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PERFORMANCE EVALUATION OF GROUND OPERATIONS AGENTS WITH GREY PIPRECIA AND GREY MARCOS

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Abstract:
In this study, the performance of four ground operations agents working in a ground handling company was evaluated using Grey Piprecia and Grey Marcos methods, which are multi criteria decision making methods. As a result of the evaluation of criteria, the criteria of "mastery of technical issues in the job description", "ability to take initiative in difficult situations", and "effective communication skill" ranked first, second and third, respectively. In the performance evaluation, ground operations agent A1 was the best performer. Very few studies using Grey PIPRECIA and Grey MARCOS methods are available in the literature. However, until now there has been no study regarding the performance evaluation of ground operations agents using mentioned methods. With these aspects, the study will fill an important gap in the literature.

Key words:
PIPRECIA-G, MARCOS-G, multi criteria decision making, ground operations agent, aviation

1 INTRODUCTION

Aviation has been a continuously developing sector since the beginning of the passion for flying. Civil aviation includes both private and commercial aviation. Scheduled air transport and general aviation are two major categories of it. Ground handling is an important activity at an airport and acts as an interface between the airlines and the airport. Ground handling has been playing an increasing role for enhancing efficiency at the airport and is a key part of airport operations than just a profit stream [1].

Ground operations agents play a key role in preventing unsafe situations from arising. The Ground Operations Agent deals with marshalling in and pushing back the aircraft, the handling of customer baggage, meet and service arriving and departing flights, operation of ground service equipment (GSE), assist customers with special needs, assist customer service agents, as needed, and any other duties as assigned [2].

Due to the importance of ground operations agents to the aviation sector, the aim of this study is to evaluate the performance of four ground operations agents working in a ground handling company and to determine the criteria that are effective in performance evaluation. In the study, Grey PIPRECIA and Grey MARCOS methods were used. The importance of the criteria was calculated by Grey PIPRECIA. The ranking of agents was determined by Grey MARCOS.

The remainder of this paper is as follows. Section 2 provides a review of extant literature on the multi criteria decision making methods used for performance evaluation. Section 3 describes methodology and explains the fundamental techniques employed therein-Grey PIPRECIA and Grey MARCOS. Section 4 presents an application case which measures performance of ground operations agents. Section 5, the last chapter of the paper, offers concluding remarks about the study.

2 LITERATURE REVIEW

Since the Grey PIPRECIA [3] and Grey MARCOS [4] methods have been newly developed, the number of publications using these methods is few. Table 1 gives a review of the related literature.

Tab. 1. *Literature review* [3-21]

Authors	Problem	Methods
	Studies Related to Aviation Sector	
Ozdagoglu et al. (2021)	Cabin crew selection for an airline [5]	Fuzzy SWARA & Fuzzy MARCOS
Bakır and Atalik (2021)	Examining e-service quality in the airline industry [6]	Fuzzy AHP&Fuzzy MARCOS
Bakır, Akan and Durmaz (2019)	Examining service quality of low-cost airlines in Europe [7]	Entropy & WASPAS
Pandey and Shukla (2019)	Examining the human performance factors of air traffic control in Thailand [8]	Fuzzy MCD
Havle and Kılic (2019)	Identifying gross navigation errors during transatlantic flights [9]	Fuzzy AHP
Li et.al (2017)	Examining in-flight service quality [10]	Fuzzy AHP
	Grey Piprecia	
Yazdani *et al.* (2019b)	Determination of supplier performances for a construction	CoCoSo-G

