Valued Neutrosophic Set (SVNS) is an instance of NS, which can handle uncertainty, imprecise, indeterminate and inconsistent information (Wang et al. (2010). Majumdar (2015) established uncertain data processing with NS and further generalized and combined with soft sets in decision making process. Ye (2013) worked on correlation and correlation coefficient of SVNS based on the extension of the correlation of IFS. Ye (2014a) worked on single valued neutrosophic cross-entropy for MADM techniques. Zhang et al. (2014) applied interval neutrosophic set applied to multi criteria decision making for investment problem. Biswas et al. (2014) presented neutrosophic MADM with unknown weight information methodology. Pramanik et al. (2015) presented hybrid vector similarity measures and their applications to multi-attribute decision making under neutrosophic environment. Ye (2014b) worked on vector similarity measures of simplified NS with investigating money case study.

3. SVNS Entropy based MADM Methodology

Steps of SNVS entropy based novel MADM as follows.

Step 1: Define the goal of MADM problem such as ranking/ evaluation/ sorting/ selection of various alternatives involved in decision making procedure.

Step 2: Identify the possible alternative with attributes (criteria's).

Step 3: Prepare the decision matrix.

Let, $A = \{A_i,\ for\ i = 1,2,3,\dots\dots..m\}$ be a set of alternative while, $C = \{C_i,\ for\ j = 1,2,3,\dots\dots..n\}$ be a set of attributes (criteria). The different values of criteria's may be quantitative and/or qualitative in nature.

Step 4: Convert qualitative information into fuzzy numbers. Normalization of matrix is shown in Table 1.

Table 1: *Matrix Normalization Techniques*

Name of Normalization Methods	Normalized Value	
	Benefit Values	Non- Beneficial Values
Linear Scale Transformation, Max Method (LSTMM)	$R_{ij} = \frac{X_{ij}}{X_{iMax}}$	$R_{ij} = \frac{X_{iMin}}{X_{ij}}$
Linear Scale Transformation, Max-Min Method (LSTMMM)	$R_{ij} = \frac{X_{ij} - MinX_{ij}}{MaxX_{ij} - MinX_{ij}}$	$R_{ij} = \frac{MaxX_{ij} - X_{ij}}{MaxX_{ij} - MinX_{ij}}$
Linear Scale Transformation Sum Method (LSTSM)	$R_{ij} = \frac{X_{ij}}{\sum_{i=1}^{m} X_i}$	$R_{ij} = 1 - \frac{X_{ij}}{\sum_{i=1}^{m} X_i}$
Vector Normalization Method (VNM)	$R_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m} X_{ij}^2}}$	$R_{ij} = 1 - \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m} X_{ij}^2}}$

Step 5: Conversion classic set/ fuzzy set to SVNS

To validate proposed MADM method with other MADM techniques, we propose the conversion rule to use the input matrix in classic or fuzzy set to SVNS for beneficial and non-beneficial criteria.

(i) **Beneficial criteria:** (higher value of performance measures of selection criteria is desirable i.e., profit, quality, etc.): Considering positive ideal solution (PIS) as $< T_{\max}{}^{*}(x), I_{\min}{}^{*}(x), F_{\min}{}^{*}(x) >$; normalized input matrix beneficial criteria are considered as degree of truthness $T_{\mathrm{A}}(x)$, while degree of indeterminacy and degree of falsehood as $I_{\mathrm{A}}(x) = F_{\mathrm{A}}(x) = 1 - T_{\mathrm{A}}(x)$ respectively.

(ii) **Non beneficial criteria:** (Lower value of performance measure of selection criteria is desirable i.e. cost): Considering negative ideal solution (NIS) as $< T_{\min}{}^{*}(x), I_{\max}{}^{*}(x), F_{\max}{}^{*}(x) >$; normalized input matrix non beneficial criteria are considered as degree of indeterminacy and falsehood as $I_{\mathrm{A}}(x) = F_{\mathrm{A}}(x)$ while degrees of truthness is considered as $T_{\mathrm{A}}(x) = 1 - I_{\mathrm{A}}(x) = 1 - F_{\mathrm{A}}(x)$.

