technologies

Article

# Evaluation Based on the Distance from the Average Solution Approach: A Derivative Model for Evaluating and Selecting a Construction Manager

**Phuong Thanh Phan [1,2] and Phong Thanh Nguyen [1,2,*]**

[1] Department of Project Management, Faculty of Civil Engineering, Ho Chi Minh City Open University, Ho Chi Minh City 700000, Vietnam
[2] Professional Knowledge & Project Management Research Team (K2P), Ho Chi Minh City Open University, Ho Chi Minh City 700000, Vietnam
* Correspondence: phong.nt@ou.edu.vn

**Abstract:** In the current market of integration and globalization, the competition between engineering and construction companies is increasing. Construction contractors can improve their competitiveness by evaluating and selecting qualified personnel for the construction engineering manager position for their company's civil engineering projects. However, most personnel evaluation and selection models in the construction industry rely on qualitative techniques, which leads to unsuitable decisions. To overcome this problem, this paper presents evaluation criteria and proposes a new model for selecting construction managers based on the evaluation based on the distance from the average solution approach (EDASA). The research results showed that EDASA has many strengths, such as solving the problem faster when the number of evaluation criteria or the number of alternatives is increased.

**Keywords:** construction manager; construction project; engineering management; EDASA; resource management; personnel selection; project management



**Citation:** Phan, P.T.; Nguyen, P.T. Evaluation Based on the Distance from the Average Solution Approach: A Derivative Model for Evaluating and Selecting a Construction Manager. *Technologies* **2022**, *10*, 107. https://doi.org/10.3390/technologies10050107

Academic Editors: Manoj Gupta, Eugene Wong and Gwanggil Jeon

Received: 15 September 2022
Accepted: 12 October 2022
Published: 14 October 2022



## 1. Introduction

Resource management is just as critical as challenging engineering project management themes such as schedule management, time management, cost management, quality management, and risk management [1–4]. In resource management, evaluating and recruiting personnel for engineering projects are always given top priority. Any project's success may be attributed to the fundamental human principle of selecting the appropriate personnel, delivering the correct product, and delivering the product at the right time [5–10]. Therefore, appropriate candidate evaluation criteria are needed for evaluating and selecting personnel for the position of construction manager in civil engineering projects [11–18]. A new scientific and objective selection method is needed for the company to select a qualified candidate. However, a portion of the currently used models for personnel selection relies on qualitative methods, often resulting in inappropriate decisions [19,20]. The goal of this study is to present evaluation criteria and propose a new method for choosing a construction manager using an EDASA to address this issue.

Next, this paper presents a literature review on personnel competence in construction projects to provide the foundation for identifying basic criteria for selecting a construction manager for civil engineering projects.

Competence is the ability to use skills, knowledge, and personal characteristics to improve efficiency in work performance, increasing the likelihood of project success [21]. According to the Project Management Institute (PMI), there are three types of project management competencies: knowledge, performance, and personal competence [22]. When a project manager applies methods, tools, and techniques to project activities, they are said to have knowledge competency. The project manager's ability to implement their project management expertise to complete the project's needs is performance competence. Finally, personal competencies, in addition to attitudes and fundamental personality qualities, describe how project managers perform when engaging in activities within the context of a project. The capacity framework identifies ten management implementation capacities, including managing project (1) integration, (2) scope, (3) time and schedule, (4) cost, (5) quality, (6) resource, (7) risk, (8) procurement, (9) communication, and (10) stakeholders. The six personal competencies include (1) communication, (2) leadership, (3) management, (4) cognitive ability, (5) efficiency, and (6) professionalism.

Construction managers have an important role in projects. Knowledge and skills are two core factors for construction managers [23]. The development and implementation of personnel training methods in the enterprise will help the management apparatus be flexible in assigning personnel, permitting maximum project efficiency. This benefits the construction manager and helps the company, which has a key human resource for long-term development. El-Sabaa [24] identifies the characteristics and skills of an effective construction manager. The author considers communication skills as the top criterion of project managers, while technical skills were less influential. In addition, the authors also highlight the difference between a project manager and a construction company executive. While both require resourcefulness, a construction manager requires extensive, broad knowledge to make the best use of resources. In addition, construction managers must have soft skills, accept change, and be proactive in their work. The construction manager should be the leader throughout the project lifecycle. In that role, the construction manager must be the individual who knows how to plan and monitor the entire project for the best efficiency.

Gharehbaghi and McManus [17] explore the necessary leadership qualities for successful construction projects. They depend on the task, team, work environment, resources, schedule, and budget. The author also suggests four important criteria that construction management engineers need, including (1) knowing other people, (2) knowing yourself well, (3) being able to communicate, and (4) decisiveness. A good leader must know and understand the wishes of their subordinates and demonstrate concern for their lives. In other words, understand personnel at the construction site, share experiences, and unite to accomplish individual goals. Construction managers must understand themselves and continue to learn and develop. A good leader must communicate well and be decisive in all situations. In addition, a construction manager must possess good general knowledge and skills and thoroughly understand the company culture and the construction site. These conditions require construction companies to equip themselves with the necessary additional knowledge through training, including short-term training courses.