	business in Madrid [11]	
Dalic et.al. (2020)	Selection of green supplier [12]	Fuzzy PIPRECIA
Ulutas et.al. (2020)	Personnel selection [3]	Grey PIPRECIA& Grey OCRA
Jocic et.al. (2020)	E-learning course selection [13]	PIPRECIA& Fuzzy ARAS
Matic et.al. (2021)	Selection of asphalt production plants [14	IRINA PIPRECIA& IRN EDAS
Stanujkic et.al. (2018)	Examining website quality of hotel industry [15]	PIPREICA&WS PLP
Stevic et.al. (2018)	Implementing information technology in a warehouse system [16]	Fuzzy PIPRECIA
	Grey MARCOS Method	
Stevic *et al.* (2020)	Selection of supplier in healthcare industries [17]	MARCOS
Badi and Pamucar (2020)	Selection of supplier for steelmaking company [18]	Grey-Marcos
Chakraborty et.al. (2020)	Selection of supplier in an iron and steel industry [19]	D-MARCOS
Puska et.al. (2020)	Evaluation software of project management [20]	MARCOS
Stevic and Brkovic (2020)	Examining human resources in a transport company [21]	FUCOM MARCOS
Stankovic et.al. (2020)	Road traffic risk analysis [4]	Fuzzy MARCOS
Ulutas et.al. (2020)	Stackers selection in a logistics system [3]	CCSD-ITIRA-MARCOS

3 RESEARCH METHODOLOGY

In this study, Grey PIPRECIA and Grey MARCOS methods were used. Since both methods are new to the literature, there are very few studies employing these methods. In this section, the algorithms of these methods are explained step-by-step using the equations.

3.1 Grey PIPRECIA

Grey PIPRECIA (Grey Pivot Pairwise Relative Criteria Importance Assessment) is a method that integrates PIPRECIA and grey theory. The procedure is as follows [3].

In the first phase of PIPRECIA-G method, the criteria are determined by experts.

$$j: criterion; j = 1,2,3, \dots, n$$

In the second phase of PIPRECIA-G method, the decision makers evaluate the criteria. Grey evaluation scale can be seen in Ulutas et al., 2020, 5.

$$d: decision\ maker; d = 1,2,3, \dots, D$$

$$\underline{s}_{jd}: gray\ evaluation\ scale\ lower\ limit\ value\ according\ to\ decision\ maker\ d$$

$\overline{s}_{jd}: gray\ evaluation\ scale\ upper\ limit\ value\ according\ to\ decision\ maker\ d$

The structure of relative importance can be seen in Equation 1.

$$\begin{cases} Criterion\ j\ is\ more\ important\ than\ criterion\ (j-1) \Rightarrow \underline{s}_{jd} \geq 1 \\ Criterion\ j\ is\ more\ important\ than\ criterion\ (j-1) \Rightarrow \overline{s}_{jd} \geq 1 \\ importance\ of\ criterion\ j = importance\ of\ criterion\ (j-1) \Rightarrow \underline{s}_{jd} = 1 \\ importance\ of\ criterion\ j = importance\ of\ criterion\ (j-1) \Rightarrow \overline{s}_{jd} = 1 \\ Criterion\ (j-1)\ is\ more\ important\ than\ criterion\ j \Rightarrow \underline{s}_{jd} \leq 1 \\ Criterion\ (j-1)\ is\ more\ important\ than\ criterion\ j \Rightarrow \overline{s}_{jd} \leq 1 \end{cases} \tag{1}$$

The opinions of the decision makers are integrated by using Equation 2 and 3.

$\underline{s}_j: gray\ relative\ importance\ lower\ limit\ value$

$\overline{s}_j: gray\ relative\ importance\ upper\ limit\ value$

$$\underline{s}_j = \sqrt[D]{(\underline{s}_{j1})(\underline{s}_{j2})(\underline{s}_{j3}) \dots (\underline{s}_{jD})} \tag{2}$$

$$\overline{s}_j = \sqrt[D]{(\overline{s}_{j1})(\overline{s}_{j2})(\overline{s}_{j3}) \dots (\overline{s}_{jD})} \tag{3}$$

Grey coefficient is calculated by using Equation 4 and 5.

$\underline{k}_j: gray\ coefficient\ lower\ limit\ value\ of\ criterion\ j$

$\overline{k}_j: gray\ coefficient\ upper\ limit\ value\ of\ criterion\ j$

$$\underline{k}_j = \begin{cases} j = 1 \Rightarrow 1 \\ j > 1 \Rightarrow 2 - \overline{s}_j \end{cases} \tag{4}$$

$$\overline{k}_j = \begin{cases} j = 1 \Rightarrow 1 \\ j > 1 \Rightarrow 2 - \underline{s}_j \end{cases} \tag{5}$$

The weights of criteria are calculated by Equation 6 and 7.

