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PERFORMANCE EVALUATION OF ROAD TRANSPORT COMPANIES THROUGH RATIO BASED MCDM METHODS

Lakshmi Narayana Veeravalli
Part time PhD Scholar, Department of Mechanical Engineering, College of Engineering, Andhra University, Andhra Pradesh, 530003, India

V.V.S. Kesava Rao
Department of Mechanical Engineering, College of Engineering, Andhra University, Andhra Pradesh, 530003, India

ABSTRACT

Performance evaluation does a crucial role in assessing the efficiency and competitiveness of passenger road transport companies. To aid decision-makers in this process, ratio-based Multiple Criteria Decision-Making (MCDM) methods have been developed, such as MOORA (Multi-Objective Optimization on the basis of Ratio Analysis), MOOSRA (Multi-Objective Optimization by Ratio Analysis plus Full Multiplicative Form), MultiMOORA (Multi-Objective Optimization on the basis of Ratio Analysis), and MOOSRAL (Multi-Objective Optimization on the basis of Ratio Analysis plus Level of Similarity). These methods provide a systematic framework for evaluating company performance based on various criteria and ratios. The objective of this study is to present an abstract on the performance evaluation of passenger road transport companies using these ratio-based MCDM methods. These methods consider Learning and Growth, Internal business, Financial and customer perspectives with 20 criteria and provide a comprehensive approach to rank and evaluate companies based on their performance. Sensitivity analysis based on methods and the relative weights is made to analyze the performance pattern of 5 road transport companies.

Keywords: MCDM, MOORA, MOOSRA, MultiMOORA

1. INTRODUCTION

These ratio-based MCDM methods provide decision-makers with valuable tools to evaluate and compare the performance of passenger road transport companies. By considering multiple criteria and ratios, these methods offer a comprehensive and objective approach to assess company performance, identify areas for improvement, and make informed decisions for enhancing competitiveness in the industry.

2. LITERATURE SURVEY

Anand Kumar, et al., (2020) [1] evaluated performance of some major road transport companies in India using DEA-AHP.In this study, the researchers have taken 23 criteria to assess the efficiency of 42 public transportation utilities in India.

CANITEZ Fatih, et al., (2018) [2] employed AHP and Balanced Scorecard for performance measurement of urban transport organization. In their study, it was evolved that the developed procedure is able to assess the performance measurement of maritime and rail transportation.

Randhawa and Arora, (2018) [3] evaluated Punjab Road Transport Organizations based on the financial and physical performance criteria. The study suggested the performance improvement measures of the Punjab Road Transport Organizations.

Singh and Jha, (2017) [4] measured the effectiveness and efficiency and of 15 major state transport organizations by considering the data from FY 2003-04 to FY 2013-14 through DEA. The authors suggested that size correction or changing the scale of operation will be economical.

Estefania, et al., (2021) [5] developed an evaluation framework to calculate the performance of transporting companies with a case study using SCOR model. The authors concluded that the proposed model consolidates and encompasses total inform in the supply chain.

Rajan and Regi, (2014) [6] proposed benchmarking models for performance evaluation of road transport organizations through DEA and implemented with a case study. In the study, the areas which need to be improved for better performance of the transport organizations are highlighted.

Kovács GY, (2017) [7] considered time utilization, weight of transported freight, transport way utilization and fuel usage as performance indicators and determined the indices of proposed factors to determine the overall performance of the road freight transport activity. The author developed a decision support system for evaluation.

Mahesha, (2023) [8] evaluated the efficiency of Karnataka State Road Transport Corporation. The author considered fleet utilization, personnel percentage per schedule, accident rate, kilometers per 1000ml of fuel consumption, return on investment, the earnings in their schedules per useful kilometer and accident rate for evaluation of the transport organization.

Devaraj Hanumappa, et al., (2015) [9] considered the case study of Bangalore Metropolitan Transport Corporation and measured the performance through data envelopment analysis. Authors indicated the opportunities for improvement in the efficiency the depots and routs of transportation corporation.