Dainty, et al. [25] identify the core competencies related to the construction manager's role and deploy a predictive model to make selection decisions and train personnel for construction managers for large construction companies. The authors reveal that many project manager candidates participate in surveys in which their employees are asked to recount problems and solutions. This practice allows managers to understand their capabilities. The authors provide a logistic regression model for assessing candidate competence, and their results show that self-control and team leadership are the dominant factors determining a construction manager's competence. In addition to 12 performance-related abilities important for project managers, the study identified 10 additional competency characteristics: accomplishment orientation, initiative, information seeking, attention, impact, and efficacy in meeting client needs, direction, teamwork and collaboration, analytical and conceptual thinking, and agile execution.

Based on interviews with 13 project leaders, civil engineers, and construction managers, as well as 7 team leaders, in 13 construction projects in Sweden, Styhre and Josephson [26] find the importance of specific roles in project success. The authors also show that, although they are required to manage a substantial amount of work in their projects, most construction management engineers are satisfied with their work. The authors have shown that the position of construction engineers is indispensable to ensuring the project's success.

Construction enterprises should establish training courses for construction engineers and consider core skills for advanced training according to job characteristics. Technical skills alone are insufficient to create a successful project manager. Fisher [27] suggests six soft skills necessary for human resource management and corresponding behaviors for an effective construction manager, including (i) understanding employee behavioral characteristics, (ii) the ability to lead the team, (iii) the ability to influence, (iv) committing clear and honest actions, (v) the ability to resolve conflicts, and (vi) perceiving personality differences of project team members.

Zulch [28] recognizes essential characteristics that a construction manager must possess for successful communication. The managers should know that all leadership styles will have varying degrees of influence on the success of a project. Knowledge of leadership will help managers flexibly solve work problems according to specific situations, permitting project success. Evaluation of the capacity of the construction manager cannot be complete without assessing their experience because, without experience, competence cannot be demonstrated or improved [29]. Moreover, experience is considered an important factor for successful personal growth. To successfully fulfill their assigned role, individuals need to accumulate the necessary experience and thus complement their potential.

According to the APM Competence Framework, project managers' competencies include 20 technical competencies, 15 behavioral competencies, and 11 contextual competencies [30]. Construction project managers must have both technical knowledge and proficiency and abilities to coordinate and communicate effectively with various stakeholders. To ensure project success, construction managers must possess technical expertise, people skills, and a work ethic. Nuwan, et al. [11] discover management development approaches. The authors use the Delphi method, including 12 experts and 44 respondents, to develop 20 factors of specialized knowledge, soft skills, and working attitude that are meaningful for construction engineers. The most important of these are planning and managing progress. The most important soft skills regarding working attitude are time management and leadership.

Based on the list of capacity assessment criteria surveyed above, construction experts in Vietnam have selected the 15 most important criteria (within three groups) to select construction managers in Table 1.

**Table 1.** Criteria for the evaluation and selection of a construction manager.

| | Code | Criteria for the Evaluation and Selection of a Construction Manager |
|---|---|---|
| CE | | Construction Expertise |
| | CE1 | Construction technical knowledge |
| | CE2 | Knowledge of construction organization and management |
| | CE3 | Knowledge of the construction schedule |
| | CE4 | Knowledge of occupational safety and environmental sanitation |
| | CE5 | Understanding of construction quality and volume management |
| SS | | Soft Skills |
| | SS1 | Communication and presentation skills |
| | S2 | Construction problem-solving skills |
| | S3 | Ability to lead and guide construction workers |
| | S4 | Information management skills (documents, construction records) |
| | S5 | Creative innovation ability |
| WE | | Work Experience |
| | WE1 | Similar projects and works completed |
| | WE2 | Experience working with owner, project management unit, and supervisory unit |
| | WE3 | Experience working with contractors, project teams, and construction suppliers |
| | WE4 | Professional degrees and certificates in construction |
| | WE5 | Ability to use construction specialized software |

The rest of the paper is organized as follows. Section 2 provides the EDASA research method employed in Section 3. This section describes the empirical results and discusses the EDASA application. The final section concludes the study.

## 2. Methodology

Keshavarz et al. invented the distance from the average solution approach EDASA method in 2015 [31,32]. The best alternative is selected using EDASA by measuring the distance of each choice from the ideal value. This method is especially useful in situations with contradicting attributes or conflicting criteria. EDASA has been applied in the evaluation of airline services [33], solving air traffic problems [34], personnel selection [35], green supplier selection [36], material selection [37], and hospital site selection [38]. Using this method, suppose there are $n$ construction manager candidates and $m$ evaluation and selection criteria. The steps for using the proposed method are presented as follows [31–33,35–60]:

Step 1: Calculate the weight of each criterion.

