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MCDM Techniques for the Selection of Material Handling Equipment in the Automobile Industry

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Abstract: *Material Handling Equipments are utilized in different shops of an automobile industry. For culling congruous Material Handling Equipment, it is felt that some Multi Criteria Decision Making Methods must be used due to their ability of converting an intricate quandary to a paired comparison. These methods are predicated on some relative Criteria and Sub-criteria. Certain methods such as; Analytic Hierarchy Process (AHP), Fuzzy Analytic Hierarchy Process (FAHP), and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) Method have to be utilized for solving the quandary of Material Handling Equipment cull in different shops of automobile industry. For solving these quandaries, some criteria (Material, Move, and Method) are culled.*

The main conclusions drawn from this study are that, Method criteria is more consequential for culling Material Handling Equipment, and Conveyor System is more efficient and precise Equipment for Handling the Material in shop floor of any automobile industry. The focus of this research is in the area of Cull of Material Handling Equipment in automobile industry. Cull of congruous Material Handling Equipment is very paramount for reducing manufacturing cycle time, and cost of manufacturing.

Key Words: *Material Handling, Analytic Hierarchy Process , Fuzzy Analytic Hierarchy Process and Technique for Order Preference by Similarity to Ideal Solution.*

I. Introduction

Material Handling is the field concerned with solving the pragmatic problems involving the movement, storage in a manufacturing plant or warehouse, control and protection of materials, goods and products throughout the processes of cleaning, preparation, manufacturing, distribution, consumption and disposal of all related materials, goods and their packaging. The focus of studies of Material Handling course work is on the methods, mechanical equipment, systems and related controls used to achieve these functions. The material handling industry manufactures and distributes the equipment and services required to implement material handling systems, from obtaining, locally processing and shipping raw materials to utilization of industrial feed stocks in industrial manufacturing processes. Material handling systems range from simple pallet rack and shelving projects, to complex conveyor belt and Automated Storage and Retrieval Systems (AS/RS); from mining and drilling equipment to custom built barley malt drying rooms in breweries. Material handling can also consist of sorting and picking, as well as automatic guided vehicles.

The automotive industry is involved in the design, development, manufacturing, marketing and sale of motor vehicles. The automobile industry plays an important role in overall business cycle developments. The automobile industry is having a strong multiplier effect on the growth of a country. It plays a major role in developing transport sector in one hand and help industrial sector on the other to grow faster and thereby generate a significant employment opportunities.

II. Literature Review

There are some Criteria and Sub-criteria that can be used for solving the problem of Material Handling Equipment Selection in Automobile Industry.:-

1. Material: **-** This is most important criteria for material handling equipment selection. One should know about what type of material is required for handling.
2. Move: **-** It is necessary to know about when and where the material is to be moved.
3. Method: **-** it is also important to select the most appropriate and efficient method for handling the material. Selection of effective method minimizes the cost of production and consume less time.

The material handling principles provide fundamentals of material handling practices.
Planning principle
Standardization principle
Work principle
Ergonomic principle
Unit load principle:-
Space utilization principle
System principle
Automation principle
Environment principle
Life cycle cost principle

III. The Analytic Hierarchy Process

The AHP was developed in the 1980s by Saaty. It is a systematic decision making method which includes both qualitative and quantitative techniques.
The application of the AHP to the complex problem usually involves four major steps :-

1. Break down the complex problem into a number of small constituent elements and then structure the elements in a hierarchical form.
2. Make a series of pair wise comparisons among the elements according to a ratio scale.
3. Use the eigenvalue method to estimate the relative weights of the elements.
4. Aggregate these relative weights and synthesize them for the final measurement of given decision alternatives.