Sunita Ramesh and Rajnalkar Laxman, (2017) [10], analyzed the financial performance of transportation company by considering the criteria viz., Cost per kilometers, Earnings per kilometers, Margin per kilometer and Gross Revenue. In the study, the authors suggested that the factors such as staff cost rationalization of schedules, Fuel Management and Tyres management etc. need to be controlled for improvement in the operating performance.

Jitendra Gurjar, et al., (2016) [11] developed evaluation methodology for performance evaluation of alternate public transport and illustrated with a case study. In the study, user perspective is considered and determined performance indicators such as, Comparative in vehicle Time Index, Comparative out of vehicle Time Index, Comparative cost performance Index, Comparative quality performance index, Comparative user performance index.

Goyal, et al., (2022) [12] determine the efficiency of depots related to Rajasthan State Road Transport Corporation through TOPSI, ELECTRE, VIKOR and made a comparison. The authors recommended the critical performance metrics for development of transportation sector.

Nassereddine and Hamidreza, (2017) [13] proposed hybrid method of Delphi, GAHP and PROMETHEE for performance evaluation of transportation systems (Public) and illustrated with a case study. influence of weights of the criteria was investigated through sensitivity analysis.

Mehdi, et al., (2022) [14] presented a short chronological assessment of past studies on Multi-Criteria Decision-Making (MCDM) techniques for estimating urban and state transportation corporations. In a conclusion, the researchers have concluded in their work they found a specific approach on urban and public transportation systems using MCDM approaches

Mouhamed, et al., (2023),[15] defined seven strategies for Bus rapid Transportation System and these strategies are evaluated using five criteria. Hybrid IMF SWARA-MARCOS methodology is implemented to evaluate the proposed strategies.

Svetla, (2019) [16] proposed a procedure depended on Sequential Interactive Modelling for Urban Systems (SIMUS) method for assessment of the urban transport technologies.

Shabani, et al., (2022) [17] provide a framework to estimate customer desires fulfillment on state transportations through an integrated best-worst method and fuzzy TOPSIS

Sarbast, et al., (2020) [18] proposed AHP–BWM Model for the state road transportation supply quality criteria. His work results that the priority ranking is robust.

Mohammadi and Jafar Rezaei, (2020) [19] proposed an algorithm which is adopted to obtain aggregate ranking.

From the earlier studies so far enumerated above, it is observed that there are limited applications of ratio based MCDM methods in evaluation and ranking of alternatives in transportation sector. However, ratio based MCDM methods find applications in various other fields.

Interpretation and Decision-Making: Analyze the results of the performance evaluation to gain insights into the strengths and weaknesses of each company. The rankings and scores obtained through ratio-based MCDM methods provide a basis for decision-making, such as identifying areas for improvement, benchmarking against competitors, or selecting potential partners or investments.

3. RATIO BASED MCDM METHODS

These ratio-based MCDM methods provide decision-makers with valuable tools to evaluate and compare the performance of passenger road transport companies. By considering multiple criteria and ratios, these methods offer a comprehensive and objective approach to assess company performance, identify areas for improvement, and make informed decisions for enhancing competitiveness in the industry. In this paper, MOORA, MOOSRA, MultiMOORA, and MultiMOOSRAL methods are implemented to a case study of 5 public passenger transport organizations. The methodology of the proposed methods is discussed in the following sections.

3.1 MOORA

MOORA methodology is presented here in stepwise.

Step-1: Decision matrix formulation. The decision matrix contains the pay offs of criteria of the alternatives.

$$A_{ij} = \begin{matrix} A_1 \\ A_2 \\ A_3 \\ \vdots \\ A_m \end{matrix} \begin{bmatrix} X_1 & X_2 & \cdots & X_n \\ X_{11} & X_{12} & \cdots & X_{1n} \\ X_{21} & X_{22} & \cdots & X_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ X_{m1} & X_{m2} & \cdots & X_{mn} \end{bmatrix}$$

$X_1, X_2, \ldots, X_n$ are 'n' number of enablers.
X_{mn} is pay off of n^{th} enabler for m^{th} alternative

Step-2: Normalization of the decision matrix.

Normalization process is realized by dividing criteria by the square root of the total of every squared alternatives in which i = 1,2,3,…,n is the number of alternatives and j = 1,2,3,…,m is the number of enablers. This process is realized by the formula below.

