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SELECTION OF MATERIAL HANDLING EQUIPMENT USING HYBRID ENTROPY-VIKOR AND ENTROPY-TOPSIS TECHNIQUES

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ABSTRACT

In 21st century, manufacturing industries has served a lot to humanity and still continuing their goals. Today, a lot of materials can be prepared within a day. In this context, importance of material handling equipments cannot be overlooked. Considering these facts, present research work is devoted to investigations in the field of material handling equipment selection. In present research work, use of multi criteria decision making techniques (MCDM) is being made for selecting appropriate material handling equipment strategy for a firm. The techniques used are entropy, VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR), and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). For this purpose the selected criteria with the help of experts' opinion were capital cost, operation cost, distance moved, risk, availability, and safety, and alternatives were Conveyor, jib crane, fork lift, and manual delivery. Applications of different approaches yielded different rankings of the alternatives, which were made set to common ranking with the help of a statistical technique, coefficient of variance. In the last phase of research economic analysis of the research problem also validated the results.

KEYWORDS: *Material handling equipment, Entropy, VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR), and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), coefficient of variance.*

1. INTRODUCTION

Selecting appropriate material handling equipment plays an important part in the design of material handling system. This is because the selection process requires careful and thorough analysis of various issues (e.g. flexibility, equipment features and characteristics, facility constraints) or else the handling equipment will impose a limit on the system's performance. References [1] and [2] comment that in the future, manufacturing companies will have to achieve both objectives, that is compressed lead times and handle a wide variety of product without undue cost. So, the task of selecting appropriate material handling equipment in increasingly dynamic environments must be clearly focused on the objectives behind the shifting of manufacturing toward the agility concept. Considering these facts, present research work is dedicated to investigating research contributions in the field of material handling equipment selection for manufacturing firms. For this purpose, use of multi criteria decision making techniques (MCDM) is being made, as this approach is being accepted universally for solving problems of decision sciences. The techniques used are entropy, VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR), and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). Following are the objectives of the present research work:

a) Multi criteria decision making (MCDM) model development for material handling equipment selection for the targeted; and

b) Ranking of alternatives by using hybrid Entropy-TOPSIS and Entropy-VIKOR method.

2. LITERATURE REVIEW

Present section tells about details of research findings of different researchers in the field of material handling equipment selection, and concludes with gaps in the literature.

2.1 Research Contributions in the field of Material Handling Equipment Selection

Table 2.1 given below shows the research contributions of different researchers in the field of material handling equipment selection.

Table 2.1. Research Contribution of Different Researchers in the field of Material Handling Equipment Selection

S. No	Researcher(s) (Year)	Contribution
1.	Rajesh (2016) [3]	In present research work, ergonomic analysis of manual material hand ling (MMH) has largely been based on task analysis approach where the task are attenuated into easier tasks and studied.
2.	Ikemoto *et al.* (2015) [4]	The goal of this research is the development of a learning system for the coating and painting assignment carried out in an automobile industry.

3.	Said and Horbaty (2015) [5]	In the research work, the technique was applied on real case study of container terminal at Port -said Port in Egypt. During the research work, researchers have recommended an optimisation technique for solving container handling issues with the help of genetic algorithmic rule. The computational results show the effectiveness of the proposed methodology for container terminal wherever fifty six reductions in ship service time (loading/unloading) in port is achieved.
4.	Ray *etal.* (2015) [6]	The research work discusses the details of a survey undertaken at a construction site in India on the occupational risk factors of a number of manual material handling (MMH) tasks.
5.	Deros *et al.* (2015)[7]	According to the researchers, manual material handling is that the commonest cause of musculoskeletal disorders and low back pain. It involves manual lifting, lowering, carrying, pushing and pulling loads. This study has three main objectives, first: to identify ergonomics awareness towards MMH activities amongst the workers; second, to identify the body discomfort or body pain of the workers using Body parts Symptom Survey; and to study the risk exposure in reference to MMH practiced by the employees using rapid upper Limb Assessment.
6.	Wadhwa (2014) [8]	The research presents an extensive literature review for handling such cast components and sand cores and their respective shortcomings dependent on the delivery methods.
7.	Tsarouchi *et al.* (2013) [9]	This research presents the development of a technique for the calculation of coordinates of a part's features in a world reference frame (WRF), using pictures acquired from a camera. The method is employed to identify multiple, randomly placed, similar ob jects from the consumer goods industry.
8.	Halim *et al.*(2012) [10]	This research work presents a review on the actual implementation of a gravity flow rack system at an automotive component's assembly line in an accord to improve its existing MH system. The outcomes of the research work show significance improvement on the productivity and not to mention the material handling's time.
9.	Mansouri and Calay (2012) [11]	Present research work portrays the policy mechanisms and their impacts in the context of demonstration projects, deploying material handling equipment, involving public -private initiatives.