Various steps of Analytic Hierarchy Process are as follows:-
Assessment of a_{ij} values

Value of a_{ij}	Interpretation
1	Equal importance of i and j
2	Between equal and weak importance of i over j
3	Weak importance of i over j
4	Between weak and strong importance of i over j
5	Strong importance of i over j
6	Between strong and demonstrated importance of i over j
7	Demonstrated importance of i over j
8	Between demonstrated and absolute importance of i over j
9	Absolute importance of i over j

1. State the problem and define the objective.
2. Develop the hierarchy from the top through the intermediate levels to the lowest level of the hierarchy.
3. Construct a pair-wise comparison matrix using a scale of relative importance. Determine the maximum Eigen value λ_{max} that is the average of matrix.
4. Calculate the consistency index CI = $(\lambda_{max} - n) / (n - 1)$. The smaller the value of CI, the smaller is the deviation from the consistency.
5. Calculate the consistency ratio CR = CI/RI. Usually, a CR of 0.1 or less is considered as acceptable.
6. Compare the pair-wise alternatives with respect to how much better they are in satisfying each of the attributes.
7.

IV. The Fuzzy AHP Method

The fuzzy AHP technique can be viewed as an advanced analytical method developed from the traditional AHP. Despite the convenience of AHP in handling both quantitative and qualitative criteria of multi-criteria decision making problems based on decision maker's judgments, fuzziness and vagueness existing in many decision-making problems may contribute to the imprecise judgments of decision makers in conventional AHP approaches. So, many researchers who have studied the fuzzy AHP which is the extension of Saaty's theory, have provided evidence that fuzzy AHP shows relatively more sufficient description of these kind of decision making processes compared to the traditional AHP methods.

In complex systems, the experiences and judgments of humans are represented by linguistic and vague patterns. Therefore, a much better representation of this linguistics can be developed as quantitative data; this type of data set is then refined by the evaluation methods of fuzzy set theory. On the other hand, the AHP method is mainly used in nearly crisp (non-fuzzy) decision applications and creates and deals with a very unbalanced scale of judgment. Therefore, the AHP method does not take into account the uncertainty associated with the mapping. The AHP's subjective judgment, selection and preference of decision-makers have great influence on the success of the method. The conventional AHP still cannot reflect the human thinking style. Avoiding these risks on performance, the fuzzy AHP, a fuzzy extension of AHP, was developed to solve the hierarchical fuzzy problems.

Various steps used in fuzzy AHP are as follows:-

1. Determine objective and choosing alternatives.
2. Determines criteria to be used in the ranking process.
3. Structuring decision hierarchy.
4. Approved decision hierarchy.
5. Assigning weights to criteria and alternatives via FAHP.
6. Approving weights used.
7. Ranking the alternatives.
8. Choosing the highest ranking from the set of alternatives.

Table 1 Proposed TFN and linguistic variables (Supiah et al., 2005)

Saaty's scale of relative importance	Definition	Triangular Fuzzy Number (TFN)	Linguistic variables
1	Equal importance	(1,1,1)	Least importance
3	Moderate importance of one over another	(2,3,4)	Moderate importance
5	Essential or strong importance	(4,5,6)	Essential importance
7	Demonstrated importance	(6,7,8)	Demonstrated importance
9	Extreme importance	(9,9,9)	Extreme importance
2,4,6,8	Intermediate values between two adjacent judgements	(1,2,3), (3,4,5), (5,6,7) and (7,8,9)	Intermediate values between two adjacent judgements

V. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) Method

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) was developed by Hwang and Yoon.

This method considers three types of attributes or criteria:-

- Qualitative benefit attributes/criteria.
- Quantitative benefit attributes.
- Cost attributes or criteria.

TOPSIS assumes that we have m alternatives (options) and n attributes/criteria and we have the score of each option with respect to each criterion.

The basic concept of this method is that the selected best alternative should have the shortest distance from the ideal solution and the farthest distance from the negative-ideal solution in a geometrical sense. TOPSlS assumes that each attribute has a tendency toward monotonically increasing or decreasing utility. Therefore, it is easy to locate the ideal and negative-ideal solutions.

Various steps used in TOPSIS method are as follows:

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:

$r_{ij} = x_{ij} / (\Sigma x^2_{ij})^{1/2}$ for i = 1, …, m; j = 1, …, n.