The data on enablers is normalized by using the following equation.

$$R_{ij} = \frac{A_{ij}}{\sqrt{\sum A_{ij}^2}}$$

Rij is normalized pay off of i^{th} enebler for j^{th} alternvative.

Step-3: Estimation of criteria relative weights.

Relative weights of the criteria may be calculated through any objective or subjective rating procedures

Step-4: Determine normalized assessment Index of the alternative.

Normalized assessment index of alternative is determined from the following relation.

$$\overline{y}_j^* = \sum_{i=1}^{i=g} s_i x_{ij}^* - \sum_{i=g+1}^{i=n} s_i x_{ij}^*$$

where j = 1,2,…,m; m - the number of alternatives;
i = 1,2,…,n; n - the number of enablers;
g - the number of non-beneficial enablers;
(n-g) - the number of beneficial enablers;
s_i - Relative weight of enabler 'i'.

Step-5: Alternatives Ranking: Performance assessment results of the alternatives are used for ranking of passenger public road transportation organizations and are placed depending on the descending order of normalized assessment index.

3.2 MOOSRA

The MOOSRA method is enumerated here in stepwise

Step-1: Determine the performance score (P_i): After determining, decision matrix, normalization and weights of the criteria, the score of performance of an alternative is calculated from the following relation.

$$P_i = \frac{\sum_{j=1}^{n} B_j Q_{ij}}{\sum_{j=h+1}^{n} B_j Q_{ij}}$$

where, j = 1,2,...,g indicates the beneficial criteria.

j = g + 1, g + 2,....,n is the non-beneficial criteria and B_j; is the associated weight of the j^{th} criteria.

Step-2: Ranking of alternatives: Performance estimates of the approaches are used for ranking of alternatives depending on the descending order of preference values.

3.3 MultiMOORA

The MultiMOORA method expands on the MOORA method by considering multiple objectives simultaneously. It permits the decision-makers to estimate and rank companies depending on a broader set of performance parameter, accommodating the complexity and diversity of passenger road transport companies.

The methodology is explained in the following steps.

Step-1: Obtain utility of Full Multiplicative form; To get value of Full Multiplicative form, the formula for utility value of alternatives is presented below.

$$u_i = \prod_{j=1}^{g} (x_{ij}^*)^{w_j} \Big/ \prod_{j=g+1}^{n} (x_{ij}^*)^{w_j}$$

where j =1,2,…,g represents criteria relating to benefit;

j = g+1 to n represents criteria relating to cost

Step-2: Ranking of alternatives: Utility values of the different possibilities are used for ranking of alternatives depended on the descending order of utility values.

3.4 MultiMOOSRAL

The newly proposed MULTIMOOSRAL method (Alptekin ULUTAŞ et al., 2021) The MULTIMOOSRAL method is presented in the steps discussed below

Step-1: Developing the first decision matrix and calculating the weights of criteria.

Step-2: Developing the normalization of the decision matrix from the following relation.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} (x_{ij})^2}}$$

Step-3: Estimating the normalized overall utilities of alternatives depended on the five approaches which are made integral part of the MULTIMOOSRAL method

Step-3.1: Calculating the utility of alternatives depended on the RS approach by using the substeps as state below:

Step 3.1.1: Estimation of the value of importance which is overall of the assumed alternatives is calculated by the following equation below

$$y_i = \sum_{j\in\theta_{\max}} w_j r_{ij} - \sum_{j\in\theta_{\min}} w_j r_{ij}$$

Step 3.1.2: Estimating the value of utility of assumed alternatives which is overall from the following relation

$$m_i' = \begin{cases} y_i, & \max_i(y_i) > 0 \\ y_i + 1, & \max_i(y_i) = 0 \\ -1/y_i, & \max_i(y_i) < 0 \end{cases}$$

where m_i defines alternative's value which is of overall utility i calculated depending on ratio system approach.

