Research Article

Assessment of Causes of Delays in the Road Construction Projects in the Benin Republic Using Fuzzy PIPRECIA Method

Zeljko Stevic,1 Mouhamed Bayane Bouraima,2 Marko Subotic,1 Yanjun Qiu,3 Peter Antwi Buah,3 Kevin Maraka Ndiema,3 and Christian Magloire Ndijegwe4

1University of East Sarajevo, Faculty of Transport and Traffic Engineering Doboj, Lukavica, Bosnia and Herzegovina
2Organization of African Academic Doctors (OAAD), Off Kamiti Road, P.O Box 25305-00100, Nairobi, Kenya
3School of Civil Engineering, Southwest Jiaotong University, Chengdu 610031, China
4Ministry of Transport, Railway Department, Yaoundé, Cameroon

Correspondence should be addressed to Mouhamed Bayane Bouraima; mouba121286@yahoo.fr

Received 9 November 2021; Revised 23 December 2021; Accepted 14 March 2022; Published 11 April 2022

Academic Editor: Naeem Jan

Copyright © 2022 Zeljko Stevic et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Purpose. The purpose of this study is to examine the causes of delays in road construction projects in the Benin Republic from the consultant, client, and contractor perspectives. Design/Methodology/Approach. Through construction project reports, 20 factors that could cause delays in road construction projects were identified. The factors were arranged into a questionnaire, which was distributed to three separate experts. The fuzzy PIPRECIA (Pivot Pairwise RElative Criteria Relevance Assessment) method was used to calculate the independent importance of each delay factor. The Spearman and Pearson correlation coefficients were used to test the method’s consistency. Findings. The top five road construction project delays in the Benin Republic, according to the analysis of the 20 factors considered, are project funding, slowness during the client-endorsed payment process, scarcity of professional personnel, delay in indemnifying reimbursement (land-owners), and price escalation. This shows that of the various types of delays, the financial delay group is the most crucial. Originality/value. This study evaluates the causes of delays in road construction projects in the Benin Republic for the first time in literature. This study also examined the top 5 delay factors in road construction projects. This study is based on reports from road construction projects and a performed questionnaire survey. Based on the findings, measures have been formulated to aid project managers to alleviate the road construction delays in the Benin Republic. In addition, this study is practical for both scholars and road construction parties and provides a complete and verifiable analysis of the progress of a road construction project to make it easier and attain a competitive level of time, cost, and quality for successful road construction.

1. Introduction

Delays during the construction of infrastructure projects are universally considered to be perpetual. Numerous documents have noted the substantial delays in road construction in less developed countries. For instance, Kaliba et al. [1] noted delays in road construction in Zambia of around 227 percent of the initial timeline while in Ghana delays had climbed to 240 percent [2]. Considering road projects, especially mainly new ones can comprise a major portion of national investment budgets; considerable delays may result in serious political and economic implications. Although Benin Republic committed more of its gross domestic product (GDP) to public investment in comparison to other countries of the West African Economic and Monetary Union (WAEMU) from 1990 to 2015, its public investment is more unstable (https://www.elibrary.imf.org/view/journals/002/2020/ 028/article-A001-en.xml). Political leaders, on the other hand, have decided to reveal the country through a large-scale transformational investment. Eight large-scale projects worth a total of € 2,802 billion were initiated as part of the government’s action plan 2016–2021, including an approximately 1,300-kilometer road network extension (https://beninrevele.bj/en/programme-actions/ programme/infrastructure/).
Despite their severity, the fundamental delay parameters for road construction persist, mostly resulting in economic losses and costly litigation plans of action between contractors and customers [3]. The first step in avoiding litigation is to identify potential delays as early as possible throughout the project and then to address them. According to Derakhshanfar et al. [4] and Xenidis and Stavrakas [5], improper risk management is the primary cause of budget and time overruns. As a result, clients’ and contractors’ reputations are universally worsening. These negative consequences persist in the absence of effective risk management.

