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SELECTION OF THE BEST MANUFACTURER USING TOPSIS AND PROMETHEE FOR ASSET PROPELLED INDUSTRY (API)

Prathamesh R.Potdar
Santosh B.Rane

ABSTRACT

Decision makers at Asset Propelled Industry (API) frequently face the problem of assessing and selecting the best alternative from a wide range of options. They are also interested to know the best model manufacturer for the given operating conditions. Therefore there is a need to provide a solution to select the best alternative for a particular situation. This article illustrates the ranking of heavy equipment model and selects the best Original Equipment Manufacturer (OEM) in API using Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and compares the results with Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE). Decision makers identified necessary data and relative importance matrix based on various equipment models and attributes for ranking. The Analytic Hierarchy Process (AHP) was used to find appropriate weights of attributes. Models were ranked based on TOPSIS and PROMETHEE. The results of TOPSIS and PROMETHEE were compared,and the best feasible solution was selected in given circumstances. The selection of OEM is made based on the ranking of models.The model numbers HM300, D4K2, 3TNV76, 430ZX, 310K have received the first rank in the category of the Dumper, Bulldozer, Excavator, Wheel Loader and Backhoe loader respectively. This research identified that Caterpillar is one of the best Original Equipment Manufacturer (OEM) for Bulldozer and Excavator. The best equipment model and OEM for given conditions were identified by TOPSIS and PROMETHEE. This research results in quick and correct decision making in selecting the correct alternative for given circumstances. The revenue generated is increased by 18.23%, and profit is increased by Rs10, 09,337/-.

KEYWORDS: - Asset Propelled Industry, Decision making, AHP, TOPSIS, PROMETHEE.

1. INTRODUCTION

Asset Propelled Industries have continually gone through innovative changes. These fast changes in technology need an equally quick response from the industry to enhance the business and profit. The APIhas to select appropriate scheduling and purchasing strategies, tool and equipment selections, etc. to meet the challenges of the market. The selection of the best alternative is very complicated, as decision making is more challenging and dynamic in today's era of technology. (Simanaviciene and Ustinovichius, 2010)analyzed the quantitative multiple criteria decision-making methods and sensitivity analysis methods usages in decision support systems. (Rao, 2013)demonstrated improved multi-attribute decision-making methods to solve decision-making problems in manufacturing environments.(Govindan et al., 2015)proposed a framework to evaluate green manufacturing practices (GMP) and the same has validated within a particular single case industry situated in the south part of India, who is the leading manufacturer of rubber tyres and tubes.(Chen, 2015)developed a new multiple criteria decision-making method based on the approach of likelihood-based outranking comparisons within the environment of interval type-2 fuzzy sets.(Sakthivel et al., 2015)describtheed an application of hybrid Multi-Criteria Decision Making (MCDM) technique for the selection of optimum fuel blend in fish oil biodiesel for the IC engine. Decision makers in the API regularly face the problem of evaluating a wide range of alternative options and selecting one of the best solutions the based on a set of contradictory criteria. It has noticed that in choosing the best alternative is no definite criterion of selection but decision makers have to consider all criteria. There arises a need for simple, systematic and logical methods to help decision maker inconsidering a number of selection criteria. The objective of the selection procedure is to identify the best selection criteria and obtain the most suitable solution to the real requirements. Machinery and equipment are an essential part of thebusiness for API. The different costs involved in API are equipment purchasing cost, implementation cost, service and support cost. For example, the approximate purchasing cost of the excavator is Rs.2200000/-, implementation cost is Rs. 41786/-, service and support cost is Rs. 161037/- per year. This shows that there is a massive investment for purchasing and servicing in API. The business of API mostly depends on asset utilization, asset performance, and customer rating.

1.1. Existing Industry Solution for Ranking of Equipment Model

The current method in the industry for the ranking of an equipment model and selection of OEM has based on Customer rating, the performance of the equipment, maintenance strategy and purchasing cost. The Pareto chart, Pie chart is used for selection of Manufacturer. The existing method considered any two to three parameters for ranking of equipment model and OEM selection. This selection misguides the industry and also affects negatively on business as well as on reputation of industry in the market. The industries are in need to provide a cost-effectivesolutionto overcome this situation, for ranking the equipment model and selection of the OEM in given circumstances.

2. LITERATURE SURVEY

The literature survey was conducted in the domain of AHP, TOPSIS and PROMETHEE methods. The details of the literaturesurvey discussed in section 2.1, 2.2 and 2.3.

2.1. Literature Survey on Combine AHP and TOPSIS Method

The TOPSIS method was developed by (Hwang and Yoon, 1981). This method is based on the concept that the chosen alternative should have the shortest Euclidean distance from the positive ideal solution, and farthest from the negative ideal solution (Rao, 2007). (Cheng et al., 2002) applied Multiple criteria decision analysis (MCDA) approach to solving the landfill selection problem in Regina of Saskatchewan Canada.(Antuchevi?iene, 2005) analysed the problem of multiple attribute decision making under the fuzzy environment and presented the extended TOPSIS to the fuzzy environment. (Wang and Elhag, 2006)developed Fuzzy TOPSIS method based on alpha level sets with an application to bridge risk assessment. (Liao and Kao, 2011) proposed integrated Fuzzy TOPSIS and MCGP with trapezoidal fuzzy number adopted for selecting supplier in the company which engaged in watch manufacturing. (Bulgurcu, 2012) Proposed a multi-criteria decision-making model to measure and compare the financial performance of thirteen technology firms trading in the Istanbul Stock Exchange. These firms are examined and assessed in terms of ten financial ratios which are combined to obtain a financial performance score by using TOPSIS.(Yu et al., 2013) analyzed and compared the influence factors for the intersections traffic congestion status. They established the status of evaluation index system for urban road intersections traffic congestion by application of AHP and TOPSIS method.(Moosivand and Farahani, 2013) determined and ranked the factors attracting tourist in Isfahan province by combining analytic hierarchy process (AHP) and TOPSIS models. (Wan and Li, 2013) proposed a Fuzzy LINMAP (Linear Programming Technique for Multidimensional Analysis of Preference) to solve heterogeneous decision-making problems with fuzzy and intuitionistic fuzzy information in the static environment. (Kim et al., 2013)identified, it's a perfect logic-based computation method which represents rational decision-making, preferences, and provides an index that altogether accounts for the most excellent and poor alternatives. (Mauryaetal., 2013) performed supplier selection using analytical hierarchy process in the supply chain.(Alarcin et al., 2014)presented Fuzzy Analytic Hierarchy Process (AHP) and TOPSIS methods that can be applied for failure detection in auxiliary systems and marine diesel engine determined by a group of experts. (Shukla et al., 2014)presented how Analytic Hierarchy Process and TOPSIS in the Fuzzy environment can be integrated for more consistent evaluation and prioritization of trading partner based on four coordination criteria namely joint decision-making, information sharing, use of information technology tools, and resource sharing determined by factor analysis of survey data and expert opinion.(Mittal et al., 2016)described the significant problems faced by the plywood SSIs along with their cause and the ultimate effect, i.e., pruning the profits. (Najafabadi et al., 2016)identified potential natural hazards in Bandar Abbas city, Iran, using TOPSIS model based on an AHP structure.(Ramesh et al., 2016)presented a study to analyse the turning properties of magnesium alloy AZ91D in dry condition with polycrystalline diamond (PCD) cutting inserts. (?im?ek and Uyguno?lu, 2016)used TOPSIS based Taguchi method to determine optimal mixture proportions of concrete contains polymers such as high-density polyethylene, low-density polyethylene, polypropylene, thermoplastic elastomer, dimethyl terephthalate, polyethylene terephthalate, polyethylene naphtholate. (He et al., 2016)proposed a novel technical approach for mechanism analysis of product infant failure based on domain mapping in Axiomatic Design and the quality and reliability data from product lifecycle in the form of a relational tree. (Wang et al., 2016) presented a hybrid Multiple-criteria decision-making (MCDM) methods combining simple additive weighting (SAW), techniques TOPSIS and grey relational analysis (GRA) techniques. (Lourenzutti and Krohling, 2016) introduced a generalization of the TOPSIS method, called GMo-RTOPSIS (Group Modular Random TOPSIS), which provides freedom for the decision makers to express opinions individuality. (Meshram, etal., 2017) consolidated the total quality practices being practiced in ISO 9001 certified SMEs in India through experts and evaluated using the AHP methodology. (Chaudhary and Vrat, 2018) elaborated and analyzed the best practices of Solar Panel Recycling management followed by across the globe and makes specific recommendations for effective Solar Panel trash management in India.(Rao, 2007) discussed the stepwise procedure to calculate the weights of attributes using AHP. The Eq.1 and Eq. 2 showed the normalized weight (Wj) and geometric mean (GMj) respectively. Table 1 showed the details of Random Index (RI).