Step 3.1.3: Normalized value of the utilities which is overall in nature is calculated depending on RS method from the following relation

$$m_i' = \frac{m_i - \min(m_i)}{\max(m_i) - \min(m_i)}$$

Step 3.2: Estimation of the value of alternatives utility: The utility of alternatives dependent on the RP method by the procedure as discussed below

Step 3.2.1: Calculation of the point r* which is considered as reference as stated below:

$$r^* = (r_1^*, r_2^*, ..., r_n^*) = \left\{ \max_i r_{ij} \middle| j \in \theta_{\max}, \min_i r_{ij} \middle| j \in \theta_{\min} \right\}$$

Step 3.2.2: Estimating the maximum distance between each alternative and the reference point by the following relation.

$$t_i = \max_j \left(w_j \left| r_j^* - r_{ij} \right| \right)$$

Step 3.3: Estimating the utility of alternatives using FMF approach.

The utility of alternatives dependent on the FMF approach is derived as stated below.

Step 3.3.1: Estimation of the alternatives value of the overall utility by applying the following relation.

$$u_i = \frac{\prod_{j\in\theta_{\max}} w_j r_{ij}}{\prod_{j\in\theta_{\min}} w_j r_{ij}}$$

Step 3.3.2: Normalizing the alternatives value of the overall utility by depending on FMF approach from the following relation.

$$u_i' = \frac{u_i - \min(u_i)}{\max(u_i) - \min(u_i)}$$

Step 3.4: Estimating the alternatives value of the overall utility depending on addition form (AF) approach**:**

The steps stated below are used to determine utility of alternatives dependent on an addition form (AF) approach

Step 3.4.1: Estimating the alternatives value of the overall utility applying the following equation.

$$\upsilon_i = \frac{\sum_{j \in \theta_{\max}} w_j r_{ij}}{\sum_{j \in \theta_{\min}} w_j r_{ij}}$$

Step 3.4.2: Normalization alternatives value of the overall utility derived depending on AF approach from the following relation.

$$\upsilon_i' = \frac{\upsilon_i - \min(\upsilon_i)}{\max(\upsilon_i) - \min(\upsilon_i)}$$

where υ_i represents normalized overall utility of alternative i calculated using AF approach.

Step 3.5: Calculating the alternatives value of the overall utility dependent on LA approach as explained steps below.

Step 3.5.1: Calculating the alternatives value of the overall utility dependent on the LA method ki from the relation shown below

$$k_i = \sum_{j \in \theta_{\max}} \ln(1 + w_i r_{ij}) + \frac{1}{\sum_{j \in \theta_{\min}} \ln(1 + w_i r_{ij})}$$

Step 3.5.2: Normalization of alternatives value of the overall utility calculated by using AF method from the following relation.

$$k_i' = \frac{k_i - \min(k_i)}{\max(k_i) - \min(k_i)}$$

where k_i represents normalized overall utility of alternative i derived using the AF approach.

Step-4: Calculating the overall ranking orders of alternatives.

The overall ranking of alternatives is estimated depending on the value of total utility Si, which is derived from the following relation.

$$S_i = m_i' + t_i' + u_i' + \upsilon_i' + k_i'$$

Step 5: Ranking of alternatives.

The alternatives are graded depending on the values of Si in decreasing order and the alternative which is having greater value Si is the most suitable

3. CASE STUDY

In this paper a case study of 5 public sector passenger transportation organizations is considered. Data on 20 criteria for the 5 transportation organizations is obtained from the secondary sources. The case study aims to demonstrate the implementation of ratio-based MCDM methods, for the performance evaluation of passenger road transport companies. The study focuses on analyzing and ranking the companies based on four balanced score card perspectives: Learning and Growth, Internal business, Financial and Customer perspectives using the aforementioned MCDM methods. The data on the 20 criteria is presented in Table-1.