According to Derakhshanfar et al. [4], the investigation into construction delay factors began in 1985, with 1 to 3 publications published annually until 2006, and 4 to 7 after that, with roughly 18 published in 2017. Three similar types of research released in 2020 did a meta-analytical review, claiming to discover a comprehensive reason for the delay in the construction industry [6–8]. Through 47 study articles, Viles et al. [6] identified 1057 different reasons for delays. The major steps provided in each publication were systematized, and a new significant measure was created, which was then statistically researched to generate a list of 35 delay factors, which were then categorized. Durdyev and Hosseini [8] looked at a list of 123 research publications published in over 25 scholarly journals. Since 1985, a list of 149 delay variables has been examined based on 97 research papers that met their study criteria.

Although Sanni-Anibire et al. [7] identified 93 research papers, only 11 matched their study requirements and were included in their meta-analysis. In total, 36 universal delay reasons were identified, and their relative importance indices (RIIs) were used to compare them. Furthermore, they analyzed research based on geographical zones as well as construction project types as part of their analysis. Only five studies were found working on determining delay factors in Oceania, Europe, and North and South America, whereas 9 articles dealt with the subject in Africa and 25 in Asia. These findings follow those of Viles et al. [6], who discovered that over 80% of all research was conducted in Africa and Asia, as well as Durdyev and Hosseini [8] findings that scientists from less developed countries have spent the most time researching the causes of construction delays. This could indicate that answers to planning and delay issues have been established to a satisfactory degree in advanced countries and are no longer worthy of further investigation. Nonetheless, as Sanni-Anibire, Mohamad et al. [7] have demonstrated the causes of delay could be project-specific and location/country-specific, thus explaining country-specific study investigations.

The majority of the publications discovered in Africa were about the investigation of delay factors (see Table 1). Other studies on the duration of road construction projects were conducted, but they focused on risk assessment [11], cost escalation analysis [14], and cost overrun analysis [17, 18]. Most scholars have approved the formulation of a category of probable fundamental construction delay parameters and their subsequent classification according to the recognized project influence and several occurrences as a viable methodology to identify expected delays and provide alleviation instruction, as discovered by previous studies [1–3, 9–18]. As a result, all thirteen papers take into account the conclusions of essential road project delay reasons based on questionnaire surveys. Accordingly, their conclusions are based on expert judgment rather than the current examination of established delay reasons that occur in real projects and are unrelated to the project’s characteristics.

As a result, the following question arises: do the plethora of key parameters that cause project delays as determined by expert judgment occur frequently in real projects? The word “regularly” is crucial. All parameters estimated in the literature occurred at some point because they were linked to the expert’s own experience. The effects of established road construction delay parameters were examined using a variety of quantitative methodologies to help professionals make better decisions about how to deal with the risks. These comprise the RII [1–3, 9, 13]; the statistical model [10, 16, 18]; and the regression [11].

Other studies that addressed the delay factor analysis using the RII with either statistical model or Spearman’s rank correlation comprise Kassa [14] who conducted the causes of infrastructure project delays and cost escalation in the federal road construction in Ethiopia, Kamanga and Steyn [12] who identified the causes of delay in completing a road construction project in Malawi, and Atibu [15] who investigated the factors producing a delay in road projects in Kenya. On the other hand, to enhance the managing system in the construction sector, Alinaitwe et al. [17] applied frequency, severity, and importance indexes values to evaluate and classify the reasons of delays and overruns in construction projects in Uganda.

Surprisingly, none of the studies cited above recommended the application of multicriteria decision-making (MCDM), that is, the fuzzy PIPRECIA created by Stević et al. [19]. One of the most difficult challenges in construction is the process to make an objective choice [20]. Due to the complexity of the projects, the decision-making process can be time-consuming and difficult. Difficulties often happen at the stage of the criteria set criterion. As a result, Książek et al. [21] provided a set of relevant norms and mathematical methods that can significantly improve an impartially made judgment. These mathematical tools can be used to aid in the presentation of procedures, such as governmental mega-projects [22].