2.2 Gaps in the Literature

During the survey of available literature, following gaps in the research are being identified.

a) There is very limited research available in the field of material handling equipment selection for Indian manufacturing industries; and

b) There is very limited research available which uses multi criteria decision making techniques.

3. SOLUTION METHODOLOGY

Present section tells about the details of details of multi criteria decision making techniques applied to the research problem. The applied research techniques are Entropy, VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR), and Technique of Oder Preferences Similar to the Ideal Solution (TOPSIS), the details of which are presented in upcoming sub-sections.

3.1 Entropy

According to Dashore *et al.* (2013), the degree of index dispersion, the weight of all indicators is calculated by information entropy. Suppose there is a matrix B, with m alternatives and n indicators [12]:

Step 1: In matrix B, feature weight P_{ij} is the j[th] alternatives to the j[th] factor:

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}, \quad (1 \le i \le m,\ 1 \le j \le n) \tag{3.1}$$

Step 2: The output entropy e_j of the j[th] factor becomes

$$e_j = -k \sum P_{Ij} \ln P_{ij} \quad, (k = 1/\ln m,\ 1 \le j \le n) \tag{3.2}$$

Step 3: Variation coefficient fo the j[th] factor d_j can be defined bh the following equation:

$$d_j = 1 - e_j \quad, (1 \le j \le n) \tag{3.3}$$

Step 4: Calculate the weight of entropy w_j:

$$w_j = \frac{d_j}{\sum_{i=1}^{m} d_j} \quad, (1 \le j \le n) \tag{3.4}$$

3.1 VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR)

Accroding to Opricovic & Tzeng (2004), VIKOR is a MCDM based on outranking principle. It is used to find the compromise ranking list, the compromise solution and the weight stability intervals. The method was developed from the *Lp* – metric which is used in compromise programming as an aggregation function. The method uses *Lp* – metric concepts to find the compromise solution that is the closest to the ideal solution. The *Lp* – metric has the following form [13].

$$L_{p,j} = \left\{ \sum_{i=1}^{n} \left[w_i \left(f_i^* - f_{ij}\right) / \left(f_i^* - f_i^-\right) \right]^p \right\}^{1/p} \tag{3.5}$$

$$1 \le p \le \infty, \qquad j = 1,2,3,..............J \tag{3.6}$$

3.2.1 General Procedure of VIKOR

The following steps are involved in VIKOR method [13]:

Step 1: Representation of normalized decision matrix

The normalized decision matrix can be expressed as

$$F = [f_{ij}]_{m \times n} \tag{3.7}$$

Here,

$$f_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, i = 1,2,........m; \tag{3.8}$$

and, X_{ij} is the performance of alternative A_i with respect to the j[th] criterion.

Step 2: Obtain the maximum criterion function f_j^* and the minimum criterion function f_j^-, where j = 1...... m.

Maximum Criterion Functions

$$f_j^* = \max_i f_{ij} = \max\left[\left(f_{ij}\right) \backslash i = 1,2,3,......n\right] \tag{3.9}$$

Minimum Criteria Functions

$$f_j^- = \min_i f_{ij} = \min\left[\left(f_{ij}\right) \backslash i = 1,2,3,......n\right] \tag{3.10}$$

Step 3: Calculation of utility measure and regret measure

The utility measure and the regret measure for each alternative are given as

Utility Measure

$$S_i = \sum_{j=1}^{n} w_j \frac{\left(f_j^* - f_{ij}\right)}{\left(f_j^* - f_j^-\right)} \tag{3.11}$$

Regret Measure

$$R_i = \max_j \left[w_j \right] \frac{\left(f_j^* - f_{ij}\right)}{\left(f_j^* - f_j^-\right)} \tag{3.12}$$

Step 4: Computation of VIKOR Index

The VIKOR index can be expressed as follows:

The VIKOR index can be expressed as follows:

$$Q_i = v\left[\frac{S_i - S^*}{S^- - S^*}\right] + (1 - v)\left[\frac{R_i - R^*}{R^- - R^*}\right] \tag{3.13}$$

Q_i represents the VIKOR index value of i [th] alternative .i=1,2,………n.

$$S^* = \min_i S_i = \min\left[(S_i)/i = 1,2,3,.......n\right] \tag{3.14}$$

$$S^- = \max_i S_i = \max\left[S_i/i = 1,2,3,.......n\right] \tag{3.15}$$

$$R^* = \min_i R_i = \min\left[R_i/i = 1,2,3,.......n\right] \tag{3.16}$$

$$R^- = \max_i R_i = \max\left[R_i/i = 1,2,3,.......n\right] \tag{3.17}$$

..........where *v* is the weight for the maximum value of group utility and 1-v is the weight of the individual regret. *v* is generally set to 0.5.

3.1 Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

Among numerous MCDM methods developed to solve real-world decision problems, Technique for Order Preferences by Similarity to Ideal Solution (TOPSIS) continues to work satisfactorily in diverse application areas. Yoon & Hwang (1995) [14] originally proposed TOPSIS to help in selecting the best alternative with a finite number of criteria. As a well-known classical MCDM method, TOPSIS has received much interest from researchers and practitioners. TOPSIS is a widely accepted multi criteria decision making technique due to its sound logic, simultaneously consideration of the ideal and the anti-ideal solutions, and easily programmable computation procedure. This technique is based on the concept that the ideal alternative has the best level for all attributes, whereas the negative ideal alternative is the one with all of the worst attribute values. The basic principle of TOPSIS lies within the fact that chosen alternative should have the shortest distance from the ideal solution and the longest distance from the negative ideal solution. This method considers three types of attributes or criteria:

a) Benefit attributes/criteria (qualitative in nature);
b) Benefit attributes (quantitative in nature); and
c) Cost attributes or criteria.

In TOPSIS, two artificial alternatives are hypothesized:

a) Ideal alternative: the one which has the best level for all attributes considered; and
b) Negative ideal alternative: the one which has the worst attribute values.

3.2.1 General procedure of TOPSIS

Following is the stepwise procedure for implementing TOPSIS (Yoon & Hwang, 1995):

Step 1: Construct Normalized Decision Matrix.

This step transforms various attribute dimensions into non-dimensional attributes, which allows comparisons across criteria. Normalize scores or data as follows:

$$r_{ij} = \frac{f_{ij}}{\sum_{j=1}^{J} f_{ij}^2} \qquad (3.18)$$

where j = 1,2,3,………… J, i = 1, 2, 3 …n

Step 2: Construct the weighted normalized decision matrix.

Assume we have a set of weights for each criteria w_j for j = 1…n, multiply each element (column-wise) of the normalized decision matrix by its weight.

The weighted normalized value can be calculated as:

$$V_{ij} = \left(w_{ij} \times r_{ij} \right)$$

Where w_i is the weight of the i_{th} attribute or criterion, and it is calculated by AHP method.

$$w_i = 1 \qquad (3.20)$$

Step 3: Determination of ideal as well as negative- ideal solutions

Ideal solution:

Ideal solution:

$$A^* = \left(v_1^*, v_2^*, \ldots\ldots\ldots\ldots v_i^*\right) = \left(\left(\max v_{ij} \ / i \in I'\right) \times \left(\min v_{ij} / j \in I''\right)_j\right) \qquad (3.21)$$

Negative- Ideal Solution:

$$A^- = \left(v_1^-, v_2^-, \ldots\ldots\ldots\ldots v_i^-\right) = \left(\left(\min v_{ij} \ / i \in I'\right) . \left(\max v_{ij} / j \in I''\right)_j\right) \qquad (3.22)$$

Step 4: Investigate the separation measures, with the help of n dimensional Distance.

The separation of each option from the ideal solution is given as:

$$D_j^* = \sqrt{\sum_{i=1}^{n} (\mathrm{vij} - \mathrm{vi}*)^2}$$

where j = 1, 2, 3……….j

Similarly, the separation of each alternative from negative ideal solution is given as:

$$D_j^- = \sqrt{\sum_{i=1}^{n} (\mathrm{vij} - \mathrm{vi}-)^2}; \qquad (3.24)$$

where j = 1, 2, 3..j

Step 5: Find the relative closeness to the ideal solution

The relative closeness of the alternative a_j can be investigated as follows:

$$CC_j^* = \frac{Dj-}{Dj* + Dj-} \qquad (3.25)$$

Step 6: Preference order ranking [14].