Table 1: Data on the balanced scorecard criteria

Perspective	Criteria	Description	PPTO1	PPTO2	PPTO3	PPTO4	PPTO5
Learning and Growth	CC1	Staff Productivity (B)	80.37	55.03	71.72	64.53	157.78
	CC2	Staff Strength (B)	56602	103053	37685	54127	23497
	CC3	Staff Bus ratio (B)	4.7	5.52	4.6	5.21	2.19
	CC4	Staff Cost/ Revenue Earning KMs (B)	15.49	15.38	14.79	17.18	10.36
	CC5	Staff Cost as % of Total Cost (B)	51.69	41.77	43.32	43.25	35.99
Internal Business Perspective	CC6	Fuel efficiency (KM/liter of HSD) (B)	5.21	4.78	4.85	5.14	5.25
	CC7	Vehicle Productivity (KMs/Bus/Day) (B)	376.39	302.64	328.68	334.89	343.64
	CC8	Occupancy ratio (B)	68.15	68.85	67.9	67.98	68.1
	CC9	Average age of Fleet (C)	5.47	5.43	5.24	7.45	4.54
	CC10	Effective Kms / Revenue earning Kms covered (B)	376.39	302.64	328.68	334.89	343.64
Financial	CC11	Revenue/KM (B)	31.77	34.36	32.32	33.85	29.45
	CC12	Revenue/Bus/Day (B)	119.26	103.75	105.98	113.1	100.93
	CC13	Cost/Km (C)	29.96	36.81	34.12	39.74	28.73
	CC14	Cost/Bus/Day (C)	112.47	110.6	111.88	132.8	98.46
	CC15	Total Costs per revenue earnings (C)	2.51	4.8	1.56	2.1	3.31
Customer	CC16	Passenger KM performed (Lakhs) (B)	538562	615737	350288	432574	445738
	CC17	Number of accidents (C)	1211	2777	1055	801	653
	CC18	Passengers carried (Lakhs) (B)	24027	24448	9969	34889.8	5655.91

Perspective	Criteria	Description	PPTO1	PPTO2	PPTO3	PPTO4	PPTO5
	CC19	Overaged vehicles (%) (C)	13.39	8.48	25.3	8.82	8.36
	CC20	Fleet size N(B)	12082	18720	8222	10425	10790

Note: B-Benefit Criteria; C-Cost criteria

4. RESULTS AND DISCUSSION

The performance evaluation of passenger road transport companies using ratio-based MCDM methods, namely MOORA, MOOSRA, MultiMOORA, and Multi MOOSRAL, provides valuable insights into the relative performance of these companies. The results obtained from the case study analysis are presented below.

4.1 MOORA

Decision matrix:

The decision matrix contains the pay offs of criteria of the alternatives and is stated in Table-2.

Table-2: Decision matrix

Alts	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8	CC9	CC10
AA1	80.37	56602	4.7	15.49	51.69	5.21	376.39	68.15	5.47	376.39
AA2	55.03	103053	5.52	15.38	41.77	4.78	302.64	68.85	5.43	302.64
AA3	71.72	37685	4.6	14.79	43.32	4.85	328.68	67.9	5.24	328.68
AA4	64.53	54127	5.21	17.18	43.25	5.14	334.89	67.98	7.45	334.89
AA5	157.78	23497	2.19	10.36	35.99	5.25	343.64	68.1	4.54	343.64
Alts	**CC11**	**CC12**	**CC13**	**CC14**	**CC15**	**CC16**	**CC17**	**CC18**	**CC19**	**CC20**
AA1	31.77	119.26	29.96	112.47	2.51	538562	1211	24027	13.39	12082
AA2	34.36	103.75	36.81	110.6	4.8	615737	2777	24448	8.48	18720
AA3	32.32	105.98	34.12	111.88	1.56	350288	1055	9969	25.3	8222
AA4	33.85	113.1	39.74	132.8	2.1	432574	801	34890	8.82	10425
AA5	29.45	100.93	28.73	98.46	3.31	445738	653	5655.9	8.36	10790

4.1.1 Normalized decision matrix

Normalized Decision Matrix is obtained as discussed in step 2 of section 2.1 and is presented in Table-3.

Table-3: Normalized decision matrix

Alts	CC1	CC2	CC3	CC4	CC5	CC6	CC7	CC8	CC9	CC10
AA1	0.3845	0.4136	0.4572	0.4675	0.5315	0.4614	0.4979	0.4469	0.4285	0.4979
AA2	0.2633	0.7531	0.537	0.4642	0.4295	0.4233	0.4003	0.4515	0.4253	0.4003
AA3	0.3431	0.2754	0.4475	0.4464	0.4454	0.4295	0.4348	0.4453	0.4105	0.4348
AA4	0.3087	0.3955	0.5069	0.5185	0.4447	0.4552	0.443	0.4458	0.5836	0.443