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 column of the normalized decision matrix by its associated weight. An element of the new matrix is:

$v_{ij} = w_j \times r_{ij.}$

3. Determine the ideal and negative ideal solutions.

Ideal solution-

$A^* = \{ v_1^*, \ldots, v_n^*\}$, where

$v_j^* = \{ \max (v_{ij}) \text{ if } j \in J ;\ \min (v_{ij}) \text{ if } j \in J' \}$

Negative ideal solution-

A' = { v_1', …, v_n' }, where
v' = { min (v_{ij}) if j ∈ J ; max (v_{ij}) if j ∈ J' }
4. Calculate the separation measures for each alternative.
The separation from the ideal alternative is:
$S_i^* = [\Sigma (v_j^* - v_{ij})^2]^{½}$ i = 1, …, m.
Similarly, the separation from the negative ideal alternative is:
$S'_i = [\Sigma (v_j' - v_{ij})^2]^{½}$ i = 1, …, m.
5. Calculate the relative closeness to the ideal solution C_i^*
$C_i^* = S'_i / (S_i^* + S'_i)$, $0 < C_i^* < 1$
Select the option with C_i^* closest to 1.

VI. Numerical analysis

6.1 Body Shop

a) Analytic Hierarchy Process

Table 6.1 **Comparison matrix for Criteria-**

	Material	Move	Method	Priority Weights
Material	1	1/5	1/6	0.081
Move	5	1	1/2	0.342
Method	6	2	1	0.577

b) Fuzzy Analytic Hierarchy Process

Table 6.2 **Comparison matrix for Criteria-**

	Material	Move	Method
Material	(1,1,1)	(1/4,1/5,1/6)	(1/5,1/6,1/7)
Move	(4,5,6)	(1,1,1)	(1,1/2,1/3)
Method	(5,6,7)	(1,2,3)	(1,1,1)

c) Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) Method:-

The calculation of TOPSIS method is as follows:-

Table 6.3 **Decision matrix for Alternatives-**

Alternative/Criteria	Material (0.081)	Move (0.342)	Method (0.577)
Conveyor	7	4	9
Industrial Truck	6	8	5
Hoist	5	6	7

6.2 Paint Shop

a) Analytic Hierarchy Process:-

The calculation of AHP method is as follows:-

Table 6.4 **Comparison matrix for Criteria-**

	Material	Move	Method	Priority Weights
Material	1	1/5	1/6	0.078
Move	5	1	1/3	0.287
Method	6	3	1	0.635

b) Fuzzy Analytic Hierarchy Process:-

Table 6.5 **Comparison matrix for Criteria-**

	Material	Move	Method
Material	(1,1,1)	(1/4,1/5,1/6)	(1/5,1/6,1/7)
Move	(4,5,6)	(1,1,1)	(1/2,1/3,1/4)
Method	(5,6,7)	(2,3,4)	(1,1,1)

c) Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) Method:-

Table 6.6 **Decision matrix for Alternatives-**

Alternative/Criteria	Material (0.078)	Move (0.287)	Method (0.635)
Conveyor	8	3	9
Industrial Truck	4	7	6
Cranes & Hoist	6	5	4

6.3 Trim Shop

a) Analytic Hierarchy Process:-

The calculation of AHP method is as follows:-

Table 6.7 **Comparison matrix for Criteria-**

	Material	Move	Method	Priority Weights
Material	1	1/5	1/6	0.078
Move	5	1	1/3	0.287
Method	6	3	1	0.635

b) Fuzzy Analytic Hierarchy Process:-

Table 6.8 **Comparison matrix for Criteria-**

	Material	Move	Method
Material	(1,1,1)	(1/4,1/5,1/6)	(1/5,1/6,1/7)
Move	(4,5,6)	(1,1,1)	(1/2,1/3,1/4)
Method	(5,6,7)	(2,3,4)	(1,1,1)

c) Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) Method:-

Table 6.9 **Decision matrix for Alternatives-**

Alternative/Criteria	Material (0.078)	Move (0.287)	Method (0.635)
Conveyor	5	6	8
Forklift	9	7	4
Hoist	7	5	6