MCDM techniques are increasingly being used in the transportation industry in conjunction with decision-making, resulting in several benefits [23–30]. The majority of the peer-reviewed research relates to the application of decision-making based on the road transportation, with the remainder covering intermodal, air, and rail transportation. In general, two types of decision-making approaches are used to address transportation difficulties [31]: determining issues with a discrete set of options or selecting from a continuous range of possibilities. Saaty [32] established the analytical hierarchy process (AHP), which is the most commonly utilized decision-making approach in the transportation sector [33]. In a paper by Razi et al. [34], the AHP technique was used to conduct a practical study of risk.
| Authors                         | Year | Scope          | Source of data                                   | Sample                                                                 | Method                  | Country     | Area | No
|--------------------------------|------|----------------|-------------------------------------------------|------------------------------------------------------------------------|-------------------------|-------------|------|------|
| Rachid et al. [9]              | 2019 | DFA            | Data collection, questionnaire                   | 16 owners, 16 contractors, and 20 consultants                         | RII                     | Algeria     | Africa | 59   |
| Aziz and Abdel-Hakam [3]       | 2016 | DFA            | Questionnaire                                    | 500 construction participants                                       | RII                     | Egypt       | Africa | 293  |
| Amoatey and Ankrah [2]         | 2017 | DFA            | Data collection, questionnaire                   | 48 road projects and 123 questionnaires                             | RII                     | Ghana       | Africa | 23   |
| Alfakhri et al. [10]           | 2017 | DFA            | Data collection, questionnaire                   | 31 engineers (owners, contractors, and consultants)                 | Statistical model       | Libya       | Africa | 59   |
| Leo-Olagbaye and Odeyinka [11] | 2020 | RA             | Questionnaire                                    | 146 stakeholders, 40 road projects                                  | Regression              | Nigeria     | Africa | -    |
| Kamanga and Steyn [12]         | 2013 | DFA            | Questionnaire                                    | Client, contractor, and consultant                                  | RII, Spearman's rank correlation | Malawi     | Africa | 72   |
| Khair et al. [13]              | 2018 | DFA            | Questionnaire                                    | Group of experts and professionals                                  | RII                     | Sudan       | Africa | 66   |
| Kaliba et al. [1]              | 2009 | DFA            | Questionnaire                                    | 26 questionnaires                                                   | RII                     | Zambia      | Africa | 14   |
| Kassa [14]                     | 2020 | DFA, CEA       | Questionnaire, data collection                   | 65 client agencies, 23 contractors, and 10 consultants              | RII, statistical model, Excel | Ethiopia    | Africa | -    |
| Atibu [15]                     | 2015 | DFA            | Questionnaire                                    | 15 consultants and 16 contractors                                   | RII, Spearman's rank correlation | Kenya       | Africa | 141  |
| Ezeldin and Abdel-Ghaney [16]  | 2013 | DFA            | Questionnaire                                    | 10 practitioners, 35 professional experts (contractor, employer, and consultant) | Statistical analysis    | Egypt       | Africa | 31   |
| Alinaitwe et al. [17]          | 2013 | DFA, COA       | Questionnaire                                    | Civil Aviation authority                                            | FI, SI, and IMPI        | Uganda      | Africa | 22   |
| Chileshe et al. [18]           | 2010 | COA (cost overrun analysis) | Questionnaire                                    | 51 questionnaires                                                  | Statistical analysis    | Ghana       | Africa | 14   |
| This study                     |      | DFA            | Questionnaire report                              | One contractor, one consultant, one client                           | Fuzzy PIPRECIA (proposed method) | Benin Republic | Africa | 20   |

Note. CEA = cost escalation analysis, COA = cost overrun analysis, DFA = delay factor analysis, FI = frequency index, IMPI = importance index, RA = risk assessment, RII = relative importance index, and SI = severity index.
evaluation for an ordinary road construction project in Malaysia. Table 2 depicts the application of MCDM techniques in road construction.