AA5	0.7549	0.1717	0.2131	0.3127	0.37	0.465	0.4546	0.4466	0.3556	0.4546
Alts	**CC11**	**CC12**	**CC13**	**CC14**	**CC15**	**CC16**	**CC17**	**CC18**	**CC19**	**CC20**
AA1	0.4386	0.4902	0.3927	0.4421	0.3656	0.4963	0.3593	0.4783	0.4154	0.4301
AA2	0.4743	0.4264	0.4824	0.4347	0.6991	0.5674	0.8239	0.4867	0.2631	0.6664
AA3	0.4462	0.4356	0.4472	0.4397	0.2272	0.3228	0.313	0.1984	0.7849	0.2927
AA4	0.4673	0.4648	0.5209	0.522	0.3059	0.3986	0.2377	0.6945	0.2736	0.3711
AA5	0.4065	0.4148	0.3765	0.387	0.4821	0.4107	0.1937	0.1126	0.2594	0.3841

4.1.2 Relative weights of criteria

Initially equal weights of the criteria are considered.

4.1.3 Ranking of alternatives

Normalized assessment index of the alternatives are determined as discussed in step 4 of section 2.1 and the values and grading of alternatives depending on assessment index are stated in Table-4.

Table 4: Alternatives ranking

Alternative	Normalized assessment index	Rank
PPTO1	0.204415902	1
PPTO2	0.180752729	3
PPTO3	0.138764011	5
PPTO4	0.195706356	2
PPTO5	0.165870469	4

4.2 MOOSRA

Results obtained through MOOSRA are discussed in the following sections

4.2.1 Performance score

Performance score obtained as discussed in step 1 of section 2.2 and ranking obtained from performance score are presented in Table-5.

Table-5: Performance score and ranking of alternatives

Alternative	Overall importance		Performance score	Rank
	Benefit criteria	Cost criteria		
PPTO1	0.3246	0.1202	2.7010	1
PPTO2	0.1808	0.1564	1.1555	4
PPTO3	0.1388	0.1311	1.0582	5
PPTO4	0.1957	0.1222	1.6018	3
PPTO5	0.1659	0.1027	1.6148	2

4.3 MultiMOORA

Results obtained through MultiMOORA are discussed in the following sections.

4.3.1 Utility value of full multiplicative form

Utility values of full multiplicative form are obtained from the step step-1 of section 2.3. Ranking of Alternatives depending on the utility values of the alternatives. Table-6.

Table-6: Alternatives ranking through MultiMOORA

Alternative	Overall Importance		Performance score	Rank
	Benefit criteria	Cost criteria		
PPTO1	0.5826	0.7593	0.7672	1
PPTO2	0.5877	0.8064	0.7289	3
PPTO3	0.5038	0.7633	0.6600	5
PPTO4	0.5691	0.7498	0.7589	2
PPTO5	0.4794	0.7160	0.6695	4

4.4 MultiMOOSRAL

Results obtained through MultiMOOSRAL are discussed in section 2.4. The utility values based on RS, RP, FMF, AF and LA approaches are determined. Total utility value is determined as discussed in step-4 of section 2.4. Based on the overall utility values, the alternatives are ranked and stated in Table-7.

Table-7: Alternatives ranking through MultiMOOSRAL

Alternatives	Normalized utility based on RS(m'_i)	Normalized maximal distance based on RS(t'_i)	overall utilities based on FMF(u'_i)	overall utilities based on AF (υ'_i)	Overall utility based on LA approach (k'_i)	Total utility (S_i)	Rank
PPTO1	1.0000	1.0000	1.0000	1.0000	0.5829	4.5829	1
PPTO2	0.6396	0.0000	0.3252	0.1513	0.0000	1.1160	4
PPTO3	0.0000	0.4027	0.0000	0.0000	0.3578	0.7605	5
PPTO4	0.8673	0.7084	0.7946	0.8457	0.5419	3.7579	2
PPTO5	0.4129	0.1858	0.0171	0.8659	1.0000	2.4817	3

4.5 Comparison of Ranking through the Proposed Methods

Comparison of ranking pattern of public passenger transport organizations is presented in Table-8.