4. CASE STUDY

The research was undertaken in a manufacturing firm located in Ujjain (M.P), which makes a small machine parts and some customized machines. As the firm was newly established, it seeked for proper material handling equipment, for which candidate assisted. Present section is devoted the model formulation, and implementation of research tools to the case problem, the details of which are presented in upcoming sub-sections.

4.1 Model Formulation

The first step in the implementation of research tools to solve the research problem was the model formulation. For this purpose multi criteria decision making approach was used, and the problem was converted into a hierarchical form. For this purpose, a list of criteria (parameters needed to evaluate a material) was adopted from the consultations with the experts. List of alternatives was also suggested by the industry personnel based on their experience. As a result, a set of criteria supporting material handling equipment selection were obtained. The criteria were capital cost, operation cost, distance, risk, availability and safety. In next step, a MCDM model was formulated, the details of which are presented in Fig. 4.1.

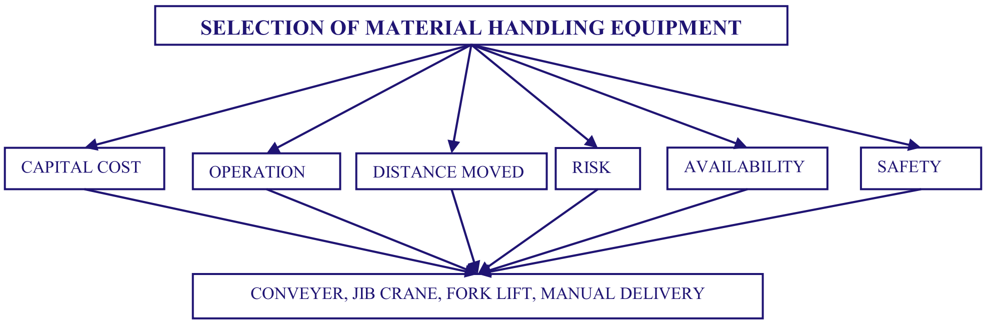

Fig. 4.1. MCDM Model Formulation for the Research Problem

4.1 Solution of Model

In next step, the model developed above was solved with the help of *two* multi criteria analysis techniques, entropy, VIKOR and TOPSIS. Weights of criteria were investigated using entropy method whereas scores of alternatives were calculated with the help of TOPSIS and VIKOR. Details of calculations are presented as follows.

1. In order to get weights of criteria first of all a systematically designed questionnaire was circulated to the industrial personnel, and their responses were collected. Details of received responses are as follows.

Table 4.2. Scores obtained from questionnaire for different alternatives on different criteria

Alternative	Capital Cost	Operation Cost	Distance Moved	Risk	Availability	Safety
Conveyor	45000	8000	20	1	1	1
Jib Crane	85000	8000	20	2	4	1
Fork Lift	165000	10000	40	2	4	2
Manual Delivery	3000	15000	60	5	3	5

2.In next step, entropy method was applied to get weights of criteria, which yielded following results.

Table 4.3. Weights of Criteria

S.No	Criteria	Weight
1.	Capital Cost	0.362
2.	Operation Cost	0.0364
3.	Distance Moved	0.107
4.	Risk	0.16
5.	Availability	0.098
6.	Safety	0.2327

Graphical representation of above results is presented as follows**.**

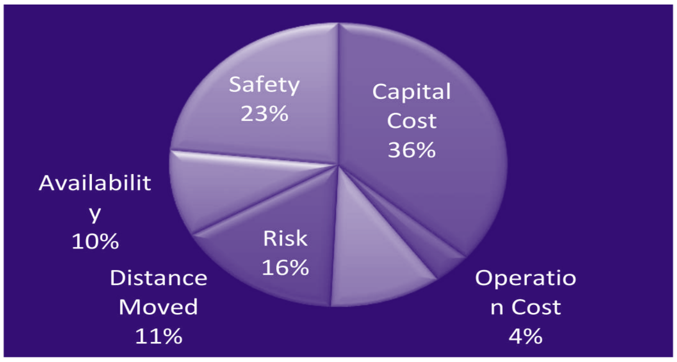

Fig. 4.2. Contributions of Criteria to the Goal

4. In next step, VIKOR technique was applied to the case problem.

Table 4.4. VIKOR Score and Ranking of Alternatives using VIKOR

S.No	Alternative	VIKOR Score	Ranking
1.	Conveyor	0.193	3
2.	Jib Crane	0.176	2
3.	Fork Lift	1.00081	4
4.	Manual Delivery	0.00569	1

5.Rankings of alternatives were also investigated using TOPSIS method, the details of which are presented as follows.