The National Government of Benin (NGB) has worked tirelessly to provide a reliable transportation infrastructure. This can be seen in various programmes started by political leaders, as noted by Boko–haya et al. [54], as well as in the priority of additional money for the road sector over the railway sector [55–58]. Nonetheless, the quality of roads varies from province to province, which is insufficient to meet the 2025 Agenda targets for sustainable development. President Patrice Talon’s administration launched a five-year Government Action Programme (2016–2021) in 2016 to improve Benin’s infrastructure, logistics, and trade. This scheme was revised and reapproved in 2021, during his second term. The programme planned to update the road network around Cotonou’s port, build a bypass in the north of Cotonou, develop the Route des Péchés (Phase 2), construct a highway between Sémé-Kpodji and Porto-Novo, develop the Djougou-Pehunco-Kerou-Banikoara route, and extend the road network by 1, 236 km. As a result of this government effort, every region of the country is being built, at an increasing rate (https://www.24haubenin.info/?Les-chantiers-reprennent-sous-Talon-2).

However, a recent assessment on the completion of these projects revealed a significant delay, which impedes the country’s road infrastructure development and, as a result, economic growth. While there is substantial literature on the diagnosis of road construction delay factors in many African countries, the same cannot be stated for the Benin Republic. As a result, using Scopus, Web of Science (WoS), and Google Scholar, keywords such as “delay factors in construction” or “construction delays” or “causes of delays” and “roads” or “highways” and “Benin” or “Benin Republic” and “Benin” or “Benin Republic” were searched from 1990 to 2020, and not a single article precisely associated with the delay factor examination. As a result, the study’s objectives were to examine the causes of delays in road construction projects in the Benin Republic and to propose applicable recommendations for considerably alleviating these issues.

The study’s objectives are to document (i) the various groups of delay cause in executing road construction projects in the Benin Republic, (ii) the most significant delay group as well as the most significant causes of delay in road construction projects in the Benin Republic, and (iii) design and distribute a questionnaire survey to construction professionals to obtain their perceptions on the main causes of delay. As a result, the following three questions are addressed in this study: (*) What are the various types of delays in the execution of road construction projects in the Benin Republic? (**) What is the most significant group causing delays in the execution of road development projects in the Benin Republic? (***) What are the primary causes of road construction project delays in the Benin Republic? (****) What are construction professionals’ assessments of the causes of delays in completing these projects on time?

The fuzzy PIPRECIA approach was employed in this investigation. It is a well-known method for determining the weights of criteria (factors) in MCDM situations. The benefits of the proposed approach are numerous: (i) it allows the evaluation of criteria without first sorting them by significance, (ii) group decision-making is also another advantage of this method, and (iii) it enables the reduction of uncertainty and subjectivity in a decision-making process. According to Stanković et al. [59] and Memiş et al. [60], the only applications of the fuzzy PIPRECIA for decision-making issues in the road sector were related to traffic risk analysis and road transport risk factors prioritization, respectively, and none referred to its use in the evaluation of delay causes in the road construction project. Subsequently, the method has been extensively used in different research areas such as green supplier selection [61], selection of the reach stackers [62], the business of passenger rail operators [63], railway traffic safety evaluation [64], evaluation of rapeseed varieties [65], the application of high-performance computing (HPC) analysis [66], safety degree assessment around the crossings of the railway [67], achievement of the business quality and durability [68], upgrade of the performance of logistics [69], and the strategic decision evaluation of the transportation corporation [70].

The application of the fuzzy PIPRECIA in the assessment of the causes of delays in road project construction is innovative in this work since it is the first time in the literature. Furthermore, this is the first study to look at the impact of delays in the country. This paper’s contribution can be explained in a variety of ways. It initially proposes and uses a new way to evaluate the causes of delays in road construction projects rather than existing ones (RII, FI, SI, IMPI, statistical model, and regression). Furthermore, the weighting mechanism improves the process’s reliability and consistency while reducing the ambiguity and subjectivity of human perception.