$$W_j = \frac{GM_j}{\sum_{j=1}^{M} GM_j} \quad (1)$$

$$GM_j = \left(\prod_{j=1}^{M} b_{ij}\right)^{\frac{1}{M}} \quad (2)$$

Where, b_{ij} denotes the comparative importance of attribute iwith respect to j, 'M' shows Number of attributes

Table 1. Random index (RI) values (Rao, 2007)

Attributes	3	4	5	6	7	8	9	10
RI	0.52	0.89	1.11	1.25	1.35	1.4	1.45	1.49

2.2. Literature Survey on PROMETHEE

The Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) method is a Multi-criteria Decision making (MCDM) tool, and it was introduced by (Brans et al., 1984). (Goumas and Lygerou, 2000)extended a multi-criteria method of ranking alternative projects, PROMETHEE to deal with fuzzy input data. (Macharis et al., 2004) discussed the strengths and weaknesses of the PROMETHEE and AHP methods. Also, recommendations are formulated to integrate into PROMETHEE a number of useful AHP features, especially as regards the design of the decision-making hierarchy (ordering of goals, sub-goals, dimensions, criteria, projects, etc.) and the determination of weights. (Kalogeras et al., 2005), (Herva and Roca, 2013) identified PROMETHEE is one of the most efficient outranking methods. (Marinoni, 2006)applied the PROMETHEE outranking approach toland suitability assessment using the raster datasets. (Venkata Rao and Patel, 2010) integrated the ANP and PROMETHEE to solve a multi-alternative problem of a wide range of alternatives in the manufacturing environment. (Turcksin et al., 2011)proposed combined AHP-PROMETHEE approach for selecting the most appropriate policy scenario to stimulate a clean vehicle fleet. (Hu and Chen, 2011)developed PROMETHEE based Classification Method (PROMCM) using preference relations with pairwise judgments for multi-criteria classification problem. (Vinodh and Jeya Girubha, 2012)used PROMETHEE in the study to select the best sustainable concept considering the criteria from social, economic and natural perspective. The study revealed that the change of material as the best orientation and it has to select at the very first stage to achieve sustainability in case organization. (Kilic et al., 2015)used two common multi-criteria decision-making techniques, Analytic Network Process (ANP) and PROMETHEE in combination to better address the ERP selection problem.(Kuang et al., 2015)designed grey-based PROMETHEE II methodology to represent and analyze decision problems under uncertainty, which are characterized by limited input data and uncertain preferences of Decision Makers (DM). (Bagherikahvarin and Smet, 2016)presented an integrated Data Envelopment Analysis-Multiple Criteria Decision Aid (DEAMCDA) model which can be applied to increase the discrimination power of DEA. The model used the stability intervals based on PROMETHEE II as weight constraints in DEA.(Prathebhu etal. 2018) presented a useful decision-making model for ideation selection of a new product using Preference Ranking Organisation Method for Enrichment Evaluations (PROMETHEE) along with Analytic Hierarchy Process (AHP) and fuzzy logic.

2.3. Literature survey on Manufacturer/ Machine/Supplier selection

(Al?Hussein et al., 2001) developed an algorithm for selecting and locating mobile cranes on construction sites. (Arslan et al., 2004) used Multi?criteria weighted average in the decision?making process to rank the machines evaluated with respect to several criteria. (Randall et al., 2010) described the business case and process that was used for the selection of a ceiling lift manufacturer. (Smith and Rennie, 2010)presented a knowledge system contained within an existing CAD environment to enable the selection of appropriate additive manufacturing (AM) materials and process technology from user-generated model data. (Farooq and O'Brien, 2012)developed a framework based on analytical hierarchy process (AHP) approach combined with strategic assessment model (SAM) to evaluate and select the technologies appropriate for providing an overall competitive advantage. (Chan and Prakash, 2012)used distance-based fuzzy multicriteria decision-making (MCDM) approach to select the appropriate maintenance policy. (Waris et al., 2014) determined selection criteria based on the fundamental concept of sustainability and provided an assessment framework. (García-Flores et al., 2015) introduced a decision support model for production and distribution of products derived from whey that extends a globally inclusive facility location problem. (Che and Chang, 2016) developed an integrated supplier selection methodology based on analytic network process, data envelopmentanalysis,andmultiple objective particle swarm optimization. (Chakraborty and Prasad, 2016)described the design and development of an expert system based on quality function deployment (QFD) methodology in Visual Basic 6.0 for selecting the most appropriate industrial truck which is a commonly practiced material handling equipment (MHE) in any manufacturing organization. (Hwang et al., 2016) identified the key third-party logistics (3PL) selection criteria for the integrated circuit (IC) manufacturing industry in Taiwan. (Hu and Yu, 2016) proposed an integrated approach for the electronic contract manufacturer selection problem, combining the voting method and the goal programming (GP) model to take into account the quantitative factors involved in the selection process. (Kavilal et al., 2017) used fuzzy Interpretive Structural Modelling(ISM) to establish the interdependence of Supply chain complexity (SCC) drivers, and then a fuzzy AHP and fuzzy PROMETHEE are used to quantify and prioritize the complexity drivers.

2.4. Research gap based on a literature survey

Many researchers work on the TOPSIS, integration of AHP with TOPSIS or PROMETHEE, Fuzzy Scale with TOPSIS or PROMETHEE for different industrial application but no one has compared the results of PROMETHEE with TOPSIS. Also, TOPSIS and PROMETHEE are not used for Manufacturer selection. In this research, the results of TOPSIS and the results of PROMETHEE are compared to obtain a solution for heavy asset industry.

3. PROBLEM SELECTION

Delphi method was used to collect opinions from domain experts. The data was collected from 28 experts of the group of Management, construction site managers, and OEM manufacturers. The panel of experts is as shown in Table 2. The form was developed and circulated among the experts to register their comments on the criteria of strong effect (10), moderate effect (7), low effect (5) and no effect (3). The summarized results of the Delphi method is as shown in Table 3. The matrix for problem selection shows business has highest weighted importance, i.e. 5 in industry. The Delphi method concludes that the problem of identifying the best equipment model and OEM is the most critical problem in heavy asset industries because it has received the highest rating, i.e. 66.

3.1. Problem Statement

The problem statement is to identify the best equipment model and OEM for future investment. The TOPSIS and PROMETHEE methods are used for ranking the equipment models and based on the ranking of the model the manufacturer have been selected. This paper presents a simple, systematic and logical method, for the ranking of heavy equipment models and selects the best manufacturer in API using TOPSIS and compare the results with PROMETHEE.

Table 2. Panel of Experts for Delphi Method

Sr. No.	Expert	No. of Experts	Percentage (%)
1	Management	7	25.00
2	Construction site Managers	13	46.43
3	OEM manufacturer	8	28.57

Table 3. Matrix for Problem Selection

Sr. No.	Weighted by Importance	5		3		2		Rating
	Process Inputs	Business		Cost Saving Potential		Customer Satisfaction		
1	Equipment Health monitoring	8	40	8	24	12	24	88
2	Identification of the best equipment Model and OEM	13	65	8	24	7	14	103
3	Equipment maintenance Planning	7	35	11	33	10	20	88
4	Equipment utilization	9	45	7	21	12	24	90

3.2. Stakeholder Analysis

a) Stakeholders

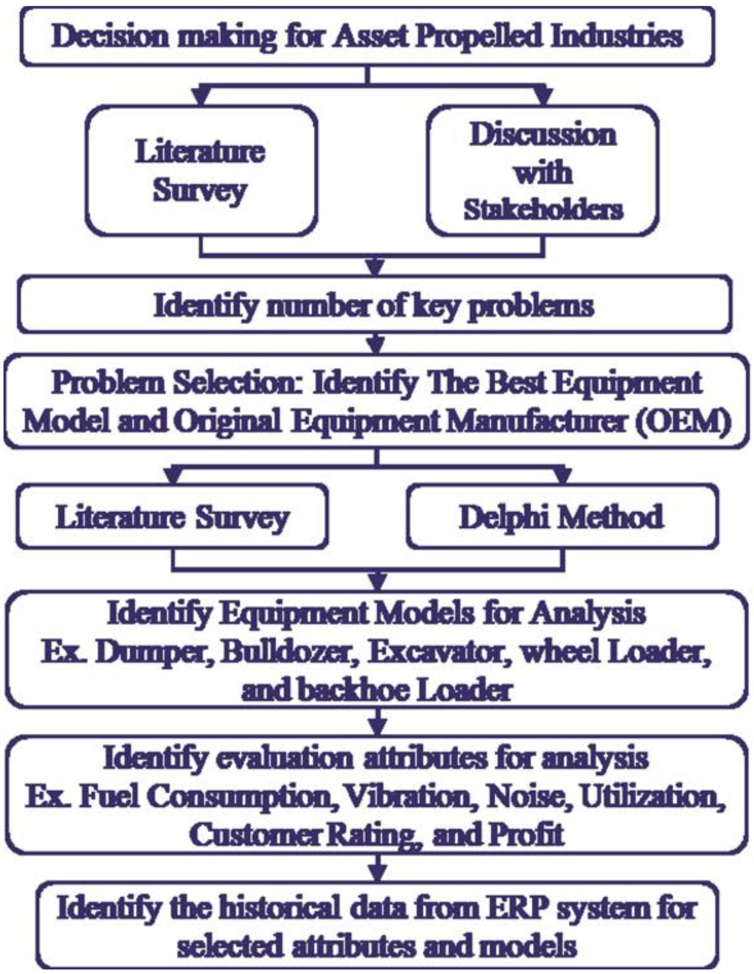
I) L&T Construction
ii) LeeBoy India Construction Equipment private imitated.
iii) JCB India Limited