(iii) Find the entropy value for attribute with equation no (1).

$$E_j = 1 - {}^{1}\!/_{n} \sum_{i=1}^{m} (T_{\mathrm{ij}}(x_i) + F_{\mathrm{ij}}(x_i)) \left|2(I_{\mathrm{ij}}(x_i)) - 1\right| \tag{1}$$

Step 6: We find entropy weight for attribute using the method proposed by Wang and Zhang (2009).

$$W_j = \frac{1-E_j}{\sum_{j=1}^{n}(1-E_j)} \tag{2}$$

We get weight vector $W = (w_1, w_{2,} w_{3,\ldots\ldots\ldots\ldots\ldots} w_n)^T$ of attributes,

$C = \{C_j for j = 1, 2, 3, \ldots\ldots.. n\}$ with $W_j \geq 0$ and $\sum_{j=1}^{n} W_j = 1$.

Step 7: Calculate the alternative value with following equation (3).

$$A_w = \sum_{j=1}^{n} W_{\mathrm{j}} * \left((T_{\mathrm{ij}}(x) * T_{\mathrm{ij}}{}^{*}(x)) + (I_{\mathrm{ij}}(x) * I_{\mathrm{ij}}{}^{*}(x) + (F_{\mathrm{ij}}(x) * F_{\mathrm{ij}}{}^{*}(x)\right) \tag{3}$$

Where, beneficial attribute PIS=$< T_{\max}{}^{*}(x) I_{\min}{}^{*}(x), F_{\min}{}^{*}(x) > = < 1,\ 0,\ 0 >$,

For non-beneficial attribute NIS=$< T_{\min}{}^{*}(x) I_{\max}{}^{*}(x), F_{\max}{}^{*}(x) > = < 0,\ 1,\ 1 >$.

Step 8: Ranking of alternatives after calculation is performed according to ascending order.

4. Case Study

An example is considered to show and validate the SVNS entropy based novel MADM method for selection of an AGV for an industrial application. The detailed rationalization of steps involved in the application of novel MADM for section of AGV is explained below.

Step 1: The objective is to ranking and selection of the best AGV for a given industrial application.

Step 2: In the present work eight alternatives of AGV and six attributes (Criteria) are considered, the same as (K. D. Maniya & Bhatt, 2011). Criteria are: controllability (C1), accuracy (C2), cost (C3), range (C4), reliability (C5) and flexibility (C6). Here cost (C3) from the given attributes is given as non-beneficial attribute indicate with (-) sign in decision matrix; while other attributes are the beneficial attribute indicate with (+) sign in decision matrix.

Step 3: Here, in the AGV alternative and attributes and their values are presented in matrix format. The crisp data for AGV selection adopted from (K. D. Maniya & Bhatt, 2011) is shown in Table 2.

Table 2: *The crisp data for AGV selection attributes (decision matrix)[adopted from (K. D. Maniya & Bhatt, 2011)]*

	C1 (+)	C2 (+)	C3 (-)	C4 (+)	C5 (+)	C6 (+)
A1	0.895	0.495	0.695	0.495	0.895	0.295
A2	0.115	0.895	0.895	0.895	0.495	0.495
A3	0.115	0.115	0.895	0.115	0.695	0.895
A4	0.295	0.895	0.115	0.495	0.495	0.895
A5	0.895	0.495	0.115	0.695	0.295	0.495
A6	0.495	0.495	0.895	0.115	0.695	0.695
A7	0.115	0.295	0.895	0.115	0.895	0.895
A8	0.115	0.495	0.695	0.495	0.495	0.695

Step 4: Normalization of decision matrix

In the proposed case study we use Linear Scale Transformation, Max Method (LSTMM) as shown in Table 3.

Table 3: *Normalized decision matrix with (linear scale transformation, max method)*

	C1 (+)	C2 (+)	C3 (-)	C4 (+)	C5 (+)	C6 (+)
A1	1.0000	0.5531	0.1655	0.5531	1.0000	0.3296
A2	0.1285	1.0000	0.1285	1.0000	0.5531	0.5531
A3	0.1285	0.1285	0.1285	0.1285	0.7765	1.0000
A4	0.3296	1.0000	1.0000	0.5531	0.5531	1.0000
A5	1.0000	0.5531	1.0000	0.7765	0.3296	0.5531
A6	0.5531	0.5531	0.1285	0.1285	0.7765	0.7765
A7	0.1285	0.3296	0.1285	0.1285	1.0000	1.0000
A8	0.1285	0.5531	0.1655	0.5531	0.5531	0.7765

Step 5: Convert crisp normalized matrix into SVNS decision matrix with $< T_{ij}(x), I_{ij}(x), F_{ij}(x) >$ degree of truthness, indeterminate and falsehood. As shown in Table 4.