The study includes six components, in addition to the introduction. Section 2 describes the technique used in this study. The presentation of fuzzy scales for criterion evaluation as well as the various steps of the fuzzy PIPRECIA has been presented. The case study is covered in Section 3. Section 4 presents the findings and discussion of the examination of the causes of delays in the country’s road development project. A sensitivity analysis, as reported in section 5, was used to validate the results. Section 6 depicts the plan formulation for mitigating delays in road construction projects. The seventh section contains the conclusions as well as some recommendations for future works.

2. Methodology

Figure 1 depicts the entire course of the investigation, which includes examining the causes of delays in the road construction project using a fuzzy PIPRECIA approach. The first stage of the initial phase was to recognize the need for research, followed by the identification of research challenges and objectives in the second step. The first phase of the study concludes with the development of a set of criteria for assessing delay causes in the road construction project. The formation of a decision-making group comprised a consultant, a client, and a contractor that is the first stage in the
### Table 2: The studies related to the application of MCDM techniques on road transport.

| Authors                  | Year | Country          | Methods                                         | Research topic                                    |
|--------------------------|------|------------------|-------------------------------------------------|--------------------------------------------------|
| Wagale and Singh [35]    | 2019 | India            | ANFIS, FDM                                      | Assessing socio-economic impacts of construction of rural roads |
| Phogat and Singh [36]    | 2013 | India            | AHP, SAW, DBM, PROMETHEE, ELECTRE               | Selecting adequate equipment for construction of a hilly road |
| Hasnain et al. [37]      | 2018 | Pakistan         | ANP                                            | Selecting contractor in road construction project |
| Yücelgazi and Yitmen [38]| 2019 | Europe, Middle East | ANP                  | Risk evaluation in transport infrastructure projects |
| Yücelgazi and Yitmen [39]| 2020 | Europe, Middle East | ANP                  | Prioritizing risk response on bridge projects     |
| Mosalman et al. [40]     | 2019 | Iran             | WASPAS                                         | Determining time delay in road construction project |
| Badalpur and Nurbakhsh [41]| 2019 | Iran             | ANP                                            | Assessing negative influences of risks on the project |
| Zavadskas et al. [42]    | 2008 | Worldwide        | MADM                                           | Evaluation of quality in bridge and road construction management |
| Khorasani et al. [43]    | 2012 | Europe           | Fuzzy TOPSIS, TOPSIS                           | Assessing road safety management                 |
| Kishore et al. [44]      | 2020 | Iran             | AHP, SAW                                       | Selecting subcontractor in construction project   |
| Paredes and Herrera [45] | 2020 | Worldwide        | WRC, CBA, AHP                                  | Teaching MCDM techniques applied in the road infrastructure projects |
| Antoniou [46]            | 2021 | Greece           | TOPSIS                                         | Assessing delay risk in road projects             |
| Sandra et al. [47]       | 2007 | India            | MADM                                           | Prioritizing the pavement stretches              |
| Talebi et al. [48]       | 2019 | Iran             | MCDM, AHP                                      | Evaluating road network for tourism purposes      |
| Nenadić [49]             | 2019 | Bosnia and Herzegovina | FUCOM, WASPAS                      | Classifying dangerous sections of road           |
| Taş and Çakır [50]       | 2021 | Turkey           | Fuzzy MARCOS                                   | Analyzing road risk                               |
| Vrtačić et al. [51]      | 2021 | Republic of Srpska | IMF SWARA                                      | Classifying road sections                         |
| Liachovičius et al. [52] | 2020 | World            | SAW, COPRAS, TOPSIS, EDAS, PROMETHEE           | Evaluating asset-based road freight transport     |
| Malik et al. [53]        | 2021 | Malaysia         | AHP, ENTROPY, VIKOR                             | Proposing a new roadside unit positioning framework |

