R&D Project Selection with Gray-WASPAS Method

Halil ŞEN[1*]

[1] Burdur Mehmet Akif Ersoy University, Industrial Engineering Department, Burdur-Turkey,
ORCID ID: 0000-0003-4062-5366, halilsen@mehmetakif.edu.tr
[*] Correspondence: halilsen@mehmetakif.edu.tr; Tel.: +905302936266
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Abstract

Research and development (R&D) studies that carried out systematically to increase scientific and technical knowledge and to combine this knowledge with creativity and express its use in new applications, are extremely important in terms of sustainability in competition, development of new products and production processes, as well as the development and improvement of existing products and production systems. R&D has the same importance for cosmetics companies. Today, leading companies in the cosmetics industry allocate serious budgets to research and development activities to meet customer demands. Choosing the right R&D projects plays a key role in the correct use of this budget. This selection problem is a complex problem in terms of characteristics of alternatives, criteria and decision makers. In this study, the Gray-WASPAS (Gray - Weighted Aggregated Sum Product Assessment) method was chosen considering the characteristics of the criteria and the difficulties of expression in evaluating the alternatives according to these criteria, and this complex problem was solved.

Keywords: *MCDM, WASPAS, Gray System Theory*

1. Introduction

Research and development (R&D) studies that carried out systematically to increase scientific and technical knowledge and to combine this knowledge with creativity and express its use in new applications, are extremely important in terms of sustainability in competition, development of new products and production processes, as well as the development and improvement of existing products and production systems. Today, leading companies allocate serious budgets to research and development activities to meet customer demands. The right selection of R&D projects plays a key role in the correct use of this budget. This selection problem is a complex problem in terms of the characteristics of alternatives, criteria and decision makers. In the solution of this

problem, we see that different methods are used depending on the characteristics of the problem.

Poh et al. (2001), presented a comparative study of a number of classes of R&D evaluation methods based on the Analytical Hierarchy Process. They examined various factors and characteristics that affect the suitability of R&D evaluation methods and also performed a sensitivity analysis to identify critical factors. [1]. Meade and Presley (2002) used ANP, a general form of Saaty's analytical hierarchy process, as a model for evaluating competing R&D project proposals [2]. Hsu et al. (2003), discussed the selection of state-supported R&D projects in their study and used AHP to determine the criterion weights and a fuzzy approach to the project selection [3]. Wang et al. (2005), used AHP and fuzzy scoring method for R&D project evaluation in their studies [4]. Mohantyy et al. (2005), used the fuzzy analytical network process (F-ANP) [5]. Linton et al. (2007) and Eilat et al. (2008) used data envelopment analysis (DEA) in their studies [6,7]. Kuchta (2007), proposed a fuzzy model for the selection of R&D projects with benefit, cost and resource interactions [8]. Cheung et al. (2009), proposed an easily functionalized and flexible approach to R&D project selection, in which different techniques are made comparable with reference to normative methodology in economics and aligned with the basic model definition of the real world in any application [9]. Z. Wang and Yu (2011), presented a quantitative evaluation method for businesses to select projects and project portfolios in their study [10]. Liu and Wang (2011), proposed a general model for maximizing the total profit of selected projects for construction and R&D departments given scheduling problems with various resource constraints at certain time intervals, including consumable and renewable resource constraints [11]. Karasakal and Aker (2017), proposed a multi-criteria ranking approach based on data envelopment analysis [12]. Kundakcı and Bayrakdaroğlu (2019), on the other hand, proposed the fuzzy EDAS method for the R&D project selection problem [13]. Binici and Aksakal (2020), used the UTA method in their studies [14].

2. Materials and Methods

In this study, the Gray-WASPAS (Gray - Weighted Aggregated Sum Product Assessment) method was chosen, considering the characteristics of the criteria and the difficulties of expression in the evaluation of alternatives according to these criteria.

2.1. WASPAS-G Method

The gray theory developed by Ju Long Deng in 1982; in research in the fields of situation analysis, forecasting and decision making, it focuses on uncertainty and lack of information to analyze and understand systems [15].

Light colors indicate clarity, dark colors indicate uncertainty. Black indicates that the researcher has no knowledge of the system structure, parameters, characteristics, while white indicates that the researcher has complete knowledge. Colors between black and white indicate subtle systems such as social, economic and weather systems.

The WASPAS (Weighted Aggregated Sum Product Assessment) method is based on the combination of the Weighted Sum Model (WSM) and the Weighted Product Model (WPM), which are widely used in MCDM [16]. The WASPAS-G method was presented by adapting the gray numbers to the WASPAS method [17].