Step 6: Find the entropy weight using equation (2) with $W_j \geq 0$ and $\sum_{j=1}^{n} W_j = 1$ as shown in Table 4.

Step 7: Calculate the alternative value with following equation (3) as shown in Table 4.

Step 8: Ranking or selections of alternative: The alternatives are ranked according to ascending order as shown in Table 4.

Table 4: *SVNS entropy based decision matrix*

	C1 (+)	C2 (+)	C3 (-)	C4 (+)	C5 (+)	C6 (+)	A_w	Rank
A1	<1.0000, 0.0000, 0.0000>	<0.5531, 0.4469, 0.4469>	<0.8345, 0.1655, 0.1655>	<0.5531, 0.4469, 0.4469>	<1.0000, 0.0000, 0.0000>	<0.3296, 0.6704, 0.6704>	0.6235	3
A2	<0.1285, 0.8715, 0.8715 >	<1.0000, 0.0000, 0.0000>	<0.8715, 0.1285, 0.1285>	<1.0000, 0.0000, 0.0000>	<0.5531, 0.4469, 0.4469>	<0.5531, 0.4469, 0.4469>	0.5354	4
A3	<0.1285, 0.8715, 0.8715>	<0.1285, 0.8715, 0.8715>	<0.8715, 0.1285, 0.1285>	<0.1285, 0.8715, 0.8715>	<0.7765, 0.2235, 0.2235>	<1.0000, 0.0000, 0.0000>	0.3969	8
A4	<0.3296, 0.6704, 0.6704>	<1.0000, 0.0000, 0.0000>	<0.0000, 1.0000, 1.0000>	<0.5531, 0.4469, 0.4469>	<0.5531, 0.4469, 0.4469>	<1.0000, 0.0000, 0.0000>	0.9313	2
A5	<1.0000, 0.0000, 0.0000>	<0.5531, 0.4469, 0.4469>	<0.0000, 1.0000, 1.0000>	<0.7765, 0.2235, 0.2235>	<0.3296, 0.6704, 0.6704>	<0.5531, 0.4469, 0.4469>	0.9335	1
A6	<0.5531, 0.4469,0.4469 >	<0.5531, 0.4469, 0.4469>	<0.8715, 0.1285, 0.1285>	<0.1285, 0.8715, 0.8715>	<0.7765, 0.2235, 0.2235>	<0.7765, 0.2235, 0.2235>	0.4996	5
A7	<0.1285, 0.8715, 0.8715>	<0.3296, 0.6704, 0.6704>	<0.8715, 0.1285, 0.1285>	<0.1285, 0.8715, 0.8715>	<1.0000, 0.0000, 0.0000>	<1.0000, 0.0000, 0.0000>	0.4547	7

A8	<0.1285, 0.8715, 0.8715 >	<0.5531, 0.4469, 0.4469>	<0.8345, 0.1655, 0.1655>	<0.5531, 0.4469, 0.4469>	<0.5531, 0.4469, 0.4469>	<0.7765, 0.2235, 0.2235>	0.4619	6
A^*	<1,0, 0>	<1,0,0 >	<0,1,1 >	<1,0,0 >	<1,0,0 >	<1,0, 0>		
E_j	0.3226	0.5615	0.3362	0.4874	0.5293	0.4176		
W_j	0.2025	0.1311	0.1984	0.1532	0.1407	0.1741	$\sum_{j=1}^{n} W_j=1$	