Step 2: Create a decision-making matrix, shown as follows:

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{21} & \cdots & x_{2n} \\ \vdots & \vdots & & \vdots \\ x_{1n} & x_{2n} & \cdots & x_{mn} \end{bmatrix}; \; i = 1,\, 2,\, \ldots,\, m;\; j = 1,\, 2,\, \ldots,\, n \tag{1}$$

where

$x_{ij}$ denotes the performance value of the $i^{\text{th}}$ alternative on the $j^{\text{th}}$ criterion. Moreover, the assessor weight of the criteria $w = [w_1, w_2, \ldots, w_n]$.

Step 3: Identify the average solution based on each of the following criteria:

$$\overline{x}_j = (x_1,\; x_2, \ldots, x_n), \tag{2}$$

where

$$\overline{x}_j = \frac{\sum_{i=1}^{m} x_{ij}}{m};\; j = 1,\, 2, \ldots,\, n.$$

Step 4: Determine the positive and negative distances from the average solution.

The positive distances from the average (PDA) and the negative distances from the average (NDA) are dependent on the type of criteria (benefit and cost), calculated as follows:

$$d_{ij}^{+} = \begin{cases} \frac{\max(0,(x_{ij}-\overline{x}_j))}{\overline{x}_j}, j \in \Omega_{\max} \\ \frac{\max(0,(\overline{x}_j-x_{ij}))}{\overline{x}_j}, j \in \Omega_{\min} \end{cases}. \tag{3}$$

and

$$d_{ij}^{-} = \begin{cases} \frac{\max(0,(\overline{x}_j-x_{ij}))}{\overline{x}_j}, j \in \Omega_{\max} \\ \frac{\max(0,(x_{ij}-\overline{x}_j))}{\overline{x}_j}, j \in \Omega_{\min} \end{cases}. \tag{4}$$

where

$d_{ij}^{+}$ and $d_{ij}^{-}$ denote the positive and negative distance of $i^{\text{th}}$ candidates from the average solution of $j^{\text{th}}$ factors, respectively;

$\Omega_{\max}$ and $\Omega_{\min}$ are positive real numbers that represent the set of benefit criteria and the cost criteria, respectively.

Step 5: Determine the weighted sum of PDA, and the weighted sum of NDA, for all alternatives, shown as follows:

$$Q_i^{+} = \sum_{j=1}^{n} w_j d_{ij}^{+};\; i = 1,\, 2,\, \ldots,\, m \tag{5}$$

$$Q_i^{-} = \sum_{j=1}^{n} w_j d_{ij}^{-};\; i = 1,\, 2,\, \ldots,\, m \tag{6}$$

where

$w_j$ denotes the nonnegative weight of the criterion $j$.

Step 6: Normalize the values of the weighted sums of PDA and NDA for each of the candidates, as shown below:

$$S_i^+ = \frac{Q_i^+}{\max_k Q_k^+}. \tag{7}$$

$$S_i^- = 1 - \frac{Q_i^-}{\max_k Q_k^-}. \tag{8}$$

where

$S_i^+$ and $S_i^-$ denotes the normalized weighted sum of the PDA and the NDA, respectively.

Step 7: The appraisal scores $S_i$ for all project managers are computed as follows:

$$S_i = \frac{S_i^+ + S_i^-}{2}. \tag{9}$$

where

$0 \leq S_i \leq 1; i = 1, 2, \ldots, m$

The appraisal scores for construction manager candidates are listed in descending order. Among the applicants, the one with the highest $S_i$ is the best option.

## 3. Results

We applied the EDASA through a case study in one construction project in Vietnam. The recruitment committee consists of five professionals who must evaluate and select one of three candidates (A1, A2, A3) for the construction manager position. First, construction experts used Saaty's scale of 1–9 to make a pairwise comparison of evaluation and selection criteria for construction managers. The results of the weight calculation of these criteria are presented in Table 2.

**Table 2.** The weight of criteria for the evaluation and selection of a construction manager.

| | Code | Criteria for the Evaluation and Selection of a Construction Manager | Weight |
|---|---|---|---|
| CE | | Construction Expertise | |
| | CE1 | Construction technical knowledge | 0.1760 |
| | CE2 | Knowledge of construction organization and management | 0.0920 |
| | CE3 | Knowledge of the construction schedule | 0.0630 |
| | CE4 | Knowledge of occupational safety and environmental sanitation | 0.2900 |
| | CE5 | Understanding of construction quality and volume management | 0.0380 |
| SS | | Soft Skills | |
| | SS1 | Communication and presentation skills | 0.0070 |
| | SS2 | Construction problem-solving skills | 0.0500 |
| | SS3 | Ability to lead and guide construction workers | 0.0300 |
| | SS4 | Information management skills (documents, construction records) | 0.0110 |
| | SS5 | Creative innovation ability | 0.0170 |
| WE | | Work Experience | |
| | WE1 | Similar projects and works completed | 0.0270 |
| | WE2 | Experience working with owner, project management unit, and supervisory unit | 0.1040 |
| | WE3 | Experience working with contractors, project teams, and construction suppliers | 0.0580 |
| | WE4 | Professional degrees and certificates in construction | 0.0230 |
| | WE5 | Ability to use construction specialized software | 0.0140 |

Second, five construction experts created the decision-making matrix and calculated the average solution using Equation (2) according to all selection criteria, as shown in Table 3.