b) Requirements of Stakeholders

I) Optimization in the ranking of heavy equipment models and selection of OEM.
ii) To know the best equipment model and OEM forequipment for future investment.
iii) To know the significance of decision making on business.
iv) Investigate the attributes for decision making in heavy asset industry.

4. RESEARCH METHODOLOGY

The paper aims to rank the models, select the best equipment and OEM in API using TOPSIS and PROMETHEE method.



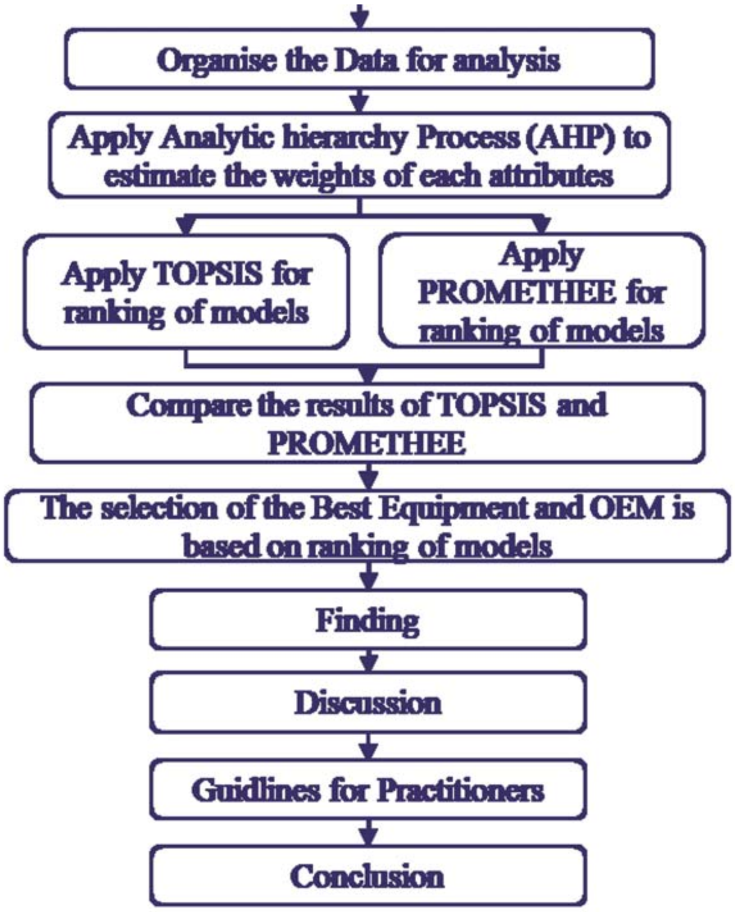


Figure 1. Research Methodology Flow Chart

The Analytic Hierarchy Process (AHP) is also used to determine the relative importance of the selected criteria. The research methodology is as shown in Figure 1. The list of abbreviations used in the research is as shown in Table 4.

Table 4. List of abbreviation

Sr. No.	Abbreviation	Details
1	FC	Fuel Consumption
2	V	Vibration
3	N	Noise
4	U	Utilization
5	CR	Customer Rating
6	P	Profit
7	Q	Quantity
8	MN	Model Number

In this research, the researchers have selected identified asset propelled industries to apply decision-making tools after discussion with experts. The different problems were identified in the domain of decision making based on literature survey and discussion with stakeholders. The critical problem was selected for analysis based on the Delphi method, i.e. Identify the Best Equipment Model and OEM for API. The expert comments and literature survey were used to identify attributes for analysis. The required data was collected from the ERP system based on equipment model and attributes. The data was organized,and data analysis was carried out. Based on the literature survey it is identified that integration of AHP with TOPSIS/ PROMETHEE will be the good proposed solution. That will take care of model to model and attribute to attribute comparison. The results of TOPSIS and PROMETHEE were compared and selected the best suitable solution for a given situation. The discussions on findings were carried out and noted. The conclusions are derived. The Future scope is identified. Next section will illustrate the data collection activity.

5. DATA COLLECTION PLAN

The data collection plan is developed to investigate The Best Model and OEM in API, as shown in Table 5.

Table 5. Data Collection Plan

Sr. No.	Subject	Details
1	Which types of models are selected for analysis of heavy equipment?	Dumper, Bulldozer, Excavator, Wheel Loader and Backhoe Loader.
2	Which are the selected OEMs for analysis?	Komatsu, Caterpillar, JCB and John Deere.
3	Which are the selected parameters for analysis?	Fuel Consumption, Vibration, Noise, Utilization, Customer Rating and Profit.
4	How is the data of the selected parameter collected?	Collect the data from ERP
5	Which type of data was captured?	Continue Data
6	Who will collect the data?	Supervisor
7	What is the frequency of data collection?	• 'V' and 'N' in the interval of 30min. • Other parameters once in a day.

5.1. Data Collection method

The required data for research can be collected by questionnaire, interviews, observations, case study, and report. In this research, the data was collected from Enterprise Resource Planning (ERP) system. The required data was collected from the ERP system for problem analysis and to give the solution.

5.2. Sample Size

The sample size is an essential feature of any research study. The sample size used in research is determined based on expenses of data collection and the need to have sufficient statistical power. The sample size can be decided by experience, target variance and target for the power of the statistical test. The formula to estimate sample size is as shown in Eq.3. The parameters like confidence level, standard deviation, and margin of error are considered as 95%, 0.5 and 0.05 respectively to estimate sample size. The estimated value of sample size is 9.8 but for analysis 12 is considered as a sample size as a requirement of the industry. The decision maker decided to have 12 items per equipment model based on availability. This selection of sample size will minimize the computational effort and time as well as will give the close result to actual. Further, the decision makers have selected the most suitable attributes of equipment for the evaluation. Total6 numbers of attributes are selected for analysis based on criteria of beneficial and non-beneficial attributes.

$$\text{Sample Size} = \frac{Z_{\alpha} \times \sigma \times (1 - \sigma)}{ME} \tag{3}$$

Where, $Z_{\alpha} =$ Confidence level (1.96 for 95% confidence level)

$\sigma =$ Standard Deviation, ME = Margin of Error

$$\text{Sample Size} = \frac{1.96 \times 0.5 \times (1 - 0.5)}{0.05} = 9.8$$

6. CASE STUDY: ASSET PROPELLED INDUSTRY (API)

For this situation in API, the decision makers have selected most demandable and useful assets for analysis; those are Dumpers, Bulldozers, Excavators, Wheel Loaders, and Backhoe Loader from a different construction site. The details of OEMs and Models with quantity are as shown in Table 6.

Table 6. Asset details with OEM

OEM	Name of Equipment with Model No (MN) and Quantity (Q)										Total
	Dumper		Bulldozer		Excavator		Wheel Loader		Backhoe Loader		
	MN	Q	MN	Q	MN	Q	MN	Q	MN	Q	
Komatsu	HM300	1	D21A-8EO	2	PC210 LC	2	WA50	1	WB142	2	15
	HM350	2	D31EX-22	2	PC138 US	1	WA65	1	WB146	1	
Caterpillar	735B	2	D4K2	2	345C L	1	966M XE	2	427F2	1	15
	740B	1	D3K2	2	3TNV76	2	972M	1	432F2	1	
JCB	9T	1	-	-	2DX	2	3DXL	2	3CX ECO	2	15
	10T	2	-	-	3DX eco	2	430ZX	2	4CX ECO	2	
JOHN DEERE	460E	1	950J	2	210G LC	1	204K	2	310K	2	15
	370E	2	1050J	2	250G LG	1	244K	1	310L	1	
Total		12		12		12		12		12	60

The codes given to model numbers are as shown in Table 7. The decision makers are interested to know the best model out of 12 models of each equipment. Therefore decision makers have identified the different attributes like Engine Speed, Engine Oil Temperature, Hydraulic Fluid Temperature, Vibration, Noise, Fuel Consumption, Utilization, Customer Rating, and Profit. The attributes are finalized based on the criteria of beneficial and non-beneficial attributes suggested by stakeholders. The finalized attributes are Fuel Consumption, Vibration, Noise, Utilization, Customer Rating, and Profit for decision making. Out of selected attributes the Fuel Consumption, Vibration, Noise are non-beneficial attributes and Utilization, Customer Rating, Profit is beneficial attributes. Hence for better results of the analysis the 12 models of each equipment, 15 items of each manufacturer, and also 3 beneficial and non-beneficial attributes are selected for ranking of models and selection of OEM. The observed values of selected attributes are shown in Table 8.