5. Validation with Sensitivity Analysis

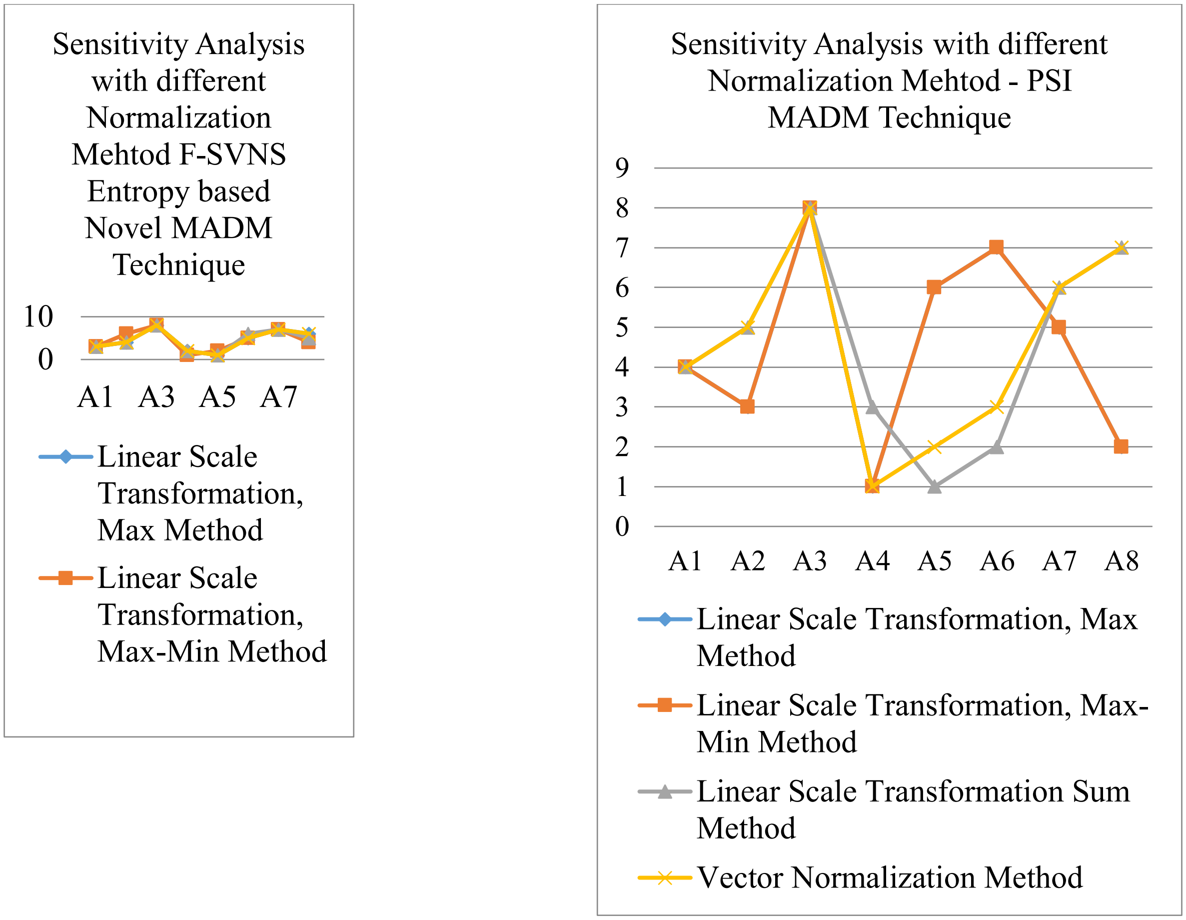
Sensitivity analysis of proposed methodology regarding ranking of alternatives with various normalization methods for same input data is shown in Table 5.

The graphical representation of sensitivity analysis for mentioned MADM techniques has been shown in the figure 1. It proves that SVNS entropy based novel MADM technique with different normalizing techniques shows negligible effect on final ranking order of AGV as compared to with PSI technique.

Table: 5 *Ranking comparison with different normalization methods for F-SVNS Novel MADM and PSI MADM Technique.*

	F-SVNS Entropy based Novel MADM Technique				PSI (K. D. Maniya & Bhatt, 2011)			
	LST MM	**LST MMM**	**LST SM**	**VNM**	**LST MM**	**LST MMM**	**LST SM**	**VNM**
A1	3	3	3	3	4	4	4	4
A2	4	6	4	4	3	3	5	5
A3	8	8	8	8	8	8	8	8
A4	2	1	2	2	1	1	3	1
A5	1	2	1	1	6	6	1	2
A6	5	5	6	5	7	7	2	3
A7	7	7	7	7	5	5	6	6
A8	6	4	5	6	2	2	7	7

Figure 1: *Graphic representation of Sensitivity Analysis with different Normalization Method F-SVNS Entropy based Novel MADM and PSI Method*



6. Result and Discussions

In this paper, SVNS entropy weight MADM technique is developed and implemented to examine its feasibility for selecting and ranking of AGV for material handling system for a given industrial application. The main concluding remarks of proposed technique are listed below:

- The proposed methodology of ranking or selection of alternatives is suitable to decision making under incomplete information, indeterminate and inconsistent information.
- The proposed SVNS entropy weight MADM technique gives more efficient and compromise selection of best alternative.
- During calculation and normalization there is no loss of information; no single attribute has become zero.
- A sensitivity analysis also shows negligible effect on final ranking order and selection of AGV.
- Proposed methodology is capable to converting decision maker’s crisp information or fuzzy information into SVNS form, which makes more efficient ranking solution.

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