Pavlovskis and Antuchevičienė (2016) analyzed the concept, aims and problems of transforming abandoned industrial buildings and areas, as well as the benefits of successful conversion to urban development, and used the WASPAS-G method to evaluate different conversion projects [18]. Leonaviciute et al. (2016) used the WASPAS-G method to select the most appropriate protection device to help prevent accidents while working at height [19]. Pavlovskis et al. (2016) used the WASPAS-G method to evaluate asset redevelopment solutions in their study [20]. Bakhat and Rajaa (2019) proposed a new Gray integrated multi-criteria approach to improve the supplier selection procedure of a textile company and used WASPAS-G in this approach [21]. Wang et al. (2021) developed a multi-criteria decision-making model for the selection of suitable renewable energy sources using WASPAS-G in their study [22].

The WASPAS-G method was transformed into a multi-criteria group decision-making method in this study. Steps of this method:

Step 1: Constructing the Gray Decision matrix: To extend the method in the uncertain environment with the help of gray numbers, the first decision matrix should be presented as a gray decision matrix (GDMM) [17]. The matrix is created based on the preferences of the decision alternatives ranked according to their attributes.

$$\otimes X = \begin{bmatrix} \otimes x_{11} & \cdots & \otimes x_{1j} & \cdots & \otimes x_{1n} \\ \vdots & \ddots & \cdots & \ddots & \vdots \\ \otimes x_{i1} & \cdots & \otimes x_{ij} & \cdots & \otimes x_{in} \\ \vdots & \ddots & \ddots & \ddots & \vdots \\ \otimes x_{m1} & \cdots & \otimes x_{mj} & \cdots & \otimes x_{mn} \end{bmatrix} \tag{1}$$

Here, m – number of alternatives, n – number of criteria, i = 1,…, m; j = 1,…,n; $\otimes x_{ij}$ – gray rating value of alternative i according to j criteria

Step 2: Normalization of the Gray Decision matrix:

$$\otimes \bar{X} = \begin{bmatrix} \otimes \bar{x}_{11} & \cdots & \otimes \vec{x}_{1j} & \cdots & \otimes \bar{x}_{1n} \\ \vdots & \ddots & \cdots & \ddots & \vdots \\ \otimes \bar{x}_{i1} & \cdots & \otimes \bar{x}_{ij} & \cdots & \otimes \bar{x}_{in} \\ \vdots & \ddots & \ddots & \ddots & \vdots \\ \otimes \bar{x}_{m1} & \cdots & \otimes \bar{x}_{mj} & \cdots & \otimes \vec{x}_{mn} \end{bmatrix} \tag{2}$$

The criteria with maximum preferred values (ie, benefit criteria) are normalized as follows:

$$\otimes \bar{x}_{ij} = \frac{\otimes x_{ij}}{\max_i \otimes x_{ij}} \tag{3}$$

$\otimes x_{ij}$ in the number of gray; $x_{ij\alpha}$ indicates the lower bound value of the number, and $x_{ij\beta}$ indicates the upper bound value of the number. According to the normalization formula, the lower and upper limit values are determined as follows.

$$\bar{x}_{ij\alpha} = \frac{x_{ij\alpha}}{\max_i x_{ij\beta}} \; ve \; \bar{x}_{ij\beta} = \frac{x_{ij\beta}}{\max_i x_{ij\beta}} \tag{4}$$

The criteria with minimum preferred values (ie cost criteria) are normalized as follows:

$$\otimes \bar{x}_{ij} = \frac{\min_i \otimes x_{ij}}{\otimes x_{ij}} \tag{5}$$

The lower and upper limit values are determined as follows.

$$\bar{x}_{ij\propto} = \frac{\min_i x_{ij\alpha}}{x_{ij\beta}} \; ve \; \bar{x}_{ij\beta} = \frac{\min_i x_{ij\alpha}}{x_{ij\alpha}} \tag{6}$$

3. Step: Determination of Criteria Weights: Criteria weights will be determined between 0 and 1 and their sum will be 1. It can also be set to gray.

Step 4: The next step is to determine the gray values of the optimality functions. According to WSM, the total relative importance of an alternative is determined as the weighted sum of the criteria values; According to WPM, it is calculated as the product of the performance value of an alternative on the basis of criteria as much as the criterion weight.