**Table 3.** The average solution of criteria for the evaluation and selection of a construction manager.

| Code | Criteria for Evaluation and Selection of Construction Manager | A1 | A2 | A3 | $\bar{x}_j$ |
|---|---|---|---|---|---|
| CE | Construction Expertise | 75 | 60 | 82 | 72.3333 |
| CE1 | Construction technical knowledge | 83 | 62 | 74 | 73.0000 |
| CE2 | Knowledge of construction organization and management | 84 | 71 | 64 | 73.0000 |
| CE3 | Knowledge of the construction schedule | 72 | 62 | 82 | 72.0000 |
| CE4 | Knowledge of occupational safety and environmental sanitation | 62 | 84 | 71 | 72.3333 |
| CE5 | Understanding of construction quality and volume management | 71 | 85 | 63 | 73.0000 |
| SS | Soft Skills | 73 | 62 | 82 | 72.3333 |
| SS1 | Communication and presentation skills | 82 | 73 | 63 | 72.6667 |
| SS2 | Construction problem-solving skills | 74 | 81 | 61 | 72.0000 |
| SS3 | Ability to lead and guide construction workers | 62 | 83 | 71 | 72.0000 |
| SS4 | Information management skills (documents, construction records) | 84 | 60 | 74 | 72.6667 |
| SS5 | Creative innovation ability | 72 | 63 | 81 | 72.0000 |
| WE | Work Experience | 63 | 73 | 80 | 72.0000 |
| WE1 | Similar projects and works completed | 83 | 62 | 74 | 73.0000 |
| WE2 | Experience working with owner, project management unit, and supervisory unit | 64 | 81 | 71 | 72.0000 |
| WE3 | Experience working with contractors, project teams, and construction suppliers | 75 | 60 | 82 | 72.3333 |
| WE4 | Professional degrees and certificates in construction | 83 | 62 | 74 | 73.0000 |
| WE5 | Ability to use construction specialized software | 84 | 71 | 64 | 73.0000 |

The positive and negative distances from the average solution are calculated using Equations (3) and (4), as shown in Tables 4 and 5.

**Table 4.** Values of the positive distances from the average (PDA).

| Code | Criteria for the Evaluation and Selection of a Construction Manager | A1 | A2 | A3 |
|---|---|---|---|---|
| CE1 | Construction technical knowledge | 0.0369 | 0.0000 | 0.1336 |
| CE2 | Knowledge of construction organization and management | 0.1370 | 0.0000 | 0.0137 |
| CE3 | Knowledge of the construction schedule | 0.1507 | 0.0000 | 0.0000 |
| CE4 | Knowledge of occupational safety and environmental sanitation | 0.0000 | 0.0000 | 0.1389 |
| CE5 | Understanding of construction quality and volume management | 0.0000 | 0.1613 | 0.0000 |
| SS1 | Communication and presentation skills | 0.0000 | 0.1644 | 0.0000 |
| SS2 | Construction problem-solving skills | 0.0092 | 0.0000 | 0.1336 |
| SS3 | Ability to lead and guide construction workers | 0.1284 | 0.0046 | 0.0000 |
| SS4 | Information management skills (documents, construction records) | 0.0278 | 0.1250 | 0.0000 |
| SS5 | Creative innovation ability | 0.0000 | 0.1528 | 0.0000 |
| WE1 | Work experience | 0.1560 | 0.0000 | 0.0183 |
| WE2 | Similar projects and works completed | 0.0000 | 0.0000 | 0.1250 |
| WE3 | Experience working with owner, project management unit, and supervisory unit | 0.0000 | 0.0139 | 0.1111 |
| WE4 | Experience working with contractors, project teams, and construction suppliers | 0.1370 | 0.0000 | 0.0137 |
| WE5 | Professional degrees and certificates in construction | 0.0000 | 0.0000 | 0.0000 |

The weighted sum and the weighted normalized sum of PDA and NDA for the candidates are calculated using Equations (5)–(8). Finally, the appraisal score of each construction manager candidate is calculated using Equation (9). All results are shown in Table 6.