$\underline{q}_j: weight\ lower\ limit\ value\ of\ criterion\ j$

$\overline{q}_j: weight\ upper\ limit\ value\ of\ criterion\ j$

$$\underline{q}_j = \begin{cases} j = 1 \Rightarrow 1 \\ j > 1 \Rightarrow \frac{\underline{q}_{(j-1)}}{\overline{k}_j} \end{cases} \tag{6}$$

$$\overline{q}_j = \begin{cases} j = 1 \Rightarrow 1 \\ j > 1 \Rightarrow 2 - \frac{\overline{q}_{(j-1)}}{\underline{k}_j} \end{cases} \tag{7}$$

Grey relative weights of criteria are calculated by Equation 8 and 9.

$\underline{w}_j: gray\ relative\ weight\ lower\ limit\ value\ of\ criterion\ j$

$\overline{w}_j: gray\ relative\ weight\ upper\ limit\ value\ of\ criterion\ j$

$$\underline{w}_j = \frac{\underline{q}_j}{\sum_{j=1}^{n} \overline{q}_j} \tag{8}$$

$$\overline{w}_j = \frac{\overline{q}_j}{\sum_{j=1}^{n} q_j} \tag{9}$$

These weight values show the grey importance levels of criteria according to PIPRECIA-G.

3.2 MARCOS-G (Grey measurement alternatives and ranking according to the compromise solution)

MARCOS-G is a method that integrates MARCOS and grey theory. The procedure is as follows [4].

The decision makers evaluate the performance of the alternatives by using the grey scale in Ulutas and Bayrakcil, 2017, 193.

$$i: alternative; i = 1,2,3,\dots,m$$

$$\underline{x}_{ijd}: gray\ performance\ lower\ limit\ value\ decision\ maker\ d$$

$$\overline{x}_{ijd}: gray\ performance\ upper\ limit\ value\ decision\ maker\ d$$

The evaluations of the decision makers are integrated by using Equations 10 and 11.

$$\underline{x}_{ij}: grey\ performance\ lower\ limit\ value$$

$$\overline{x}_{ij}: grey\ performance\ upper\ limit\ value$$

$$\underline{x}_{ij} = \frac{\sum_{d=1}^{D} \underline{x}_{ijd}}{D} \tag{10}$$

$$\overline{x}_{ij} = \frac{\sum_{d=1}^{D} \overline{x}_{ijd}}{D} \tag{11}$$

Extended grey decision matrix is set up by calculating grey ideal and anti-ideal solutions. Grey anti-ideal solution values are found by using Equations 12 and 13.

$$\underline{x}_{AIj}: grey\ anti-ideal\ solution\ lower\ limit\ value\ for\ criterion\ j$$

$$\overline{x}_{AIj}: grey\ anti-ideal\ solution\ upper\ limit\ value\ for\ criterion\ j$$

$$\underline{x}_{AIj} = \begin{cases} j \in benefit \Rightarrow \min_j \underline{x}_{ij} \\ j \in cost \Rightarrow \max_j \underline{x}_{ij} \end{cases} \tag{12}$$

$$\overline{x}_{AIj} = \begin{cases} j \in benefit \Rightarrow \min_j \overline{x}_{ij} \\ j \in cost \Rightarrow \max_j \overline{x}_{ij} \end{cases} \tag{13}$$

Grey ideal solution values are calculated by Equations 14 and 15.

$$\underline{x}_{Ij}: grey\ ideal\ solution\ lower\ limit\ value\ for\ criterion\ j$$

$$\overline{x}_{Ij}: grey\ ideal\ solution\ upper\ limit\ value\ for\ criterion\ j$$

$$\underline{x}_{Ij} = \begin{cases} j \in benefit \Rightarrow \max_j \underline{x}_{ij} \\ j \in cost \Rightarrow \min_j \underline{x}_{ij} \end{cases} \tag{14}$$

$$\overline{x}_{Ij} = \begin{cases} j \in benefit \Rightarrow \max_j \overline{x}_{ij} \\ j \in cost \Rightarrow \min_j \overline{x}_{ij} \end{cases} \tag{15}$$

Extended grey decision matrix values are normalized by using Equations 16 and 17.