Table 7. Details of codes for model number

Sr. No.	Dumper		Bulldozer		Excavator		Wheel Loader		Backhoe Loader	
	MN	Code	MN	Code	MN	Code	MN	Code	MN	Code
1	HM300	D-1	D21A-8EO	B-1	PC210 LC	E-1	WA50	WL-1	WB142	BL-1
2	HM350	D-2	D31EX-22	B-2	PC138 US	E-2	WA65	WL-2	WB146	BL-2
3	735B	D-3	D4K2	B-3	345C L	E-3	966M XE	WL-3	427F2	BL-3
4	740B	D-4	D3K2	B-4	3TNV76	E-4	972M	WL-4	432F2	BL-4
5	9T	D-5	D21A-8EO	B-5	2DX	E-5	3DXL	WL-5	3CX ECO	BL-5
6	10T	D-6	D31EX-22	B-6	3DX eco	E-6	430ZX	WL-6	4CX ECO	BL-6
7	460E	D-7	950J	B-7	210G LC	E-7	204K	WL-7	310K	BL-7
8	370E	D-8	1050J	B-8	250G LG	E-8	244K	WL-8	310L	BL-8
9	HM350	D-9	D4K2	B-9	PC210 LC	E-9	966M XE	WL-9	WB142	BL-9
10	735B	D-10	D3K2	B-10	3TNV76	E-10	3DXL	WL-10	3CX ECO	BL-10
11	10T	D-11	950J	B-11	2DX	E-11	430ZX	WL-11	4CX ECO	BL-11
12	370E	D-12	1050J	B-12	3DX eco	E-12	204K	WL-12	310K	BL-12

Table 8. Equipment Observation

Equipment	Mod. No	Fuel Consumption FC (Lit)	Vibration V(m/s^2)	Noise N(dB)	Utilization U (%)	Customer Rating CR	Profit P (%)
Dumper	D-1	14.1	1.4	112.1	90.7	4.2	38.1
	D-2	12.7	1.7	126.4	84.6	3.7	31.4
	D-3	14.1	1.3	117.8	87.4	4.1	29.4
	D-4	18.1	1.4	114.2	91.5	4.2	36.4
	D-5	17.8	1.4	126.2	88.3	4.1	29.4
	D-6	19.9	1.7	110.7	87.6	3.9	26.7
	D-7	18.3	1.5	109.9	92.4	3.8	34.5
	D-8	12.1	1.8	109.2	83.4	4.6	31.6
	D-9	17.4	1.7	107.3	88.7	4.4	28.6
	D-10	18.4	1.6	117.9	92.4	3.7	29.1
	D-11	13.4	1.3	119.9	93.4	3.7	26.5
	D-12	15.6	1.4	117.9	89.5	3.9	33.3
Bulldozer	B-1	137.9	1.6	103.2	87.8	3.3	29.5
	B-2	115.8	1.7	129.2	89.3	3.9	32.6
	B-3	127.2	1.7	122.4	91.8	3.8	38.7
	B-4	119.2	1.4	94.3	93.7	3.3	34.7
	B-5	113.5	1.3	118.5	89.4	3.7	31.8
	B-6	128.7	1.4	114	88.1	2.8	28.9
	B-7	123.8	1.2	101.7	89.2	3.8	32.1

	B-8	110.4	1.3	138.8	88.4	3.6	29.8
	B-9	121.7	1.6	119.6	92.5	4.3	34.7
	B-10	112.1	1.8	105.2	90.5	4.1	28.9
	B-11	114.9	1.7	116	89.3	4.4	30.1
	B-12	120.2	1.9	103.7	90.7	3.8	31.5
Excavator	E-1	111.1	1.8	117.3	91.4	4.7	24.6
	E-2	114.5	1.2	116.4	89.7	4.1	29.8
	E-3	116.4	1.2	115.9	88.4	4.1	24.1
	E-4	104.9	1.4	117.1	86.4	5.1	30.4
	E-5	110.8	1.7	119.7	89.1	2.8	25.6
	E-6	109.8	1.6	121.5	86.5	4.3	27.8
	E-7	112.7	1.4	119.2	90.5	2.9	24.1
	E-8	111.7	1.8	122.9	92.4	3.7	24.1
	E-9	104.5	1.9	115.2	92.1	4.1	23.1
	E-10	117.8	1.2	114.2	86.5	4.2	27.6
	E-11	108.8	1.4	108.7	91.5	3.5	23.4
	E-12	112.7	1.6	105.2	87.5	3.9	26.7
Wheel Loader	WL-1	49.2	1.2	107.5	84.3	3.9	26.1
	WL-2	48.8	1.8	105.2	89.1	3.5	22.8
	WL-3	41.6	1.3	108.7	86.4	4.1	28.9
	WL-4	53.6	1.7	114.7	83.5	3.4	30.2
	WL-5	50.1	1.6	106.3	86.5	4.2	29.1
	WL-6	46.9	1.3	104.5	88.6	4.5	29.8
	WL-7	49.9	1.4	105.4	81.9	3.3	21.8
	WL-8	41.5	1.1	101.3	90.1	3.7	22.5
	WL-9	51.1	1.6	119.2	93.2	4.1	22.8
	WL-10	49.0	1.6	118.1	83.1	4.4	23.9
	WL-11	48.5	1.1	117.1	93.2	4.1	22.7
	WL-12	44.8	1.7	109.8	86.9	4.3	29.5
Backhoe Loader	BL-1	51.9	1.6	110.8	92.1	3.6	21.6
	BL-2	43.6	1.5	108.5	89.5	3	30.6
	BL-3	56.1	1.5	109.7	88.3	3.9	26.9
	BL-4	56.8	1.3	111.6	84.1	4.2	32
	BL-5	49	1.5	110.1	92.6	2.7	26.1
	BL-6	50.7	1.6	113.8	87	3.8	31.1
	BL-7	42.0	1.3	116.1	82.6	4.1	36.2
	BL-8	53.9	1.5	108.1	92.6	3.7	25.9
	BL-9	46.9	1.4	117.6	90	3.8	22.9
	BL-10	46.8	1.4	111.5	85.3	4	27.5
	BL-11	50.1	1.3	121.3	84.2	4.3	28.4
	BL-12	44.6	1.1	110.6	90.3	4	21.5

6.1. Implementation of TOPSIS

The stepwise implementation of TOPSIS for dumper discussed below, and similar steps have been performed to know the rank of different models.

Step 1: Ranking of dumper models based on selected attributes.
Step 2: Identify the information of attributes and shown in Table 8.
Step 3: Obtain a normalized decision matrix based on Eq. 4(Rao, 2007),Rij is an element of the normalized matrix and sample calculation as shown below. The results of the normalized matrix is shown in Table 9.

$$R_{ij} = \frac{m_{ij}}{\sqrt{\sum_{j=1}^{M} m_{ij}^2}} \quad (4)$$

Where, i = 1,2,3……..N, j = 1,2,……..M, and m_{ij} element of matrix

$$R_{11} = \frac{14.1}{\left(\begin{array}{c}14.1^2 + 12.7^2 + 14.1^2 + 18.1^2 + 17.8^2 + 19.9^2 + 18.3^2 \\ +12.1^2 + 17.4^2 + 18.4^2 + 13.4^2 + 15.6^2\end{array}\right)} = 0.251$$

Table 9 Normalized matrix

Model No.	FC	V	N	U	CR	P
D-1	0.251	0.266	0.279	0.294	0.299	0.350
D-2	0.226	0.319	0.315	0.274	0.269	0.288
D-3	0.251	0.247	0.293	0.283	0.293	0.270
D-4	0.323	0.264	0.284	0.296	0.300	0.334
D-5	0.317	0.266	0.314	0.286	0.296	0.270
D-6	0.355	0.323	0.276	0.283	0.280	0.245
D-7	0.326	0.276	0.274	0.299	0.273	0.317
D-8	0.215	0.351	0.272	0.270	0.326	0.290
D-9	0.310	0.323	0.267	0.287	0.314	0.263
D-10	0.328	0.295	0.294	0.299	0.265	0.267
D-11	0.239	0.248	0.299	0.302	0.262	0.243
D-12	0.278	0.266	0.294	0.290	0.279	0.306

Step 4: The Weights of the relative importance of the criteria is assigned using the AHP method. Let the decision maker prepare the following matrix. The assigned values in this step are for demonstration purpose only. The weight of each criterion is calculated based on the procedure presented in section 2.1 and sample calculation is shown below. The obtained values of criteria are WFC = 0.04, WV = 0.05, WN = 0.08, WU = 0.17, WCR = 0.23 and WP = 0.43. The value of and CR = 0.0315, which is much less than the allowed CR value of 0.1. Thus, there is good consistency in the judgments made. The radiated diagram shows the weights of selected the attributes. It also shows that profit has maximum a value of weight i.e. 0.43 an,,d fuel consumption has minimum a value of weight i.e. 0.04. The profit is one of the major contributor in the selection of equipment model. The weights of attributes are shown in Figure 2 by radiated diagram.