**Table 5.** Values of the negative distances from the average (NDA).

| Code | Criteria for the Evaluation and Selection of a Construction Manager | A1 | A2 | A3 |
|---|---|---|---|---|
| CE1 | Construction technical knowledge | 0.0000 | 0.1705 | 0.0000 |
| CE2 | Knowledge of construction organization and management | 0.0000 | 0.1507 | 0.0000 |
| CE3 | Knowledge of the construction schedule | 0.0000 | 0.0274 | 0.1233 |
| CE4 | Knowledge of occupational safety and environmental sanitation | 0.0000 | 0.1389 | 0.0000 |
| CE5 | Understanding of construction quality and volume management | 0.1429 | 0.0000 | 0.0184 |
| SS1 | Communication and presentation skills | 0.0274 | 0.0000 | 0.1370 |
| SS2 | Construction problem-solving skills | 0.0000 | 0.1429 | 0.0000 |
| SS3 | Ability to lead and guide construction workers | 0.0000 | 0.0000 | 0.1330 |
| SS4 | Information management skills (documents, construction records) | 0.0000 | 0.0000 | 0.1528 |
| SS5 | Creative innovation ability | 0.1389 | 0.0000 | 0.0139 |
| WE1 | Work experience | 0.0000 | 0.1743 | 0.0000 |
| WE2 | Similar projects and works completed | 0.0000 | 0.1250 | 0.0000 |
| WE3 | Experience working with owner, project management unit, and supervisory unit | 0.1250 | 0.0000 | 0.0000 |
| WE4 | Experience working with contractors, project teams, and construction suppliers | 0.0000 | 0.1507 | 0.0000 |
| WE5 | Professional degrees and certificates in construction | 0.0000 | 0.0000 | 0.0000 |

**Table 6.** The weighted normalized sum of PDA and NDA and the appraisal score.

| | A1 | A2 | A3 |
|---|---|---|---|
| $Q_i^+$ | 0.0406 | 0.0122 | 0.0920 |
| $Q_i^-$ | 0.0152 | 0.1142 | 0.0153 |
| $S_i^+$ | 0.4410 | 0.1326 | 1.0000 |
| $S_i^-$ | 0.8666 | 0.0000 | 0.8657 |
| $S_i$ | 0.6538 | 0.0663 | 0.9329 |

The calculation results in Table 6 show that candidate A3 has the highest appraisal score (0.9329). Therefore, this person is prioritized to be selected as the construction manager. The research results showed that EDASA has many strengths. First, some qualitative attributes could be converted into quantitative attributes. Second, compared with traditional assessment methods (e.g., AHP), EDASA can consider conflicting criteria in the same problem. Third, the time to apply EDASA to solve the problem was faster when the number of evaluation criteria or the number of alternatives increased. Finally, this method can be combined with other theories such as fuzzy logic or grey system theory to reflect the complexity or uncertainty of the real world because it has a solid mathematical basis [39,43,61].

## 4. Conclusions

The fundamental human principle of choosing the right personnel, delivering the right product, and delivering the product on time is necessary for the success of any engineering and construction project. This paper presents fifteen evaluation criteria for selecting a construction manager and proposes a new quantitative methodology for this selection utilizing EDASA. This method is practically applied through a case study of the evaluation and selection of construction managers, demonstrating its effectiveness, especially in the event of the evaluation of many construction manager candidates. In addition, in some situations where the selection problem is complex or has more selection criteria, the EDASA deterministic approach should be combined with another method or theory (such as fuzzy logic theory or grey system theory) to reflect the uncertainty in the judgment of the decision maker.

**Author Contributions:** Conceptualization, P.T.P.; Data curation, P.T.P.; Formal analysis, P.T.N.; Funding acquisition, P.T.P.; Investigation, P.T.N.; Methodology, P.T.N.; Project administration, P.T.P.; Resources, P.T.N.; Writing—original draft, P.T.P.; Writing—review and editing, P.T.N. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research is funded by Ho Chi Minh City Open University under the grant number E2019.11.3.