Total relative importance of alternative i according to WSM $\otimes S_i$:

$$\otimes S_i = \sum_{j=1}^{n} \otimes \bar{x}_{ij} \otimes w_j \quad j = 1, \dots \dots, m, \tag{7}$$

Total relative importance of alternative i according to WPM $\otimes P_i$:

$$\otimes P_i = \prod_{j=1}^{n} \otimes \bar{x}_{ij}^{\otimes w_j} \quad j = 1, \dots \dots, m, \tag{8}$$

Step 5: Calculate the coefficient λ. The coefficient λ is used to increase the accuracy and efficiency of the calculations. Gray values are converted to net values using the center of area method.

$$\lambda = 0{,}5 \frac{\sum_{i=1}^{m} P_i}{\sum_{i=1}^{m} S_i} \quad P_i = 0{,}5(P_{i\alpha} + P_{i\beta}) \quad S_i = 0{,}5(S_{i\alpha} + S_{i\beta}) \tag{9}$$

Step 6: The relative values (Qi) of the alternatives are determined: Here too, gray values are converted to net values using the center of area method.

$$\otimes Q_i = \lambda \sum_{j=1}^{n} \otimes \bar{x}_{ij} \otimes w_j + (1-\lambda) \prod_{j=1}^{n} \otimes \bar{x}_{ij}^{\otimes w_j} \quad \lambda = 0, \dots \dots, 1. \tag{10}$$

Step 7: Determining the group preference: By taking the geometric mean of the Qi values, the group relative values of the alternatives are obtained. The alternative with the highest value in the ranking is determined as the best alternative.

3. Application

R&D has the same importance for cosmetics companies. Today, leading companies in the cosmetics industry allocate serious budgets to research and development activities to

meet customer demands. In this study, a selection was made among five R&D projects in a cosmetic company using the WASPAS-G method. In this decision-making process, a decision-making group was formed and the members of this group consisted of the assistant general manager responsible for the R&D unit, the business development manager, the marketing manager and the factory manager. First, the criteria were determined.

• Applicability of the Project: It expresses the possibility of realizing the project considering the current situation and conditions.

• Measures Against Risks: It should be checked whether the risk planning is carried out realistically, and if there are risks in this process, whether the precautions are taken.

• Market Analysis: It should be paid attention to whether the important information that helps to determine the market requirements, the size of the market and the competitive conditions of the product to be developed is researched by the entrepreneur.

• Strategic Alignment: Compliance of the project with the strategic plan of the enterprise should be evaluated.

• Cost: Whether the cost items of the project are analyzed correctly or not, the relevance of the cost items to the project should be taken into consideration. It is important that the cost is within bearable limits.

• Investment Payback Period: The break-even point of the project and when this break-even point will be reached is important.

• Expected Return: The realistic calculation and size of the expected return from the project is important.

Each decision maker determined the criteria weights in line with the company's priorities. Afterwards, gray decision matrices were created for each decision maker. Table 1 shows the gray decision matrix and criterion weights created for the business development manager. This table was created separately for all decision makers and the following steps were followed.

Table 1: Business Development Manager's Gray Decision Matrix and Criteria Weights:

	Criteria													
	Applicability of the Project		Measures Against Risks		Market Analysis		Strategic Alignment		Expected Return		Investment Payback Period		Cost	
	0-100		1-100		1-100		1-100		1-100		Month		1-100	
	C_1		C_2		C_3		C_4		C_5		C_6		C_7	
Optimization	max	Benefit	max	Benefit	max	Benefit	max	Benefit	max	Benefit	max	Benefit	min	Cost
w	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0,1	0,1	0,1	0,1	0,2	0,2	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15
Alternative Projects														
A1	64	85	50	55	60	80	50	55	60	80	60	70	75	80
A2	57	81	52	56	62	76	50	56	62	76	62	70	70	75
A3	61	78	55	58	60	80	22	40	80	100	55	65	70	75
A4	59	93	54	62	55	72	20	45	55	60	55	60	80	90
A5	63	89	61	68	54	63	44	68	54	63	54	61	65	78
Max	93,000		68,000		80,000		68,000		100,000		70,000		90,000	
Min	57,000		50,000		54,000		20,000		54,000		54,000		65,000	

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In the next step, the data in the decision matrices were normalized. Table 2 shows the normalized gray decision matrix of the business development manager.

After normalization, the total relative importance (S and P) values of the Alternatives and the coefficient λ were calculated. Then the combined optimality value was found (Q). Table 3 shows the optimality values of alternative projects calculated with the data of the business development manager.