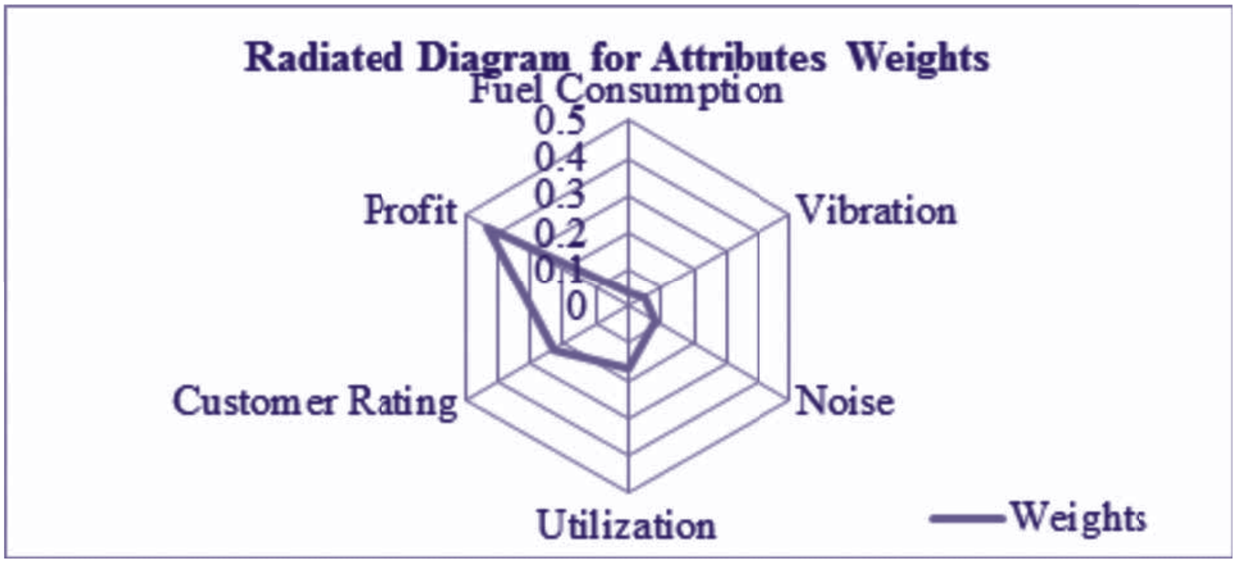


Figure 2 Radiated Diagram for attributes weights

	FC	V	N	U	CR	P
FC	1	1/2	1/3	1/5	1/5	1/7
V	2	1	1/2	3	1/5	1/7
N	3	2	1	1/3	1/3	1/5
U	5	3	3	1	1/2	1/3
CR	5	5	3	2	1	1/3
P	7	7	5	3	3	1

Step 5:

Obtain the weighted normalized matrix (Vij) based on Eq.5 and the sample calculation shown below. The results of the weighted normalized matrix are shown in Table 10.

$$V_{ij} = W_j \times R_{ij} \quad (5)$$

$$V_{11} = W_1 \times R_{11} = 0.04 \times 0.251 = 0 \ = 0.010$$

Table 10 Weighted Normalised Matrix

Model No.	FC	V	N	U	CR	P
D-1	0.010	0.013	0.022	0.050	0.069	0.150
D-2	0.009	0.016	0.025	0.047	0.062	0.124
D-3	0.010	0.012	0.023	0.048	0.067	0.116
D-4	0.013	0.013	0.023	0.050	0.069	0.144
D-5	0.013	0.013	0.025	0.049	0.068e	0.116
D-6	0.014	0.016	0.022	0.048	0.064	0.105
D-7	0.013	0.014	0.022	0.051	0.063	0.136
D-8	0.009	0.018	0.022	0.046	0.075	0.125
D-9	0.012	0.016	0.021	0.049	0.072	0.113
D-10	0.013	0.015	0.023	0.051	0.061	0.115
D-11	0.010	0.012	0.024	0.051	0.060	0.105
D-12	0.011	0.013	0.023	0.049	0.064	0.131

Step 6: Identify the ideal best and ideal worst solution from Table 10, and the results are shown in Table 11. In the case of beneficial attributes select highest and for non-beneficial attributes select the lowest value from Table 10. For attributes, FC, V, N select lower is the best and for U, CR; P attributes select highest is the best.

Table 11. Summary of ideal best and worst solution

Solution	FC	V	N	U	CR	P
Best (V_j^+)	0.009	0.012	0.021	0.051	0.075	0.150
Worst (V_j^-)	0.014	0.018	0.025	0.046	0.060	0.105

Step 7: Obtain the separation measures (Si) of each alternative from an ideal solution based on Eq.6 and Eq.7(Rao, 2007) respectively. The V_j^+andV_j^-arethe best and worst solutions for attributes. The obtained results are summarized in Table 12.

$$S_i^+ = \sqrt{\sum_{j=1}^{M} (V_{ij} - V_j^+)^2} \quad (6)$$

$$S_i^- = \sqrt{\sum_{j=1}^{M} (V_{ij} - V_j^-)^2} \quad (7)$$

$$S_1^+ = \sqrt{\begin{array}{l}(0.010-0.009)^2+(0.013-0.012)^2+(0.022-0.021)^2\\+(0.050-0.051)^2+(0.069-0.075)^2+(0.150-0.150)^2\end{array}} = 0.005$$

$$S_1^- = \sqrt{\begin{array}{l}(0.010-0.014)^2+(0.013-0.018)^2+(0.022-0.025)^2\\+(0.050-0.046)^2+(0.069-0.060)^2+(0.150-0.105)^2\end{array}} = 0.047$$

Table 12. Result in summary of separation measures and relative closeness

Model No.	D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8	D-9	D-10	D-11	D-12
S^+	0.005	0.030	0.035	0.010	0.036	0.047	0.019	0.027	0.038	0.039	0.048	0.022
S^-	0.047	0.020	0.015	0.041	0.015	0.006	0.032	0.026	0.015	0.012	0.009	0.028
P_i	0.897	0.398	0.301	0.800	0.294	0.110	0.626	0.491	0.289	0.236	0.157	0.556

Step 8: Identify the relative closeness of a particular alternative to the ideal solution;the Pi value is calculated based on Eq. 8(Rao, 2007)and sample calculation are as shown below. The obtained results are shown in Table 12.

$$P_i = \frac{S_i^-}{(S_i^+ + S_i^-)}$$

$$P_1 = \frac{0.047}{(0.005 + 0.047)} \quad (8)$$

Step 9: Identify the ranking of dumper models based on Pi values. To know the ranking arrange the Pi values in descending order. The sample ranking of dumper models shown in Table 13.

Table 13. Ranking of Dumper

Rank	1	2	3	4	5	6	7	8	9	10	11	12
Model No.	D-1	D-4	D-7	D-12	D-8	D-2	D-3	D-5	D-9	D-10	D-11	D-6

The steps 1 to 9 are repeated to know the rank of other equipment like a Bulldozer, Excavator, Wheel Loader, and Backhoe Loader.

6.2.Implementation of PROMETHEE

The stepwise implementation of PROMETHEE for dumper ranking discussed below, and similar steps have to follow for other equipment.

Step 1: Ranking of dumper models based on selected attributes.

Step 2: Identify the information of attributes, which is shown in Table 8.

Step 3: Identify weights of selected attributes using AHP. The AHP method is discussed in section 2.1 and weight values of attributes are WFC = 0.04, WV = 0.05, WN = 0.08, WU = 0.17, WCR = 0.23 and WP = 0.43.