$$\underline{n}_{ij}: grey\ normalized\ performance\ lower\ limit\ value$$

$$\overline{n}_{ij}: grey\ normalized\ performance\ upper\ limit\ value$$

$$\underline{n}_{ij} = \begin{cases} j \in benefit \Rightarrow \dfrac{\underline{x}_{ij}}{\overline{x}_{Ij}} \\ j \in cost \Rightarrow \dfrac{\underline{x}_{Ij}}{\overline{x}_{ij}} \end{cases} \tag{16}$$

$$\overline{n}_{ij} = \begin{cases} j \in benefit \Rightarrow \dfrac{\overline{x}_{ij}}{\overline{x}_{Ij}} \\ j \in cost \Rightarrow \dfrac{\underline{x}_{Ij}}{\underline{x}_{ij}} \end{cases} \tag{17}$$

Grey weighted performance values are calculated by using Equations 18 and 19.

$$\underline{v}_{ij}: grey\ weighted\ normalized\ performance\ lower\ limit\ value$$

$$\overline{v}_{ij}: grey\ weighted\ normalized\ performance\ upper\ limit\ value$$

$$\underline{v}_{ij} = \underline{w}_j \underline{n}_{ij} \tag{18}$$

$$\overline{v}_{ij} = \overline{w}_j \overline{n}_{ij} \tag{19}$$

Sum of the grey weighted normalized performance values is calculated by Equations 20 and 21.

$$\underline{S}_i: total\ grey\ weighted\ normalized\ performance\ lower\ limit\ value$$

$$\overline{S}_i: total\ grey\ weighted\ normalized\ performance\ upper\ limit\ value$$

$$\underline{S}_i = \sum_{j=1}^{n} \underline{v}_{ij} \tag{20}$$

$$\overline{S}_i = \sum_{j=1}^{n} \overline{v}_{ij} \tag{21}$$

Sum of the grey weighted normalized performance values for grey ideal solution is calculated by using Equations 22 and 23.

$$\underline{S}_I: total\ ideal\ grey\ weighted\ normalized\ performance\ lower\ limit\ value$$

$$\overline{S}_I: total\ ideal\ grey\ weighted\ normalized\ performance\ upper\ limit\ value$$

$$\underline{S}_I = \sum_{j=1}^{n} \underline{v}_{Ij} \tag{22}$$

$$\overline{S}_I = \sum_{j=1}^{n} \overline{v}_{Ij} \tag{23}$$

Sum of the grey weighted normalized performance values for grey anti-ideal solution is calculated by using Equations 24 and 25.

$$\underline{S}_{AI}: total\ anti-ideal\ grey\ weighted\ normalized\ performance\ lower\ limit\ value$$

$$\overline{S}_{AI}: total\ anti-ideal\ grey\ weighted\ normalized\ performance\ upper\ limit\ value$$

$$\underline{S}_{AI} = \sum_{j=1}^{n} \underline{v}_{AIj} \tag{24}$$

$$\overline{S}_{AI} = \sum_{j=1}^{n} \overline{v}_{AIj} \tag{25}$$

Grey utility values according to the anti-ideal solution for each alternative are calculated by Equation 26 and 27.

$$\underline{K_i}^{-}: grey\ utility\ lower\ limit\ value\ \ according\ to\ the\ anti-ideal\ solution$$

$$\overline{K_i}^{-}: grey\ utility\ upper\ limit\ value\ \ according\ to\ the\ anti-ideal\ solution$$

$$\underline{K_i}^{-} = \frac{\underline{S_i}}{\overline{S_{AI}}} \tag{26}$$

$$\overline{K_i}^{-} = \frac{\overline{S_i}}{\underline{S_{AI}}} \tag{27}$$

Grey utility values according to the ideal solution for each alternative are calculated by using Equation 28 and 29.

$$\underline{K_i}^{+}: grey\ utility\ lower\ limit\ value\ \ according\ to\ the\ ideal\ solution$$

$$\overline{K_i}^{+}: grey\ utility\ upper\ limit\ value\ \ according\ to\ the\ ideal\ solution$$

$$\underline{K_i}^{+} = \frac{\underline{S_i}}{\overline{S_I}} \tag{28}$$

$$\overline{K_i}^{+} = \frac{\overline{S_i}}{\underline{S_I}} \tag{29}$$

These grey utility values are aggregated by using Equations 30 and 31.