Table 2: Normalized Gray Decision Matrix of the Business Development Manager

	Criteria												
	Applicability of the Project		Measures Against Risks		Market Analysis		Strategic Alignment		Expected Return		Investment Payback Period		Cost	
	0-100		1-100		1-100		1-100		1-100		Month		1-100	
	C_1		C_2		C_3		C_4		C_5		C_6		C_7	
Optimization	max	Benefit	max	Benefit	max	Benefit	max	Benefit	max	Benefit	max	Benefit	min	Cost
w	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0,1	0,1	0,1	0,1	0,2	0,2	0,15	0,15	0,15	0,15	0,15	0,15	0,15	0,15
Alternative Projects														
A1	0,688	0,914	0,735	0,809	0,750	1,000	0,735	0,809	0,600	0,800	0,857	1,000	0,813	0,867
A2	0,613	0,871	0,765	0,824	0,775	0,950	0,735	0,824	0,620	0,760	0,886	1,000	0,867	0,929
A3	0,656	0,839	0,809	0,853	0,750	1,000	0,324	0,588	0,800	1,000	0,786	0,929	0,867	0,929
A4	0,634	1,000	0,794	0,912	0,688	0,900	0,294	0,662	0,550	0,600	0,786	0,857	0,722	0,813
A5	0,677	0,957	0,897	1,000	0,675	0,788	0,647	1,000	0,540	0,630	0,771	0,871	0,833	1,000

Table 3: Combined Optimality Values of Alternative Projects for Business Development Manager

Alternative Projects	S (WSM)		P (WPM)		Lambda	Combined Optimality Values
	α	β	α	β	0,492522	
A1	0,743	0,894	0,739	0,890		0,816
A2	0,759	0,886	0,753	0,883		0,820
A3	0,713	0,886	0,683	0,873		0,789
A4	0,633	0,811	0,605	0,800		0,712
A5	0,711	0,878	0,703	0,868		0,790

Each previous calculation was done separately for each decision maker (vice general manager, business development manager, marketing manager and plant manager). The combined optimality value of the group was calculated by taking the geometric mean of the combined optimality values. Table 4 shows the optimality values of alternative projects calculated for the group.

Table 4: Optimality Values of Alternative Projects

Alternative Projects	Combined Optimality Value of the Group	Ranking
A1	0,83	2
A2	0,84	**1**
A3	0,75	4
A4	0,70	5
A5	0,81	3

4. Discussion and Conclusion

The right selection of R&D projects plays a key role in the correct use of the budget. This selection problem is a complex problem in terms of the characteristics of alternatives, criteria and decision makers. In this study, the WASPAS-G method was chosen considering the features of the criteria and the difficulties of expression in evaluating alternatives according to these criteria, and this complex problem was solved.

The method was adapted to Group Decision making. Due to the complexity of the method during implementation, combining the preferences was left to the final stage. In future studies, it is possible to work on combining preferences. The A2 Project has been selected with the highest evaluation score.

References

[1]   Poh, K. L., Ang, B. W., & Bai, F. (2001). A comparative analysis of R&D project evaluation methods. R and D Management, 31(1), 63–75. https://doi.org/10.1111/1467-9310.00197

[2]   Meade, L. M., & Presley, A. (2002). R&D project selection using the analytic network process. *IEEE Transactions on Engineering Management*, *49*(1), 59–66. https://doi.org/10.1109/17.985748

[3]   Hsu, Y. G., Tzeng, G. H., & Shyu, J. Z. (2003). Fuzzy multiple criteria selection of government-sponsored frontier technology R&D projects. R&D Management, 33(5), 539–551. https://doi.org/10.1111/1467-9310.00315

[4]   Wang, K., Wang, C. K., & Hu, C. (2005). Analytic hierarchy process with fuzzy scoring in evaluating multidisciplinary R&D projects in China. IEEE Transactions on Engineering Management, 52(1), 119–129. https://doi.org/10.1109/TEM.2004.839964

[5]   Mohantyy, R. P., Agarwalz, R., Choudhuryz, A. K., & Tiwari, M. K. (2005). A fuzzy ANP-based approach to R&D project selection: a case study. International Journal of Production Research, 43(24), 5199–5216. https://doi.org/10.1080/00207540500219031

[6]   Linton, J. D., Morabito, J., & Yeomans, J. S. (2007). An extension to a DEA support system used for assessing R&D projects. R&D Management, 37(1), 29–36. https://doi.org/10.1111/J.1467-9310.2007.00456.X