**Data Availability Statement:** Not applicable.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References


1. Huemann, M.; Keegan, A.; Turner, J.R. Human resource management in the project-oriented company: A review. *Int. J. Proj. Manag.* **2007**, *25*, 315–323. [CrossRef]
2. Samimi, E.; Sydow, J. Human resource management in project-based organizations: Revisiting the permanency assumption. *Int. J. Hum. Resour. Manag.* **2020**, *32*, 49–83. [CrossRef]
3. Ling, F.Y.Y.; Ning, Y.; Chang, Y.H.; Zhang, Z. Human resource management practices to improve project managers' job satisfaction. *Eng. Constr. Arch. Manag.* **2018**, *25*, 654–669. [CrossRef]
4. Apollo, M.; Miszewska-Urbańska, E. Analysis of the Increase of Construction Costs in Urban Regeneration Projects. *Adv. Sci. Technol. Res. J.* **2015**, *9*, 68–74. [CrossRef]
5. Sulieman, H.A.; Alfaraidy, F.A.; Sulieman, H.A.; Alfaraidy, F.A. Influences of Project Management Capabilities on the Organizational Performance of the Saudi Construction Industry. *Eng. Technol. Appl. Sci. Res.* **2019**, *9*, 4144–4147. [CrossRef]
6. Belout, A.; Gauvreau, C. Factors influencing project success: The impact of human resource management. *Int. J. Proj. Manag.* **2004**, *22*, 1–11. [CrossRef]
7. Loosemore, M.; Dainty, A.; Lingard, H. *Human Resource Management in Construction Projects: Strategic and Operational Approaches*; Routledge: New York, NY, USA, 2003.
8. Yurova, V.A.; Velikoborets, G.; Vladyko, A. Design and Implementation of an Anthropomorphic Robotic Arm Prosthesis. *Technologies* **2022**, *10*, 103. [CrossRef]
9. Gemünden, H.G. Success Factors of Global New Product Development Programs, the Definition of Project Success, Knowledge Sharing, and Special Issues of Project Management Journal®. *Proj. Manag. J.* **2015**, *46*, 2–11. [CrossRef]
10. Zhou, Z.; Zhang, J.; Gong, C. Automatic detection method of tunnel lining multi-defects via an enhanced You Only Look Once network. *Comput. Civ. Infrastruct. Eng.* **2022**, *37*, 762–780. [CrossRef]
11. Nuwan, P.M.M.C.; Perera, B.A.K.S.; Dewagoda, K.G. Development of Core Competencies of Construction Managers: The Effect of Training and Education. *Technol. Knowl. Learn.* **2020**, *26*, 945–984. [CrossRef]
12. Abdullah, A.H.; Yaman, S.K.; Mohammad, H.; Hassan, P.F. Construction manager's technical competencies in Malaysian construction projects. *Eng. Constr. Arch. Manag.* **2018**, *25*, 153–177. [CrossRef]
13. Mohammad, H.; Tun, U.; Onn, H.; Hassan, P.F.; Khalijah, Y.S.; Tun, U.; Onn, H. Quantitative Significance Analysis for Technical Competency of Malaysian Construction Managers. *Issues Built Environ.* **2018**, 77–107.
14. Liu, H.; Zhang, H.; Zhang, R.; Jiang, H.; Ju, Q. Competence Model of Construction Project Manager in the Digital Era—The Case from China. *Buildings* **2022**, *12*, 1385. [CrossRef]
15. Mohammad, H.; Hassan, F.; Abd Rashid, R.; Yaman, S.K. Dimensionality analysis of technical competency for Malaysian construction managers. In Proceedings of the International UNIMAS STEM Engineering Conference, Kuching, Malaysia, 24–27 October 2016.
16. Chai, A.H.R. Competencies of Construction Manager. Ph.D. Thesis, Universiti Tunku Abdul Rahman, UTAR, Kampar, Malaysia, 2016.
17. Arditi, D.; Balci, G. Managerial Competencies of Female and Male Construction Managers. *J. Constr. Eng. Manag.* **2009**, *135*, 1275–1278. [CrossRef]
18. Gharehbaghi, K.; McManus, K. The construction manager as a leader. *Leadersh. Manag. Eng.* **2003**, *3*, 56–58. [CrossRef]
19. Sajjad, A.; Ahmad, W.; Hussain, S. Decision-Making Process Development for Industry 4.0 Transformation. *Adv. Sci. Technol. Res. J.* **2022**, *16*, 1–11. [CrossRef]
20. Zavadskas, E.K.; Turskis, Z.; Tamošaitienė, J. Multicriteria Selection of Project Managers by Applying Grey Criteria/Projektų Valdytojo Parinkimo Daugiatikslio Vertinimo Modelis. *Technol. Econ. Dev. Econ.* **2008**, *14*, 462–477. [CrossRef]
21. Moradi, S.; Kähkönen, K.; Aaltonen, K. Comparison of research and industry views on project managers' competencies. *Int. J. Manag. Proj. Bus.* **2019**, *13*, 543–572. [CrossRef]
22. Cartwright, C.; Yinger, M. Project management competency development framework. In Proceedings of the PMI Global Congress, Budapest, Hungary, 14–16 May 2007.
23. Edum-Fotwe, F.; McCaffer, R. Developing project management competency: Perspectives from the construction industry. *Int. J. Proj. Manag.* **2000**, *18*, 111–124. [CrossRef]
24. El-Sabaa, S. The skills and career path of an effective project manager. *Int. J. Proj. Manag.* **2001**, *19*, 1–7. [CrossRef]