Step 4: If two alternatives have a difference (d) 0 in criteria, then the preference value ranging from 0 to 1 is assigned to the 'better' alternative model whereas the 'worse' alternative model receives a value 0. If d = 0, then they are indifferent which results in an assignment of 0 to both alternatives. The pairwise comparison of dumper for Fuel Consumption is given in Table 14.

Table 14. Pairwise comparisons of twelve alternative models with respect to FC.

	D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8	D-9	D-10	D-11	D-12
D-1	-	1	1	1	1	1	1	1	1	1	1	1
D-2	0	-	1	1	1	1	1	0	1	1	1	1
D-3	0	0	-	1	1	1	1	0	1	1	0	1
D-4	0	0	0	-	0	1	1	0	0	1	0	0
D-5	0	0	0	1	-	1	1	0	0	1	0	0
D-6	0	0	0	0	0	-	0	0	0	0	0	0
D-7	0	0	0	0	0	1	-	0	0	1	0	0
D-8	0	1	1	1	1	1	1	-	1	1	1	1
D-9	0	0	0	1	1	1	1	0	-	1	0	0
D-10	0	0	0	0	0	1	0	0	0	-	0	0
D-11	0	0	1	1	1	1	1	0	1	1	-	1
D-12	0	0	0	1	1	1	1	0	1	1	0	-

Step 5: Repeat the step 4 for V, N, U, CR, and P.

Step 6: Obtain multiple criteria preference index by Eq. 9 and sample calculation is shown below. The results of the preference index for dumper are as shown in Table 15.

$$\prod a1a2 = \sum_{i=1}^{M} W_i P_{i,} a1a2 \qquad (9)$$

Where, $P_{i,a1a2} = G_i[C_i(a1) - C_i(a2)]$

$0 \le P_{i,a1a2} \le 1$, where G_i is a non-decreasing function of the observed deviation (d) between two alternatives a1 and a2 over the criteri $C_i,\ (i = 1,2,\ldots\ldots, M)$

Step 7: Obtain leaving flow $\varphi^+(a)$ based on Eq 10(Venkata Rao and Patel, 2010) and sample calculation is shown below. The Table 16 shows the obtained results of leaving flow.

$$\varphi^+(a) = \sum_{x\varepsilon A} \prod xa$$

$\varphi^+(a) =$ (0+0.96+0.91+0.55+0.95+0.92+0.75+0.65 +0.69+0.83+0.74+0.95) = 8.9

Step 8: Obtain entering flow $\varphi^-(a)$ based on Eq. 11(Venkata Rao and Patel, 2010). The Table16 shows the obtained results of entering flow.

$$\varphi^-(a) = \sum_{x\varepsilon A} \prod ax \qquad (11)$$

$\varphi^-(a) =$ (0 + 0.04+0.05+0.45+0 + 0.08+0.25+0.35 +0.31+0.17+0.26+0) = 1.96

Step 9: Obtain net flow $\varphi(a)$ by using Eq. 12(VenkataRao and Patel, 2010)and sample calculation shown below, also results are shown in Table 16.

$$\varphi(a_i) = \varphi^+(a) - \varphi^-(a) \qquad (12)$$

$$\varphi(a_i) = 8.9 - 1.96 = 6.94$$

Step 10: Set the alternative in descending order according to the values of $\varphi(a)$ and obtained the ranking of dumper. The results of obtained ranking are as shown in Table 17.

Table 15. Resulting preference Indices for dumper

	D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8	D-9	D-10	D-11	D-12
D-1	-	0.96	0.91	0.55	0.95	0.92	0.75	0.65	0.69	0.83	0.74	0.95
D-2	0.04	-	0.47	0.04	0.47	0.52	0.04	0.22	0.52	0.7	0.7	0.04
D-3	0.05	0.53	-	0.09	0.17	0.75	0.32	0.22	0.52	0.83	0.79	0.4
D-4	0.45	0.96	0.91	-	0.96	0.92	0.75	0.65	0.65	0.83	0.74	0.96
D-5	0	0.53	0.4	0.04	-	0.92	0.32	0.22	0.48	0.75	0.66	0.23
D-6	0.08	0.48	0.25	0.08	0.08	-	0.23	0.22	0	0.31	0.74	0.31
D-7	0.25	0.96	0.68	0.25	0.68	0.77	-	0.65	0.65	0.83	0.74	0.68
D-8	0.35	0.78	0.78	0.35	0.78	0.78	0.35	-	0.7	0.78	0.78	0.35
D-9	0.31	0.48	0.48	0.35	0.52	0.95	0.35	0.3	-	0.35	0.74	0.31
D-10	0.17	0.3	0.17	0.17	0.25	0.69	0	0.22	0.65	-	0.74	0.17
D-11	0.26	0.3	0.21	0.26	0.34	0.26	0.26	0.22	0.26	0.26	-	0.26
D-12	0	0.96	0.6	0.04	0.72	0.69	0.32	0.65	0.69	0.75	0.74	-

Table16. Leaving, entering and net flow values for dumper

	D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8	D-9	D-10	D-11	D-12
$\varphi^{+}(a)$	8.9	3.76	4.67	8.78	4.55	2.78	7.14	6.78	5.14	3.53	2.89	6.16
$\varphi^{-}(a)$	1.96	7.24	5.86	2.22	5.92	8.17	3.69	4.22	5.81	7.22	8.11	4.66
$\varphi(a)$	6.94	-3.48	-1.19	6.56	-1.37	-5.39	3.45	2.56	-0.67	-3.69	-5.22	1.5

Table 17 Ranking of Dumper

Rank	1	2	3	4	5	6	7	8	9	10	11	12
Model No.	D-1	D-4	D-7	D-12	D-8	D-2	D-3	D-5	D-9	D-10	D-11	D-6

The steps 1 to 10 are repeated to know the rank of other equipment like a bulldozer, excavator, wheel loader, and backhoe loader.

7. RESULTS

The summary of ranking for equipment models based on TOPSIS and PROMETHEE method is as shown in Table 18. Also the comparative study of ranking and revenue generated is as shown in Table 19.

Table18 Ranking of Equipment's based on TOPSIS and PROMETHEE

Rank	1	2	3	4	5	6	7	8	9	10	11	12
Dumper	D-1	D-4	D-7	D-12	D-8	D-2	D-3	D-5	D-9	D-10	D-11	D-6
Bulldozer	B-9	B-3	B-4	B-2	B-7	B-11	B-12	B-5	B-10	B-8	B-1	B-6
Excavator	E-4	E-2	E-6	E-10	E-1	E-12	E-3	E-9	E-8	E-5	E-11	E-7
Wheel Loader	WL-6	WL-12	WL-5	WL-3	WL-4	WL-10	WL-1	WL-11	WL-9	WL-8	WL-2	WL-7
Backhoe Loader	BL-7	BL-4	BL-11	BL-2	BL-6	BL-10	BL-3	BL-8	BL-5	BL-12	BL-9	BL-1

Table 19. Comparative Study of Equipment Model Ranking and Revenue Generated

Equipment	Results of Existing Ranking method		Results of Proposed Ranking Method		Increase in revenue generated in Rs	Revenue improvement in %
	Model No	Revenue Generated in Rs per year	Model No	Revenue Generated in Rs per Year		
Dumper	D-8	373154	D-1	665500	292346	6.653795
Bulldozer	B-7	388984	B-9	750393	361409	5.007587
Excavator	E-4	690216	E-4	690216	0	0
Wheel Loader	WL-6	584529	WL-6	584529	0	0
Backhoe Loader	BL-6	247345	BL-7	602927	355582	6.5783

8. DISCUSSION

The result shows that model HM300 received first ranking among the 12 models of the dumper. The Model HM300 manufactured by Komatsu, so it is the best alternative to dumper manufacturer for the given situation. Similarly, the model D4K2, 3TNV76, 430ZX, and 310K received the first ranks in the category of Bulldozer, Excavator, Wheel Loader and Backhoe Loader respectively. Caterpillar manufactured the Model D4K2 and 3TNV76; it is the best alternative of Bulldozer and Excavator manufacturer for the given circumstances. The model 430ZX and 310K are manufactured by JCB and John Deere respectively. JCB is the best alternative for Wheel

LoaderManufacturer, and John Deere is the best alternative for Backhoe Loader Manufacturer.

9. PROJECT DELIVERABLES

a) This research provided guidelines to understand implement and compare the TOPSIS and PROMETHEE method.

b) Increase in the revenue generated by 17.38%.

c) Increase in the profit by **Rs10, 09,337/- per year**.

d) Improvement in the business performance.

e) Improvement in the decision making.

f) Industry captured new business opportunities.

10. PROJECT PRODUCT DELIVERABLES

a) This research provided guidelines to solve similar problems.

b) This research optimized the decision making.

c) This research enhanced and leveraged the correct decision making in Asset Propelled Industry.