Table 4.5. Ranking of Alternatives using **TOPSIS**

S.No	Alternative	TOPSIS Score	Rank
1.	Conveyor	0.575	2
2.	Jib Crane	0.529	3
3.	Fork Lift	0.619	1
4.	Manual Delivery	0.381	4

5. RESULTS AND DISCUSSION

Present section tells about the results, and discussion made about the results, the details of which are presented in upcoming sub-sections.

5.1 Results

From section 4, the rankings from both the techniques were varying. In order to remove this problem, coefficient of variance, which is the ratio of standard deviation and average for the rankings, was calculated. While dealing with this parameter, the lower values of coefficient of variance govern the results. On using this technique, following results were obtained.

Table 5.1. Overall Ranking of Alternatives

S.No	Alternative	Entropy- VIKOR Score	Rank	Entropy-TOPSIS Score	Rank
1.	Conveyor	0.193	3	0.575	**2**
2.	Jib Crane	0.176	2	0.529	**3**
3.	Fork Lift	1.00081	4	0.619	**1**
4.	Manual Delivery	0.00569	1	0.381	**4**
	Std. Dev.	0.458183341		0.103300291	
	Av.	0.321609073		0.526638636	
	Coff. of Variance	**1.424**		**0.196**	
	%	**142.465**		**19.615**	
				Preferred Ranking	

5.2 Discussion

Results show the rankings of different material handling equipment. On investigating the merits and demerits of material equipment following points came into picture.

Fork lift has scored rank 1. On investing the reasons behind this selection it was found that yet fork lift is having maximum capital cost out of the available options, it shows comparatively low operating cost, due to intermittent delivery of goods, offers low risk factor, highly available as well as quite a safer option for workers as well as goods. Other factors in support of forklift are ease in driving, greater mobility, fuel consumption on demand, and less maintenance.

Conveyor has scored rank 2 out of the available options. According to industry personnel, supporting factors in the favour of conveyor are less capital cost, operating cost, limited risk, and easy availability as well as safety. But some factors limit its adoption by the firm. These are mobility constraints, permanent and installation constraints. Due to these constraints conveyor has scored rank 2 out of the available options.

Jib crane has scored rank 3 in the list of available alternatives. The reasons behind ranking are high capital cost, and moderate operating cost, distance moved, risk level, greater availability, greater safety factor. But the main problem with this option is the type of products firm dealing with. Firm makes low to medium sized customized machines due to which it do not needs jib crane. Other problem with the option is that its limited mobility due to which it cannot be sent outside the firm.

Manual delivery scores rank 4 in the list of alternatives. The reasons behind such a rank are salary of workers, greater moving distance and high level of risks, timely availability and greater safety factor involved. Other than these factors some of the factors which are also responsible for last ranking of manual delivery are –

- Turnover of workers;
- Workers' expectations for salary increment;
- Influence of workers unions on workers;
- Greater loss to firm as well as worker if an accident happens;
- More legal formalities for a firm if a worker is hired;
- Boredom of workers for repetitive jobs; and
- Regular salaries to the workers even if they have not worked properly.

But from VIKOR point of view, option manual delivery was chosen as best option, due to following reasons.

- Capability to do multiple jobs;
- Better understanding of work;
- Skill enhancement is possible;
- Sense of belongingness; and

Considerable IQ level of skilled workers.

- Considering above mentioned two cases, a different analysis, called economic analysis of rank 1 holder was accomplished as follows.

Actual Cost of Equipment, C_i = **165000/ - Only**

Cost of Equipment after paying all EMIs (@ 3,671 Rs. per month for interest rate of 12% per annum for 5 years), C_{final} = 2, 20,221/ - Only

Cost of forklift in 5 years = $C_p/5$ = 44044.2 /- Rs.

Operation Cost per year, C_o = 1, 20,000 /- Rs.