$$\underline{t_i}: aggregated\ grey\ utility\ lower\ limit\ value$$

$$\overline{t_i}: aggregated\ grey\ utility\ \ upper\ limit\ value$$

$$\underline{t_i} = \underline{K_i}^{-} + \underline{K_i}^{+} \tag{30}$$

$$\overline{t_i} = \overline{K_i}^{-} + \overline{K_i}^{+} \tag{31}$$

The greatest aggregated grey utility value is found by using Equations 32 and 33.

$$\underline{m}: greatest\ aggregated\ grey\ utility\ lower\ limit\ value$$

$$\overline{m}: greatest\ aggregated\ grey\ utility\ \ upper\ limit\ value$$

$$\underline{m} = \max_i \underline{t_i} \tag{32}$$

$$\overline{m} = \max_i \overline{t_i} \tag{33}$$

The greatest aggregated utility value is found by using Equation 34.

$$m: greatest\ aggregated\ utility\ value$$

$$m = \frac{\underline{m}+\overline{m}}{2} \tag{34}$$

Grey utility function with respect to ideal solution is calculated by Equations 35 and 36.

$$f\left(\underline{K_i}^{+}\right): grey\ utility\ function\ lower\ limit\ with\ respect\ to\ ideal\ solution$$

$$f\left(\overline{K_i}^{+}\right): grey\ utility\ function\ upper\ limit\ with\ respect\ to\ ideal\ solution$$

$$f\left(\underline{K_i}^{+}\right) = \frac{\underline{K_i}^{-}}{m} \tag{35}$$

$$f\left(\overline{K_i}^{+}\right) = \frac{\overline{K_i}^{-}}{m} \tag{36}$$

Grey utility function with respect to anti-ideal solution is calculated by Equations 37 and 38.

$f\left(\underline{K_i^-}\right)$: $grey\ utility\ function\ lower\ limit\ with\ respect\ to\ anti-ideal\ solution$

$f\left(\overline{K_i^-}\right)$: $grey\ utility\ function\ upper\ limit\ with\ respect\ to\ anti-ideal\ solution$

$$f\left(\underline{K_i^-}\right) = \frac{\underline{K_i^+}}{m} \tag{37}$$

$$f\left(\overline{K_i^-}\right) = \frac{\overline{K_i^+}}{m} \tag{38}$$

Utility value with respect to ideal solution is calculated by Equation 39.

K_i^+: $utility\ value\ with\ respect\ to\ ideal\ solution$

$$K_i^+ = \frac{\underline{K_i^+} + \overline{K_i^+}}{2} \tag{39}$$

Utility value with respect to anti-ideal solution is calculated by Equation 40.

K_i^-: $utility\ value\ with\ respect\ to\ ideal\ solution$

$$K_i^- = \frac{\underline{K_i^-} + \overline{K_i^-}}{2} \tag{40}$$

Utility function with respect to ideal solution is calculated by Equation 41.

$f(K_i^+)$: $utility\ function\ with\ respect\ to\ ideal\ solution$

$$f(K_i^+) = \frac{f(\underline{K_i^+}) + f(\overline{K_i^+})}{2} \tag{41}$$

Utility function with respect to anti-ideal solution is calculated by Equation 42.

$f(K_i^-)$: $utility\ function\ with\ respect\ to\ anti-ideal\ solution$

$$f(K_i^-) = \frac{f(\underline{K_i^-}) + f(\overline{K_i^-})}{2} \tag{42}$$

The ultimate utility function value is calculated by Equation 43.

$f(K_i)$: $ultimate\ utility\ function$

$$f(K_i) = \frac{K_i^+ + K_i^-}{1 + \frac{1-f\left(K_i^+\right)}{f\left(K_i^+\right)} + \frac{1-f\left(K_i^-\right)}{f\left(K_i^-\right)}} \tag{43}$$

The highest ultimate utility function shows the best alternative in the problem.

4 APPLICATION

In this study, the performance of ground operations agents is evaluated by using PIPRECIA-G and MARCOS-G methods. PIPRECIA-G method is used for determining the weights of the performance evaluation criteria. In the first phase of PIPRECIA-G method, the criteria are determined by experts. The evaluation criteria can be seen in Table 2.