11. GUIDELINES FOR PRACTITIONER

a) Select appropriate attributes to reduce the error in analysis.

b) Select the most demandable equipment for analysis.

c) Select at least two number of equipment model for each category of OEM.

d) The preference of ranking will change as the numbers of attributes are increased or decreased.

e) The analysis effort and time will be reduced if considered appropriate numbers of attributes.

f) Eliminate less significantattributes from analysis and try to keep less than 10 attributes.

g) Check Consistency Ratio. It should be less than 0.1.

h) The ranking preference of PROMETHEE and TOPSIS may vary, but it suggests a same best solution for given situation.

12. CONCLUSION

A methodology based on AHP, TOPSIS, and PROMETHEE has proposed for decision making in the API, which supports the selection of a suitable alternative among a large number of available choices for a given problem. In this research, the results of the TOPSIS method were compared with PROMETHEE. The proposed method considered the values of attributes and their relative importance values together. Hence, it provides a more accurate assessment of the alternatives. The method provides a systematic way to assign the values of relative importance to the criteria based on the AHP method. The research concluded that TOPSIS and PROMETHEE suggest the same alternative for all equipment. The proposed methodology showed an increase in revenue generated by 18.23%, also increase the profit by Rs10, 09,337/-.The selection of OEM was simply based on the ranking of the model. We identified the best OEM of equipment, Komatsu for Dumper, a Caterpillar for Bulldozer and Excavator, JCB for Wheel Loader and John Deere for Backhoe Loader. The recommended procedure can be used for any decision-making problem containing any number of selection criteria.

13. FUTURE SCOPE:

In the future, the data having qualitative attributes can be treated by fuzzy logic and the results of the same can be processed using the above methodology covering AHP, TOPSIS, and PROMETHEE.

14. ACKNOWLEDGMENT

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REFERENCES

1. *F. Alarcin, A. Balin, H. Demirel, Fuzzy AHP and Fuzzy TOPSIS integrated hybrid method for auxiliary systems of ship main engines. J. Mar. Eng. Technol. 13, pp.3-11, 2014. https://doi.org/10.1080/20464177.2014.11020288*
2. *M. Al?Hussein, S. Alkass, O. Moselhi, An algorithm for mobile crane selection and location on construction sites. Constr. Innov. 1, 91-105, 2001. https://doi.org/ 10.1108/ 14714170110814532*
3. *J. Antuchevi?iene, Evaluation of alternatives applying TOPSIS method in a fuzzy environment. Ukio Technol. Ir Ekon. Vystym. 11, pp. 242-247, 2005. https://doi.org/ 10.1080/13928619.2005.9637704*
4. *M. C. Arslan, B. Çatay, E. Budak, A decision support system for machine tool selection. J. Manuf. Technol. Manag. 15, pp. 101-109, 2004. https://doi.org/ 10.1108/ 09576060410512374*
5. *M. Bagherikahvarin, Y.D. Smet, 2016. A ranking method based on DEA and PROMETHEE II (a rank based on DEA & PR.II). Measurement Complete, pp. 333-342, 2016. https://doi.org/10.1016/j.measurement.2016.04.026*
6. *J.P. Brans, B. Marescha, P. Vincke, PROMETHEE: a new family of outranking methods in multicriteria analysis. Proc. Oper. Res. 84, pp. 477-490, 1984.*
7. *B. Bulgurcu, (Kiran), Application of TOPSIS Technique for Financial Performance Evaluation of Technology Firms in Istanbul Stock Exchange Market. Procedia - Soc. Behav. Sci., World Conference on Business, Economics and Management (BEM-2012), May 4-6 2012, Antalya, Turkey 62, pp. 1033-1040, 2012. https://doi.org /10.1016/ j.sbspro.2012.09.176*
8. *S. Chakraborty, K. Prasad, A QFD-based expert system for industrial truck selection in manufacturing organizations. J. Manuf. Technol. Manag. 27, pp. 800-817, 2016. https://doi.org/10.1108/JMTM-02-2016-0020*
9. *F.T.S. Chan, A. Prakash, 2012. Maintenance policy selection in manufacturing firms using the fuzzy MCDM approach. Int. J. Prod. Res. 50, pp.7044-7056 2012. https://doi.org/10.1080/00207543.2011.653451*
10. *K. Chaudhary, And Prem Vrat, analysis of long term impact of the end of life solar panels as e-waste in India, industrial engineering journal (2018), volume 10 (10), doi: https://doi.org/10.26488/iej.10.10.70*
11. *Z. H. Che, Y.F. Chang, Integrated methodology for supplier selection: the case of a sphygmomanometer manufacturer in Taiwan. J. Bus. Econ. Manag. 17, pp.17-34, 2016. https://doi.org/10.3846/16111699.2015.1031823*

12. T. Y. Chen, An Interval Type-2 Fuzzy PROMETHEE Method Using a Likelihood-based Outranking Comparison Approach. Inf Fusion 25, pp.105-120, 2015. https://doi.org/10.1016/j.inffus.2014.10.002
13. S. Cheng, C.W. Chan, G.H. Huang, USING MULTIPLE CRITERIA DECISION ANALYSIS FOR SUPPORTING DECISIONS OF SOLID WASTE MANAGEMENT. J. Environ. Sci. Health Part A 37, pp. 975-990, 2002. https://doi.org/10.1081/ESE-120004517
14. S. Farooq, C. O'Brien, A technology selection framework for integrating manufacturing within a supply chain. Int. J. Prod. Res. 50, pp.2987-3010, 2012. https://doi.org /10.1080/00207543.2011.588265
15. R. García-Flores, R. Martins, O.V. de Souza Filho, M. González, C. Mattos, A. Rosenthal, P. Juliano, A novel facility and equipment selection model for whey utilisation: A Brazilian case study. Comput. Electron. Agric. 117, pp. 127-140, 2015. https://doi.org/10.1016/ j.compag .2015.07.016
16. M. Goumas, V. Lygerou, 2000. An extension of the PROMETHEE method for decision making in fuzzy environment: Ranking of alternative energy exploitation projects. Eur. J. Oper. Res. pp. 123, 606-613, 2000.
17 K. Govindan, D. Kannan, M. Shankar, 2015. Evaluation of green manufacturing practices using a hybrid MCDM model combining DANP with PROMETHEE. Int. J. Prod. Res. 53, pp. 6344-6371, 2015. https://doi.org/10.1080/ 00207543.2014.898865
18. Y. H. He, L.B. Wang, Z.Z He, M. Xie, A fuzzy TOPSIS andRough Set based approach for mechanism analysis of product infant failure. Eng. Appl. Artif. Intell., Artificial Intelligence Techniques in Product Engineering 47, pp.25-37, 2016. https://doi.org/10.1016/j.engappai.2015.06.002
19. M. Herva, E. Roca, 2013. Ranking municipal solid waste treatment alternatives based on ecological footprint and multi-criteria analysis. Ecol. Indic.
20. K J Hu, V.F. Yu, An integrated approach for the electronic contract manufacturer selection problem. Omega 62, pp. 68-81, 2016. https://doi.org/10.1016/j.omega.2015.08.010
21. Y. C. Hu, C.J. Chen, A PROMETHEE-based Classification Method Using Concordance and Discordance Relations and Its Application to Bankruptcy Prediction. Inf Sci 181, pp.4959-4968, 2011. https://doi.org/ 10.1016/ j.ins .2011.06.021
22. B.N. Hwang, T.T. Chen, J.T. Lin, 3PL selection criteria in integrated circuit manufacturing industry in Taiwan. Supply Chain Manag. Int. J. 21, pp.103-124, 2016. https://doi.org/10.1108/SCM-03-2014-0089
23. C.L. Hwang, B. Yoon, B., Multiple attribute decision making: Methods and application. Springer-Verl. N. Y, 1981.
24. N. Kalogeras, G. Baourakis, C. Zopounidis, G. Van Dijk, Evaluating the financial performance of agri-food firms: a multicriteria decision-aid approach. J. Food Eng., Operational Research and Food Logistics 70, pp.365-371, 2005. https://doi.org/10.1016/j.jfoodeng.2004.01.039
25. E.G. Kavilal, S. Prasanna Venkatesan, K.D. Harsh Kumar, An integrated fuzzy approach for prioritizing supply chain complexity drivers of an Indian mining equipment manufacturer. Resour. Policy 51, pp.204-218, 2017. https://doi.org/10.1016/j.resourpol.2016.12.008
26. H.S. Kilic, S. Zaim, D. Delen, 2015. Selecting 'The Best' ERP System for SMEs Using a Combination of ANP and PROMETHEE Methods. Expert Syst Appl 42, pp.2343-2352, 2015. https://doi.org/10.1016/j.eswa.2014.10.034
27. Y. Kim, E.S. Chung, S. M. Jun, S.U. Kim, 2013. Prioritizing the best sites for treated wastewater instream use in an urban watershed using fuzzy TOPSIS. Resour. Conserv. Recycl.
28. H. Kuang, D.M. Kilgour, K.W. Hipel, Grey-based PROMETHEE II with Application to Evaluation of Source Water Protection Strategies. Inf Sci 294, pp.376-389, 2015. https://doi.org/10.1016/j.ins.2014.09.035
29 C.N. Liao, H.P. Kao, An integrated fuzzy TOPSIS and MCGP approach to supplier selection in supply chain management. Expert Syst. Appl. 38, pp. 10803-10811, 2011. https://doi.org/10.1016/j.eswa.2011.02.031
30. R. Lourenzutti, R.A. Krohling, A generalized TOPSIS method for group decision making with heterogeneous information in a dynamic environment. Inf. Sci., SI\:Visual Info Communication 330, pp.1-18, 2016. https://doi.org /10.1016/j.ins.2015.10.005
31. C. Macharis, J. Springael, K. De Brucker, A. Verbeke, PROMETHEE and AHP: The design of operational synergies in multicriteria analysis.: Strengthening PROMETHEE with ideas of AHP. Eur. J. Oper. Res. 153, pp. 307-317, 2004.
32. O. Marinoni, A discussion on the computational limitations of outranking methods for land?use suitability assessment. Int. J. Geogr. Inf. Sci. 20, pp. 69-87, 2006. https://doi.org/10.1080/13658810500287040
33. A.H. Maurya, B.E. Narkhede, R.D. Raut, And A.S. Shrawge, 'supplier selection in supply chain using analytical hierarchy process', Int. J. Productivity and Quality Management, Vol. 11, no. 3, pp.357-369, 2013.
34 R.K. Meshram, R.R. Lakhe And R.L. Shrivastava, prioritization of TQM factors in ISO 9001 SMES in India, industrial engineering journal (2017), volume 10 (3), doi: https://doi.org/10.26488/iej.10.3.11
35 K. Mittal, P. Chandra Tewari, D. Khanduja, P. Kaushik, 2016. Application of Fuzzy TOPSIS MADM approach in ranking & underlining the problems of plywood industry in India. Cogent Eng. 3, 1155839. https://doi.org/10.1080/ 23311916.2016.1155839
36. J. Moosivand, B.M. Farahani, Analysing the Relationship Between Urban Infrastructure and Attracting Urban Tourists by Using TOPSIS and AHP Models. Tour. Plan. Dev. 10, pp. 467-479, 2013. https://doi.org/ 10.1080/21568316.2013.815268
37. R.M. Najafabadi, M.H. Ramesht, I. Ghazi, S.J. Khajedin, A. Seif, A. Nohegar, A. Mahdavi, Identification of natural hazards and classification of urban areas by TOPSIS model (case study: Bandar Abbas city, Iran). Geomat. Nat. Hazards Risk 7, pp. 85-100, 2016.