6.4 Final Assembly Shop

a) Analytic Hierarchy Process:-

Table 6.10 **Comparison matrix for Criteria-**

	Material	Move	Method	Priority Weights
Material	1	1/5	1/6	0.078
Move	5	1	1/3	0.287
Method	6	3	1	0.635

b) Fuzzy Analytic Hierarchy Process:-

Table 6.11 **Comparison matrix for Criteria-**

	Material	Move	Method
Material	(1,1,1)	(1/4,1/5,1/6)	(1/5,1/6,1/7)
Move	(4,5,6)	(1,1,1)	(1/2,1/3,1/4)
Method	(5,6,7)	(2,3,4)	(1,1,1)

c) Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) Method:-

Table 6.12 **Decision matrix for Alternatives-**

Alternative/Criteria	Material (0.078)	Move (0.287)	Method (0.635)
Conveyor	3	6	9
Industrial Truck	7	8	4
Cranes & Hoist	5	4	6

VII. Computational Result

For Body Shop:-

Table 1 Preference Ratio and Ranking of Alternatives in Body Shop-

	AHP Method		Fuzzy AHP Method		TOPSIS Method	
Alternatives	Preference Ratio	Ranking	Preference Ratio	Ranking	Preference Ratio	Ranking
Conveyor	0.664	1	0.662	1	0.613	1
Industrial Truck	0.244	2	0.245	2	0.387	3
Hoist	0.092	3	0.093	3	0.48	2

For Paint Shop:-

Table 2 Preference Ratio and Ranking of Alternatives in Paint Shop-

	AHP Method		Fuzzy AHP Method		TOPSIS Method	
Alternatives	Preference Ratio	Ranking	Preference Ratio	Ranking	Preference Ratio	Ranking
Conveyor	0.709	1	0.71	1	0.675	1
Industrial Truck	0.09	3	0.092	3	0.515	2
Hoist	0.197	2	0.198	2	0.2	3

For Trim Shop:-

Table 3 Preference Ratio and Ranking of Alternatives in Trim Shop-

	AHP Method		Fuzzy AHP Method		TOPSIS Method	
Alternatives	Preference Ratio	Ranking	Preference Ratio	Ranking	Preference Ratio	Ranking
Conveyor	0.698	1	0.697	1	0.852	1
Industrial Truck	0.095	3	0.096	3	0.201	3
Hoist	0.206	2	0.207	2	0.458	2

For Final Assembly Shop:-

Table 4 Preference Ratio and Ranking of Alternatives in Final Assembly Shop-

	AHP Method		Fuzzy AHP Method		TOPSIS Method	
Alternatives	Preference Ratio	Ranking	Preference Ratio	Ranking	Preference Ratio	Ranking
Conveyor	0.709	1	0.71	1	0.823	1
Industrial Truck	0.09	3	0.092	3	0.278	3
Hoist	0.197	2	0.198	2	0.367	2

Thus, it is clear that the Conveyor System is more important Material Handling Equipment in the shop floor of an automobile industry.

VIII. Conclusion

Various Material Handling Equipments such as: Conveyors, Industrial Trucks, Cranes and Hoists are used in Automobile Industries. For selecting the best equipment, certain Multi Criteria Decision Making Methods (based on different criteria and sub-criteria) are employed. These methods based on pair wise comparison matrices and after calculating the weights of all selected alternatives, it can be concluded that, the Method criteria is more important for selecting Material Handling Equipment, and Conveyor System is more efficient and accurate Material Handling Equipment for any Automobile Industry.

Today various Automobile Industries are present in India for manufacturing variety of vehicles. In Automobile Industry proper and accurate handling of material is very necessary for reducing cost of manufacturing, and manufacturing cycle time. It is also important for increasing the capacity of production, and for improving the working conditions.

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