Tab. 2. *Evaluation Criteria*

Criterion Code	Criterion Name
K1	Mastery of technical issues in the job description
K2	Ability to take initiative in difficult situations

K3	Effective communication skill
K4	Ability to speak a foreign language
K5	Ability to keep up with digital technologies
K6	Ability to work in a team
K7	Ability to work rotating shifts

The performance evaluation of the ground operations agents was done by five experts. Two of these experts are working in the human resources unit of a ground handling company at Isparta Suleyman Demirel Airport, two are working in the human resources unit of a ground handling company at Denizli Cardak Airport, and the last one is a manager of the ground handling company operating at the mentioned airports. The reason to choose these experts is that they are responsible for recruitment and that they have substantial experience in the commercial aviation sector.

In the second phase of PIPRECIA-G method, the decision makers evaluate the criteria. Grey evaluations for criteria according to expert 1 and 2 can be found in Table 3.

Tab. 3. *Grey evaluations for criteria (expert 1 and 2)*

Criterion	$\underline{s}_{j1}$	$\overline{s}_{j1}$	$\underline{s}_{j2}$	$\overline{s}_{j2}$
K1				
K2	0.5840	0.8340	0.3100	0.3670
K3	0.4500	0.5840	0.3670	0.4500
K4	0.8340	1.0000	0.3100	0.3670
K5	0.5840	0.8340	0.2680	0.3100
K6	0.4500	0.5840	1.1250	1.1750
K7	0.5840	0.8340	0.2680	0.3100

The opinions of the decision makers are integrated by using Equation 2 and 3. Grey coefficient is calculated by Equation 4 and 5. The results can be found in Table 4.

Tab. 4. *Integrated grey evaluations and grey coefficients*

Criterion	$\underline{s}_{j}$	$\overline{s}_{j}$	$\underline{k}_{j}$	$\overline{k}_{j}$
K1			1.0000	1.0000
K2	0.4056	0.5149	1.4851	1.5944
K3	0.3850	0.4795	1.5205	1.6150
K4	0.7358	0.8183	1.1817	1.2642
K5	0.3879	0.4927	1.5073	1.6121
K6	0.4816	0.5810	1.4190	1.5184
K7	0.3768	0.4764	1.5236	1.6232

The weights of criteria are calculated by using Equation 6 and 7. Grey relative weights of criteria are calculated by using Equation 8 and 9. The results can be seen in Table 5.

Tab. 5. *Weights and grey relative weights*

Criterion	$\underline{q}_{j}$	$\overline{q}_{j}$	$\underline{w}_{j}$	$\overline{w}_{j}$
K1	1.0000	1.0000	0.3300	0.3682

K2	0.6272	0.6734	0.2070	0.2479
K3	0.3883	0.4429	0.1282	0.1631
K4	0.3072	0.3748	0.1014	0.1380
K5	0.1905	0.2486	0.0629	0.0915
K6	0.1255	0.1752	0.0414	0.0645
K7	0.0773	0.1150	0.0255	0.0423

According to the Table 5, the most important criteria are “mastery of technical issues in the job description” with a score of 0.3682, “ability to take initiative in difficult situations” with a score of 0.2479, and “effective communication skill” with a score of 0.1631, respectively. On the flip side, the criterion of "ability to work rotating shifts" with a score of 0.0423 comes in the last place in terms of importance.

According to these results, mastery of technical issues in the job description is the most important criterion in performance evaluation of the ground operations agents. It is also observed that ability to take initiative in difficult situations and effective communication skill are important in the success and performance of the agent.

After finding grey relative weights of the criteria, the alternatives are evaluated by using MARCOS-G. The grey performance values for criterion 1 and 2 can be found in Table 6.