25. Dainty, A.R.J.; Cheng, M.-I.; Moore, D.R. Competency-Based Model for Predicting Construction Project Managers' Performance. *J. Manag. Eng.* **2005**, *21*, 2–9. [CrossRef]
26. Styhre, A.; Josephson, P.E. Revisiting site manager work: Stuck in the middle? *Constr. Manag. Econ.* **2006**, *24*, 521–528. [CrossRef]
27. Fisher, E. What practitioners consider to be the skills and behaviours of an effective people project manager. *Int. J. Proj. Manag.* **2011**, *29*, 994–1002. [CrossRef]
28. Zulch, B. Leadership Communication in Project Management. *Procedia Soc. Behav. Sci.* **2014**, *119*, 172–181. [CrossRef]
29. IPMA. *Individual Competence Baseline*; International Project Management Association: Nijkerk, The Netherlands, 2015; p. 432.
30. De Rezende, L.B.; Blackwell, P. Project management competency framework. *Iberoam. J. Proj. Manag.* **2019**, *10*, 34–59.
31. Turskis, Z.; Morkunaite, Z.; Kutut, V. A Hybrid Multiple Criteria Evaluation Method of Ranking of Cultural Heritage Structures for Renovation Projects. *Int. J. Strat. Prop. Manag.* **2017**, *21*, 318–329. [CrossRef]
32. Ghorabaee, M.K.; Zavadskas, E.K.; Olfat, L.; Turskis, Z. Multi-Criteria Inventory Classification Using a New Method of Evaluation Based on Distance from Average Solution (EDAS). *Informatica* **2015**, *26*, 435–451. [CrossRef]
33. Ghorabaee, M.K.; Amiri, M.; Zavadskas, E.K.; Turskis, Z.; Antucheviciene, J. A new hybrid simulation-based assignment approach for evaluating airlines with multiple service quality criteria. *J. Air Transp. Manag.* **2017**, *63*, 45–60. [CrossRef]
34. Kikomba, M.; Mabela, R.; Ntantu, D. Applying EDAS method to solve air traffic problems. *Int. J. Sci. Innov. Math. Res. (IJSIMR)* **2016**, *4*, 15–23.
35. Stanujkic, D.; Popovic, G.; Brzakovic, M. An approach to personnel selection in the IT industry based on the EDAS method. *Transform. Bus. Econ.* **2018**, *17*, 44.
36. Wei, G.; Wei, C.; Guo, Y. EDAS method for probabilistic linguistic multiple attribute group decision making and their application to green supplier selection. *Soft Comput.* **2021**, *25*, 9045–9053. [CrossRef]
37. Kumar, R.; Dubey, R.; Singh, S.; Singh, S.; Prakash, C.; Nirsanametla, Y.; Królczyk, G.; Chudy, R. Multiple-Criteria Decision-Making and Sensitivity Analysis for Selection of Materials for Knee Implant Femoral Component. *Materials* **2021**, *14*, 2084. [CrossRef] [PubMed]
38. Adalı, E.A.; Tuş, A. Hospital site selection with distance-based multi-criteria decision-making methods. *Int. J. Health Manag.* **2019**, *14*, 534–544. [CrossRef]
39. Stanujkic, D.; Zavadskas, E.K.; Ghorabaee, M.K.; Turskis, Z. An Extension of the EDAS Method Based on the Use of Interval Grey Numbers. *Stud. Inform. Control* **2017**, *26*. [CrossRef]
40. Stević, Z.; Vasiljević, M.; Zavadskas, E.K.; Sremac, S.; Turskis, Z. Selection of carpenter manufacturer using fuzzy EDAS method. *Eng. Econ.* **2018**, *29*, 281–290. [CrossRef]
41. Maksimović, M.; Brzakovic, M.; Grahovac, M.; Jovanovic, I. An approach for evaluation the safety and quality of transport at the open pit mines, based on the EDAS method. *Min. Met. Eng. Bor* **2017**, 139–144. [CrossRef]
42. Zavadskas, E.K.; Kaklauskas, A.; Turskis, Z.; Tamošaitienė, J. Multi-Attribute Decision-Making Model by Applying Grey Numbers. *Informatica* **2009**, *20*, 305–320. [CrossRef]
43. Vesković, S.; Stević, Z.; Karabašević, D.; Rajilić, S.; Milinković, S.; Stojić, G. A New Integrated Fuzzy Approach to Selecting the Best Solution for Business Balance of Passenger Rail Operator: Fuzzy PIPRECIA-Fuzzy EDAS Model. *Symmetry* **2020**, *12*, 743. [CrossRef]
44. Keshavarz-Ghorabaee, M.; Amiri, M.; Zavadskas, E.K.; Turskis, Z.; Antucheviciene, J. A Dynamic Fuzzy Approach Based on the EDAS Method for Multi-Criteria Subcontractor Evaluation. *Information* **2018**, *9*, 68. [CrossRef]
45. Ghorabaee, M.K.; Zavadskas, E.K.; Amiri, M.; Turskis, Z. Extended EDAS Method for Fuzzy Multi-criteria Decision-making: An Application to Supplier Selection. *Int. J. Comput. Commun. CONTROL* **2016**, *11*, 358–371. [CrossRef]
46. Naik, G.; Kishore, R.; Dehmourdi, S.A.M. Modeling a Multi-Criteria Decision Support System for Prequalification Assessment of Construction Contractors using CRITIC and EDAS Models. *Oper. Res. Eng. Sci. Theory Appl.* **2021**, *4*, 79–101. [CrossRef]
47. Das, P.P.; Chakraborty, S. Multi-response Optimization of Hybrid Machining Processes Using Evaluation Based on Distance from Average Solution Method in Intuitionistic Fuzzy Environment. *Process Integr. Optim. Sustain.* **2020**, *4*, 481–495. [CrossRef]
48. Zhang, S.; Wei, G.; Gao, H.; Wei, C.; Wei, Y. Edas Method for Multiple Criteria Group Decision Making with Picture Fuzzy Information and Its Application to Green Suppliers Selections. *Technol. Econ. Dev. Econ.* **2019**, *25*, 1123–1138. [CrossRef]
49. Schitea, D.; Deveci, M.; Iordache, M.; Bilgili, K.; Akyurt, I.Z.; Iordache, I. Hydrogen mobility roll-up site selection using intuitionistic fuzzy sets based WASPAS, COPRAS and EDAS. *Int. J. Hydrog. Energy* **2019**, *44*, 8585–8600. [CrossRef]
50. Karaşan, A.; Kahraman, C. A novel interval-valued neutrosophic EDAS method: Prioritization of the United Nations national sustainable development goals. *Soft Comput.* **2018**, *22*, 4891–4906. [CrossRef]
51. Ecer, F. Third-Party Logistics (3pls) Provider Selection Via Fuzzy Ahp and Edas Integrated Model. *Technol. Econ. Dev. Econ.* **2017**, *24*, 615–634. [CrossRef]
52. Peng, X.; Liu, C. Algorithms for neutrosophic soft decision making based on EDAS, new similarity measure and level soft set. *J. Intell. Fuzzy Syst.* **2017**, *32*, 955–968. [CrossRef]
53. Peng, X.; Dai, J.; Yuan, H. Interval-valued Fuzzy Soft Decision Making Methods Based on MABAC, Similarity Measure and EDAS. *Fundam. Inform.* **2017**, *152*, 373–396. [CrossRef]
54. Ghorabaee, M.K.; Amiri, M.; Zavadskas, E.K.; Turskis, Z.; Antucheviciene, J. Stochastic EDAS method for multi-criteria decision-making with normally distributed data. *J. Intell. Fuzzy Syst.* **2017**, *33*, 1627–1638. [CrossRef]