[7]   Eilat, H., Golany, B., & Shtub, A. (2008). R&D project evaluation: An integrated DEA and balanced scorecard approach. Omega, 36(5), 895–912. https://doi.org/10.1016/J.OMEGA.2006.05.002

[8]   Kuchta, D. (2007). A FUZZY MODEL FOR R&D PROJECT SELECTION WITH BENEFIT, OUTCOME AND RESOURCE INTERACTIONS. http://dx.doi.org/10.1080/00137910108967571, 46(3), 164–180. https://doi.org/10.1080/00137910108967571

[9]   Cheung, M. T., Greenfield, P. F., & Liao, Z. (2009). Selecting R&D projects for technology-based innovation: An application of the core model approach. IEEM 2009 - IEEE International Conference on Industrial Engineering and Engineering Management, 974–977. https://doi.org/10.1109/IEEM.2009.5373527

[10]   Wang, Z., & Yu, Y. (2011). Information entropy method for project portfolio selection. Proceedings - 2011 8th International Conference on Fuzzy Systems and Knowledge Discovery, FSKD 2011, 4, 2618–2622. https://doi.org/10.1109/FSKD.2011.6020005

[11]   Liu, S. S., & Wang, C. J. (2011). Optimizing project selection and scheduling problems with time-dependent resource constraints. Automation in Construction, 20(8), 1110–1119. https://doi.org/10.1016/J.AUTCON.2011.04.012

[12]   Karasakal, E., & Aker, P. (2017). A multicriteria sorting approach based on data envelopment analysis for R&D project selection problem. Omega (United Kingdom), 73, 79–92. https://doi.org/10.1016/J.OMEGA.2016.12.006

[13]   Kundakcı, N., & Kas Bayrakdaroğlu, F. (2019). BULANIK EDAS YÖNTEMİ İLE AR-GE PROJESİ SEÇİMİ. Uluslararası İktisadi ve İdari İncelemeler Dergisi. https://doi.org/10.18092/ulikidince.538332

[14]   Binici, E., & Aksakal, E. (2020). A new approach to R-D project selection problem and a solution proposal: UTA method. Pamukkale University Journal of Engineering Sciences, 26(1), 211–226. https://doi.org/10.5505/pajes.2019.45945

[15]   Ju-Long, D. (1982). Control problems of grey systems. Systems and Control Letters, 1(5), 288–294. https://doi.org/10.1016/S0167-6911(82)80025-X

[16]   Zavadskas, E. K., Turskis, Z., Antucheviciene, J., & Zakarevicius, A. (2012). Optimization of weighted aggregated sum product assessment. Elektronika ir Elektrotechnika, 122(6), 3–6. https://doi.org/10.5755/J01.EEE.122.6.1810

[17]   Zavadskas, E. K., Turskis, Z., & Antucheviciene, J. (2015). Selecting a Contractor by Using a Novel Method forMultiple Attribute Analysis: Weighted Aggregated SumProduct Assessment with Grey Values (WASPAS-G). Studies in Informatics and Control, 24(2), 141–150. https://doi.org/10.24846/V24I2Y201502

[18]   Pavlovskis, M., & Antuchevičienė, J. (2016). Importance and Advantages of Conversion of Unused Industrial Buildings in Lithuania. Mokslas - Lietuvos Ateitis, 8(5), 475–483. https://doi.org/10.3846/MLA.2016.971

[19]   Leonavičiute, G., Dejus, T., & Antuchevičiene, J. (2016). Analysis and prevention of construction site accidents. Građevinar, 68(5), 399–410. https://doi.org/10.14256/JCE.1428.2015

[20]   Pavlovskis, M., Antucheviciene, J., & Migilinskas, D. (2016). Application of MCDM and BIM for Evaluation of Asset Redevelopment Solutions. Studies in Informatics and Control, 25(3), 293–302. https://doi.org/10.24846/V25I3Y201603

[21]   Bakhat, R., & Rajaa, M. (2019). Developing a novel Grey integrated multi-criteria approach for enhancing the supplier selection procedure: A real-world case of Textile Company. undefined, 8(3), 211–224. https://doi.org/10.5267/J.DSL.2019.4.001

[22]   Wang, C. N., Kao, J. C., Wang, Y. H., Nguyen, V. T., Nguyen, V. T., & Husain, S. T. (2021). A Multicriteria Decision-Making Model for the Selection of Suitable Renewable Energy Sources. Mathematics, 9(12). https://doi.org/10.3390/MATH9121318