Tab. 6. *The grey performance values for criterion 1 and 2*

	$\underline{x}_{i1d}$	$\overline{x}_{i1d}$	$\underline{x}_{i2d}$	$\overline{x}_{i2d}$
A1	7	9	7	9
A2	5	7	5	7
A3	7	9	7	9
A4	5	7	5	7
A1	9	10	9	10
A2	7	9	7	9
A3	7	9	9	10
A4	7	9	7	9
A1	9	10	7	9
A2	7	9	5	7
A3	9	10	7	9
A4	7	9	5	7
A1	7	9	7	9
A2	7	9	5	7
A3	7	9	7	9
A4	7	9	5	7

The evaluations of the decision makers are integrated by using Equations 10 and 11. Extended grey decision matrix is set up by calculating grey ideal and anti-ideal solutions. Grey anti-ideal solution values are found by Equations 12 and 13. Grey ideal solution values are found by Equations 14 and 15. Integrated evaluations, grey ideal and anti-ideal solutions for criterion 1 and 2 can be seen in Table 7.

Tab. 7. *Integrated evaluations, grey ideal and anti-ideal solutions for criterion 1 and 2*

	$\underline{x}_{i1}$	$\overline{x}_{i1}$	$\underline{x}_{i2}$	$\overline{x}_{i2}$

A1	8.0000	9.5000	7.5000	9.2500
A2	6.5000	8.5000	5.5000	7.5000
A3	7.5000	9.2500	7.5000	9.2500
A4	6.5000	8.5000	5.5000	7.5000
Anti-ideal	6.5000	8.5000	5.5000	7.5000
Ideal	8.0000	9.5000	7.5000	9.2500

Extended grey decision matrix values are normalized by using Equations 16 and 17. Grey normalized performance values for criterion 1 and 2 can be found in Table 8.

Tab. 8. *Grey normalized performance values for criterion 1 and 2*

	$\underline{\boldsymbol{n}}_{i1}$	$\overline{\boldsymbol{n}}_{i1}$	$\underline{\boldsymbol{n}}_{i2}$	$\overline{\boldsymbol{n}}_{i2}$
A1	0.8421	1.0000	0.8108	1.0000
A2	0.6842	0.8947	0.5946	0.8108
A3	0.7895	0.9737	0.8108	1.0000
A4	0.6842	0.8947	0.5946	0.8108
Anti-ideal	0.6842	0.8947	0.5946	0.8108
Ideal	0.8421	1.0000	0.8108	1.0000

Grey weighted performance values are calculated by Equations 18 and 19. At this phase, PIPRECIA-G results are used. Grey weighted normalized performance values for criterion 1 and 2 can be found in Table 9.

Tab. 9. *Grey weighted normalized performance values for criterion 1 and 2*

	$\underline{v}_{i1}$	$\overline{v}_{i1}$	$\underline{v}_{i2}$	$\overline{v}_{i2}$
A1	0.2779	0.3682	0.1678	0.2479
A2	0.2258	0.3294	0.1231	0.2010
A3	0.2606	0.3585	0.1678	0.2479
A4	0.2258	0.3294	0.1231	0.2010
Anti-ideal	0.2258	0.3294	0.1231	0.2010
Ideal	0.2779	0.3682	0.1678	0.2479

Sum of the grey weighted normalized performance values is calculated by Equations 20 and 21. Sum of the grey weighted normalized performance values for grey ideal solution is calculated by Equations 22 and 23. Sum of the grey weighted normalized performance values for grey anti-ideal solution is calculated by using Equations 24 and 25. The results can be found in Table 10.

Tab. 10. *Total grey weighted normalized performance values*

	$\underline{\boldsymbol{S}}_i$	$\overline{\boldsymbol{S}}_i$
A1	0.7518	1.1155
A2	0.6134	0.9992
A3	0.7093	1.0889

A4	0.6046	0.9898
Anti-ideal	0.6046	0.9898
Ideal	0.7518	1.1155

Grey utility values according to the anti-ideal solution for each alternative are calculated by Equation 26 and 27. Grey utility values according to the ideal solution for each alternative are calculated by Equation 28 and 29. The results can be found in Table 11.

Tab. 11. *Grey utility values*

	$\underline{K}_i^-$	$\overline{K}_i^-$	$\underline{K}_i^+$	$\overline{K}_i^+$
A1	0.7596	1.8451	0.6740	1.4837
A2	0.6197	1.6527	0.5498	1.3290
A3	0.7166	1.8010	0.6358	1.4483
A4	0.6108	1.6372	0.5420	1.3165

These grey utility values are aggregated by Equations 30 and 31. The greatest aggregated grey utility value is found by Equations 32 and 33. The greatest aggregated utility value is found by using Equation 34. The results can be found in Table 12.