Table-8: Ranking of proposed ratio based methods.

Alternatives	MOORA	MOOSRA	MultiMOORA	MultiMOOSRAL
PPTO1	1	1	1	1
PPTO2	3	4	3	4
PPTO3	5	5	5	5
PPTO4	2	3	2	2

PPTO5	4	2	4	3

From the finding of the work, it is found that PPTO1 received the good rank in all the worked methods. It demonstrated excellent Staff Cost as % of Total Cost, Vehicle Productivity (KMs/Bus/Day), Effective Kms / Revenue earning Kms covered and Revenue/Bus/Day. PPTO3 obtained poor rank. It demonstrated good in Total Costs per revenue earnings and Fleet Size. In case of PPIO2, PPIO4 and PPIO 5, similar ranking was obtained with the proposed methods. Similar ranking pattern is obtained with MOORA and MultiMOORA

5. CORRELATIONS OF THE METHODS

Correlation between the proposed methods in respect of their ranking is computed using Minitab-16. It is observed that there is high significant positive correlation existed between the proposed methods, since the p-value is equal to 0.00, there is sufficient evidence at $\alpha = 0.00$ that there exists significant correlation between the proposed ratio based methods in evaluation and ranking of public passenger transport organizations.

Table-9: Correlation among the proposed methods

Method	MOORA	MOOSRA	MultiMOORA	MultiMOOSRAL
MOORA	1.0000	0.7000	1.0000	0.9000
MOOSRA	0.7000	1.0000	0.7000	0.9000
MultiMOORA	1.0000	0.7000	1.0000	0.9000
MultiMOOSRAL	0.9000	0.9000	0.9000	1.0000

5.1 Aggregation of Ranks

Aggregating ranks obtained through different methods in MCDMs can present a more comprehensive and robust evaluation of alternatives. Different MCDM methods may utilize distinct approaches, criteria weighting techniques, or normalization procedures. Aggregating the ranks obtained from various methods helps ensure consistency and minimize potential biases or limitations associated with a single method.

When aggregating ranks obtained from different methods, various techniques can be employed, such as the Borda count, Copeland, rank averaging, weighted rank aggregation etc.

It's important to note that the aggregation process should be done carefully, taking into account the relative importance of each method, the quality of data and rankings, and potential biases or inconsistencies across methods. Transparent documentation and communication of the aggregation approach will help ensure the credibility and acceptance of the final decision outcomes.

The ranking algorithm is presented below. The algorithm is implemented through Matlab14 to arrive final ranking. Aggregate ranks of the alternatives are presented in Table-10.

Table-10: Aggregate ranks of alternatives

Algorithm 1 Ensemble ranking

Input: Rankings R_m, $m = 1,2,\ldots,M$.

while Not converged **do**
$\alpha_m = \delta(||R^m - R^*||2$, m = 1,2,…,M
$w_m = \alpha_m/\Sigma_j\alpha_j$, m = 1,2,…,M
$R^* = \Sigma_m w_m R^m$
end while
Output Final ranking R*, α

Based on the aggregate ranks, rank order is obtained as given below.

PPTO1 > PPTO4 > PPTO5 > PPTO2 > PPTO3.

The ranking is similar to the rank obtained with MultiMOOSRAL.

Every MCDM method has its own merits and demerits. Aggregation allows for leveraging the strengths of multiple methods while mitigating their limitations. By combining different methods, decision-makers can gain a better meaning of the decision problem.

MCDM procedures inherently involve uncertainty, particularly when subjective judgments or imprecise data are involved. Aggregating ranks from multiple methods can help reduce uncertainty by providing a more robust and well-rounded evaluation of alternatives.

MCDM methods may incorporate different perspectives or preferences, depending on the criteria weighting or evaluation techniques used. Aggregation allows decision-makers to consider diverse viewpoints, leading to more inclusive and balanced decision outcomes.

Aggregating ranks provides a composite picture of the alternatives' performance across different MCDM methods. It helps identify consistent high-ranking or low-ranking alternatives, allowing decision-makers to gain more confidence in their decisions.

Aggregation of ranks can facilitate stakeholder engagement and consensus-building processes. By considering results from multiple methods, decision-makers can foster discussions and negotiations among stakeholders with different perspectives, leading to more informed and collaborative decisions.