55. Keshavarz-Ghorabaee, M.; Amiri, M.; Zavadskas, E.K.; Turskis, Z.; Antucheviciene, J. A new multi-criteria model based on interval type-2 fuzzy sets and EDAS method for supplier evaluation and order allocation with environmental considerations. *Comput. Ind. Eng.* **2017**, *112*, 156–174. [CrossRef]
56. Keshavarz-Ghorabaee, M.; Amiri, M.; Zavadskas, E.K.; Turskis, Z. Multi-criteria group decision-making using an extended edas method with interval type-2 fuzzy sets. *E+M Èkon. A Manag.* **2017**, *20*, 48–68. [CrossRef]
57. Kahraman, C.; Keshavarz-Ghorabaee, M.; Zavadskas, E.K.; Onar, S.C.; Yazdani, M.; Oztaysi, B. Intuitionistic Fuzzy Edas Method: An Application to Solid Waste Disposal Site Selection. *J. Environ. Eng. Landsc. Manag.* **2017**, *25*, 1–12. [CrossRef]
58. Ahn, C.W.; An, J.; Yoo, J.-C. Estimation of particle swarm distribution algorithms: Combining the benefits of PSO and EDAs. *Inf. Sci.* **2012**, *192*, 109–119. [CrossRef]
59. Zhang, X. Criteria for Selecting the Private-Sector Partner in Public–Private Partnerships. *J. Constr. Eng. Manag.* **2005**, *131*, 631–644. [CrossRef]
60. Sun, H.; Wei, G.-W.; Chen, X.-D.; Mo, Z.-W. Extended EDAS method for multiple attribute decision making in mixture z-number environment based on CRITIC method. *J. Intell. Fuzzy Syst.* **2022**, *43*, 2777–2788. [CrossRef]
61. Stević, Z.; Vasiljević, M.; Puška, A.; Tanackov, I.; Junevičius, R.; Vesković, S. Evaluation of Suppliers under Uncertainty: A Multiphase Approach Based on Fuzzy Ahp and Fuzzy Edas. *Transport* **2019**, *34*, 52–66. [CrossRef]