Tab. 12. *Aggregated grey utility values*

	$\underline{t}_i$	$\overline{t}_i$
A1	1.4335	3.3289
A2	1.1695	2.9817
A3	1.3524	3.2493
A4	1.1528	2.9537
Greatest	1.4335	3.3289
m	2.3812	

Grey utility function with respect to ideal solution is calculated by Equations 35 and 36. Grey utility function with respect to anti-ideal solution is calculated by Equations 37 and 38. The results can be found in Table 13.

Tab. 13. *Grey utility functions*

	$f(\underline{K}_i^+)$	$f(\overline{K}_i^+)$	$f(\underline{K}_i^-)$	$f(\overline{K}_i^-)$
A1	0.3190	0.7749	0.2830	0.6231
A2	0.2602	0.6941	0.2309	0.5581
A3	0.3009	0.7563	0.2670	0.6082
A4	0.2565	0.6875	0.2276	0.5529

Utility value with respect to ideal solution is calculated by Equation 39. Utility value with respect to anti-ideal solution is calculated by Equation 40. Utility function with respect to ideal solution is calculated by Equation 41. Utility function with respect to anti-ideal solution is calculated by Equation 42. The results can be found in Table 14.

Tab. 14. *Utility functions and values*

	$\boldsymbol{K_i^+}$	$\boldsymbol{K_i^-}$	$\boldsymbol{f(K_i^+)}$	$\boldsymbol{f(K_i^-)}$
A1	1.0789	1.3024	0.5469	0.4531
A2	0.9394	1.1362	0.4772	0.3945
A3	1.0420	1.2588	0.5286	0.4376
A4	0.9292	1.1240	0.4720	0.3902

The ultimate utility function value is calculated by Equation 43. The ultimate utility function and ranks can be found in Table 15.

Tab. 15. *Ultimate utility functions and ranks*

	$\boldsymbol{f(K_i)}$	**Rank**
A1	0.7844	1
A2	0.5717	3
A3	0.7243	2
A4	0.5578	4

When all the criteria are evaluated together, it is concluded that ground operations agent A1 with a score of 0.7844 is the best performer, and agent A4 with a score of 0.5578 is the worst performer.

According to these results, the most effective criteria that determine the performance of ground operations agents based on expert opinions are as follows.

- Mastery of technical issues in the job description,
- Ability to take initiative in difficult situations,
- Effective communication skill.

5 CONCLUSIONS

Air transportation as the fastest and safest mode of transport is of strategic importance for world tourism and social interaction. Airlines and ground handling companies need to employ qualified personnel and track the performance of personnel to survive in this competitive environment. Personnel responsible for ramp services perform an important task within the sector. The ground operations agent deals with marshalling in and pushing back the aircraft, the handling of customer baggage, meet and service arriving and departing flights, operation of ground service equipment, assist customers with special needs, assist customer service agents, as needed, and any other duties as assigned. Due to these important duties, the performance evaluation of ground operations agents by airlines or ground handling companies has become an important issue.

In this study, seven criteria that are important for evaluating the performance of ground operations agents were determined by the opinions of experts working in the human resources unit of a ground handling company operating at Isparta Suleyman Demirel Airport and Denizli Cardak Airport. The weights of the criteria were calculated by the Grey Piprecia method. According to the results of the analysis, the criterion of “mastery of technical issues in the job description” was given the highest importance in the performance evaluation of ground operations agents. In addition, the criteria of “ability to take initiative in difficult situations" and "effective communication skill" were given higher importance. Among the seven criteria, the criterion of "ability to work rotating shifts" was given the lowest importance.

In the study, the performance ranking of ground operations agents was done by Grey Marcos. According to the ranking, ground operations agent A1 was the best performer, and agent A4 was the worst performer.

Further research could elaborate on the following points:

- The new methods used in this study, the Grey Piprecia and Grey Marcos methods, can be applied to a different selection problem.
- The performance of other personnel groups in the airline sector can be evaluated.
- Employee performance can be evaluated with different MCDM methods.

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