https://doi.org/10.1080/19475705.2013.871353

38. *Prabhu, Tushar Prakash, Chaudhari, Harshal B., Pathak, Ameya G. and Rajhans, N. R., ideation selection of a new product using fuzzy multi criteria decision making and PROMETHEE, industrial engineering journal (2018), volume 10 (7), doi: https://doi.org/10.26488/iej.10.7.49*
39. *S. Ramesh, R. Viswanathan, S. Ambika, Measurement and optimization of surface roughness and tool wear via grey relational analysis, TOPSIS and RSA techniques. Measurement 78, pp. 63-72, 2016. https://doi.org/10.1016/j.measurement.2015.09.036*
40. *S.B. Randall, W.J. Pories, G. Lucas, A Process for the Selection of a Patient Handling Ceiling Lift Manufacturer. J. Radiol. Nurs. 29, pp.69-74, 2010. https://doi.org/10.1016/j.jradnu.2010.05.001*
41. *R.V. Rao, Applications of Improved MADM Methods to the Decision Making Problems of Manufacturing Environment. Decis. Mak. Manuf. Environ. Using Graph Theory Fuzzy Mult. Attrib. Decis. Mak. Methods pp.41-135, 2013.*
42. *R.V. Rao, 2007. Decision making in the manufacturing environment using graph theory and fuzzy multiple attribute decision making methods. Lond. Springer-Verl.*
43. *G. Sakthivel, M. Ilangkumaran, A. Gaikwad, A hybrid multi-criteria decision modeling approach for the best biodiesel blend selection based on ANP-TOPSIS analysis. Ain Shams Eng. J. 6, pp. 239-256, 2015. https://doi.org/10.1016/j.asej.2014.08.003*
44. *R.K. Shukla, D. Garg, A. Agarwal, 2014. An integrated approach of Fuzzy AHP and Fuzzy TOPSIS in modeling supply chain coordination. Prod. Manuf. Res. 2, pp. 415-437, 2014. https://doi.org/ 10.1080/21693277 .2014.919886*
45. *R. Simanaviciene, L. Ustinovichius, Sensitivity Analysis for Multiple Criteria Decision Making Methods: TOPSIS and SAW. Procedia - Soc. Behav. Sci., Sixth International Conference on Sensitivity Analysis of Model Output 2, pp. 7743-7744, 2010. https://doi.org/ 10.1016/j.sbspro. 2010.05.207*
46. *B. ?im?ek, T. Uyguno?lu, Multi-response optimization of polymer blended concrete: A TOPSIS based Taguchi application. Constr. Build. Mater. Complete, pp. 251-262, 2016. https://doi.org/10.1016/j.conbuildmat.2016.05.027*
47. *P. Smith, A. Rennie, Computer aided material selection for additive manufacturing materials. Virtual Phys. Prototyp. 5, pp. 209-213, 2010. https:// doi.org /10.1080/17452759.2010.527556*
48. *L. Turcksin, A. Bernardini, C. Macharis, A combined AHP-PROMETHEE approach for selecting the most appropriate policy scenario to stimulate a clean vehicle fleet. Procedia - Soc. Behav. Sci., The State of the Art in the European Quantitative Oriented Transportation and Logistics Research - 14th Euro Working Group on Transportation & 26th Mini Euro Conference & 1st European Scientific Conference on Air Transport 20, pp. 954-965, 2011. https://doi.org/10.1016/j.sbspro.2011.08.104*
49. *R. Venkata Rao, B.K. Patel, Decision making in the manufacturing environment using an improved PROMETHEE method. Int. J. Prod. Res. 48, pp. 4665-4682, 2010. https://doi.org/10.1080/00207540903049415*
50. *S. Vinodh, R. Jeya Girubha, PROMETHEE based sustainable concept selection. Appl. Math. Model. 36, pp. 5301-5308, 2012. https://doi.org /10.1016/ j.apm.2011.12.030*
51. *S.P. Wan, D.F. Li, Fuzzy LINMAP approach to heterogeneous MADM considering comparisons of alternatives with hesitation degrees. Omega 41, pp. 925-940, 2013.*
52. *P. Wang, Z Zhu, Y. Wang, A Novel Hybrid MCDM Model Combining the SAW, TOPSIS and GRA Methods Based on Experimental Design. Inf Sci 345, pp. 27-45, 2016. https://doi.org/10.1016/j.ins.2016.01.076*
53. *Y.M. Wang, T.M.S. Elhag, Fuzzy TOPSIS method based on alpha level sets with an application to bridge risk assessment. EXPERT SYST APPL 31, pp. 309-319, 2006.*
54. *M. Waris, M. Shahir Liew, M.F. Khamidi, A. Idrus, Criteria for the selection of sustainable onsite construction equipment. Int. J. Sustain. Built Environ. 3, pp. 96-110, 2014. https://doi.org/10.1016/j.ijsbe.2014.06.002*
55. *J. Yu, L. Wang, X. Gong, Study on the Status Evaluation of Urban Road Intersections Traffic Congestion Base on AHP-TOPSIS Modal. Procedia - Soc. Behav. Sci., Intelligent and Integrated Sustainable Multimodal Transportation Systems Proceedings from the 13th COTA International Conference of Transportation Professionals (CICTP2013) 96, pp. 609-616, 2013. https://doi.org/10.1016/j.sbspro.2013.08.071*

AUTHORS

Prathamesh R.Potdar, Research Scholar, Sardar Patel College of Engineering, Munshi Nagar, Andheri -West, Mumbai, Maharashtra, India Email: prathameshpotdar122@gmail.com

Santosh B.Rane, Associate Professor, Sardar Patel College of Engineering , Munshi Nagar, Andheri -West, Mumbai, Maharashtra, India Email: s_rane@spce.ac.in