Total Cost for Fork Lift, $C_{total} = C_p + C_o$

= 44044.2 + 1, 20,000 = 1, 64,044 /- Rs.

Hence Total Cost of Equipment for first Five Years, $C_{totalV} = C_{total} \times 5$

= 1, 64,044 × 5

C_{totalV} = 8, 20,220 /- Rs.(5.1) ***Cost of Equipment from 6 th Year = 1, 20,000/- Rs.***(5.2)

Salary of employee per month = 15000 /- Rs. per month

Salary of employees per year, C_{Salary} = 15000×12 = 180000/- Rs.

Accidental expenses per year, $C_{Accident}$ = 9,000/- Rs.

Bonus per year, C_{Bonus} = 500/- Rs.

Training Charges, $C_{Training}$ = 3,000/- Rs.

Hence Total Cost of Employee for first Year, $C_{Employeel} = C_{Salary} + C_{Accident} + C_{Bonus} + C_{Training}$

$= 180000 + 9000 + 500 + 3000$

$C_{EmployeeI} = 1, 92, 500$/- **Rs.**

Total Cost of Employee for II, III, IV and V Year, $C_{EmployeeII,III,IV,V} = C_{Salary} + C_{Accident} + C_{Bonus}$

$= 180000 + 9000 + 500$

$C_{EmployeeII,III,IV,V} = 189500$/- **Rs.**

Hence Total Cost of Employee for first Five Years, $C_{Manual} = C_{EmployeeI} + C_{EmployeeII,III,IV,V}$

$= 1, 92, 500 + 189500 \times 4C_{Manual}$ **= 9, 50,500/- Rs.**(5.3)***Cost of Manual Delivery from 6 th Year = 1, 89,500/- Rs.***(5.4)

From above equations, one can find that cost of manual delivery are greater than cost of equipment for first five years, and also for sixth year, it can be concluded that selection of equipment (fork lift) is more economic than manual delivery.

Table 5.2. Costs of Manual Delivery

S.No	Entity	Amount	1 Year	2 Year
1.	Salary of Employees	15000*12	180000	360000
2.	Accidental expenses	20000	20000	40000
3.	Bonus	500	500	1000
4.	Training Charges	3000	3000	0
			203500	**401000**

Table 5.2. Costs associated with Fork Lift

S.No	Entity	Amount	1 Year	2 Year
1.	Cost of Equipment	165000	165000	0
2.	Operational Cost	10000*12	120000	240000
	Total		**285000**	240000

Table 5.3. Total Expenditure Considering Rank 1 Holders

S.No	Entity	I Year	II Year	Rank
1.	Manual Delivery	203500	**401000**	**2**
2.	Fork Lift	285000	**240000**	**1**

Considering above results also, alternative fork lift is being considered for rank 1.

6. CONCLUSION, LIMITATIONS AND FUTURE SCOPE OF THE RESEARCH

Present section tells about the conclusion of the research, and limitations and future scope of the research, the details of which are presented in upcoming sub-sections.

6.1 Conclusion

In the present research work, ranking of material handling equipment is carried out with the help of different multi criteria decision making techniques, entropy, VIKOR and TOPSIS. For this purpose, first of all a systematically designed questionnaire was circulated to the targeted firm and responses were collected. From the responses obtained MCDM model for the research problem was made and solved. For getting values of weights of criteria entropy technique was used, while in order to get scores of alternatives, techniques VIKOR and TOPSIS were used. Due to application of different algorithm, unity of results couldn't obtain which was made possible by using the principle of coefficient of variance, and then economic analysis was also carried out to investigate the stability of results. Following are the conclusion drawn out of the research work.

a) The best alternative for the targeted firm is fork lift;

b) The second best alternative for the firm is conveyor; and

c) The worst option for the firm is manual delivery.

6.2 Limitations and Future Scope of the Research

Following are the limitations of the present research work.

a) The research work is limited to a particular firm;

b) The research is made limited by number of criteria responsible for material handling equipment selection;

c) The research is also made limited by number of alternatives; and

d) The research is also limited to the use of limited number of multi criteria decision making techniques.

Based on above mentioned limitations, following points indicate the future scope of the research work.

a) A vast research considering broader sets of industries may be initiated;

b) A detailed research considering a vast set of criteria may be initiated;

c) A vast research considering a bigger set of alternatives may be undertaken; and

d) A research with a broader set of multi criteria decision making techniques may be initiated.

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