These methods emphasize on simple mathematical operations on the criteria which is depending benefit and the other criteria which is dependent on cost to quantify the relative efficiency or preference of alternatives based on the benefit and cost criteria. Ratio-based methods allow the people who make decisions to understand the relative efficiency of alternatives, making it easier to interpret and communicate the decision-making outcomes. Ratio-based methods focus on simple mathematical operations, without explicitly capturing complex dependencies or trade-offs between the criteria. Ratio-based methods like MOORA, MOOSRA, MultiMOORA and MultiMOOSRAL are relatively easy to implement and computationally efficient. They require minimal data processing and do not involve complex calculations or extensive data requirements.

The results from this work will present valuable information to the performance assessment of passenger road transport companies and aid decision-makers in making informed decisions for enhancing competitiveness and operational efficiency in the industry.

6. SENSITIVITY ANALYSIS

In this study Vector normalization scheme is adopted. However, this process is used to verify the impact of normalization methods on the problem. In this study, the five well known normalization techniques namely: Linear Sum, Linear Maximum, Linear Max-Min and Enhanced accuracy. The results are presented in Table-11.

Table-11: Results of sensitive analysis

Alternatives	MOORA					Alternatives	MOOSRA				
	Vector normalization	Linear Max	Linear Sum	Linear Max -Min	Enhanced accuracy		Vector normalization	Linear Max	Linear Sum	Linear Max -Min	Enhanced accuracy
PPTO1	1	1	1	1	1		1	1	1	2	1
PPTO2	3	3	3	2	3		4	4	4	4	4
PPTO3	5	5	5	5	5		5	5	5	5	5
PPTO4	2	2	2	3	2		3	3	3	3	3
PPTO5	4	4	4	4	4		2	2	2	1	2
Alternatives	MultiMOORA					Alternatives	MultiMOOSRAL				
	Vector normalization	Linear Max	Linear Sum	Linear Max -Min	Enhanced accuracy		Vector normalization	Linear Max	Linear Sum	Linear Max -Min	Enhanced accuracy
PPTO1	1	1	1	1	1		1	1	1	1	1
PPTO2	3	3	3	3	3		4	4	4	3	4
PPTO3	5	5	5	3	5		5	5	5	4	5
PPTO4	2	2	2	2	2		2	2	2	5	3
PPTO5	4	4	4	3	4		3	3	3	2	2

Analysis of Variance for Rank

There are two factors viz., MCDM Method and Normalization method each with four levels and five levels respectively. Analysis of variance is conducted using Minitab 16. The ANOVA results are presented below.

Source DF SS MS F P

Method 3 0.270 0.090 0.04 0.988

N Method 4 0.360 0.090 0.04 0.997

Error 92 194.280 2.112

Total 99 194.910

From the results of the ANOVA, it is observed that there is no significant effect of method or normalization method on the ranking value of alternatives at p-value 0.05 since the p- values (0.988 and 0.997) are more than 0.05.

7. CONCLUDING REMARKS

In conclusion, the application of MOORA, MOOSRA, (MultiMOORA), and MultiMOOSRAL can be highly beneficial for performance evaluation and ranking of public transport organizations. These methods provide a comprehensive and systematic route to estimate the efficiency of state transport organizations by taking multiple parameters and objectives.

One of the key advantages of these techniques is their ability to handle multiple criteria simultaneously, allowing decision-makers to consider various factors such as efficiency, effectiveness, safety, environmental impact, and customer satisfaction. By employing these methods, decision-makers can make informed decisions and identify areas for improvement in public transport systems.

Furthermore, these techniques facilitate the comparison and ranking of different public transport organizations. The application of MOORA, MOOSRA, MultiMOORA, and MultiMOOSRAL enables decision-makers to objectively evaluate the performance of multiple organizations and identify the best performers based on the defined criteria. This can lead to healthy competition among organizations, driving them to improve their services and overall performance. Integrating sustainability metrics into the evaluation framework to assess the environmental impact of public transport organizations. This includes evaluating energy efficiency, emissions reduction, adoption of clean technologies, and promoting sustainable transportation practices.

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