**Note.** AHP: analytical hierarchy process, ANFIS: adaptive neuro-fuzzy inference system, ANP: analytical network process, CBA: choosing by advantage, COPRAS: COmplex PRoportional Assessment, DBM: distance-based method, EDAS: evaluation based on Distance from Average Solution, ELECTRE: Elimination Et Choice Translating Reality, FDM: fuzzy Delphi method, FMCMD: fuzzy multi-criteria decision-making, FUCOM: Full Consistency Method, MADM: multiattribute decision-making, MARCOS: Measurement Alternatives and Ranking according to the COmpromise Solution, PROMETHEE: preference ranking organization method, SAW: simple additive weights method, SWARA: stepwise weight assessment ratio analysis, WRC: weighting rating and calculating, TOPSIS: Technique for Order Preference by Similarity to Ideal Situation, and VIKOR: Vlsekriterijumska Optimizacija I Kompromisno Resenje.
second phase. The second part of the second phase entails
describing to the decision-makers how they used the
method. The final step in this phase is to allow the decision-
makers (DMs) to evaluate depending on their experience
and preferences. The third phase begins with an analytical
part that includes data processing and result calculations.
Finally, the correlation coefficients were computed to do a
sensitivity analysis.

The fuzzy PIPRECIA method comprises eleven steps as
can be seen below:

**Step 1.** Establishing category criteria and classifying the
criteria based on marks from the initial to the final, which
suggests that they require to be sorted unspecified.

**Step 2.** Each decider separately assesses preclassified criteria
by beginning from the second criterion, as can be shown in equation.

\[
\bar{S}_j = \begin{cases} 
> T & \text{if } C_j > C_{j-1}, \\
= T & \text{if } C_j = C_{j-1}, \\
< T & \text{if } C_j < C_{j-1},
\end{cases}
\]

(1)

\(\bar{S}_j\) represents the evaluation of criteria by a decider \(r\).

To get \(\bar{S}_j\), the integration of the matrix \(S_j\) is important to
be examined through the usage of the geometric mean. The
criteria are assessed by the deciders through the application
of scales explained in Tables 3 and 4.

When the criterion is of considerable significance
concerning the preceding one, the evaluation is done using the scale in
Table 4.

**Step 3.** Finding out the coefficient \(k_j\):

\[
k_j = \begin{cases} 
= T & \text{if } j = 1, \\
\frac{2}{j} & \text{if } j > 1.
\end{cases}
\]

(2)

**Step 4.** Finding out the fuzzy weight \(q_j\):

\[
q_j = \begin{cases} 
= T & \text{if } j = 1, \\
\frac{q_{j-1}}{k_j} & \text{if } j > 1.
\end{cases}
\]

(3)

---

**Table 3: Scale 1–2 for the assessment of criteria.**

| Linguistic scale          | 1 | m | u | DFV |
|---------------------------|---|---|---|-----|
| Almost equal value        | 1 | 1.000 | 1.000 | 1.050 | 1.008 |
| Slightly more significant | 2 | 1.100 | 1.150 | 1.200 | 1.150 |
| Moderately more significant| Scales 1–2| 3 | 1.200 | 1.300 | 1.350 | 1.292 |
| More significant          | 4 | 1.300 | 1.450 | 1.500 | 1.433 |
| Much more significant     | 5 | 1.400 | 1.600 | 1.650 | 1.575 |
| Dominantly more significant| 6 | 1.500 | 1.750 | 1.800 | 1.717 |
| Absolutely more significant| 7 | 1.600 | 1.900 | 1.950 | 1.858 |

---

When the criterion is of less significance in comparison
to the preceding one, the evaluation is done using the scale in
Table 4.

---

**Figure 1:** Proposed methodology of the research.
Step 5. Finding out the corresponding weight of the criterion $w_j$:

$$w_j = \frac{q_j}{\sum_{j=1}^{n} q_j}. \quad (4)$$

In the subsequent steps, the inverted methodology of the fuzzy PIPRECIA method requires to be implemented.

Step 6. Carrying out the evaluation but this time beginning from a final criterion.

$$s_j^* = \begin{cases} > T & \text{if } C_j > C_{j+1}, \\ = T & \text{if } C_j = C_{j+1}, \\ < T & \text{if } C_j < C_{j+1}. \end{cases} \quad (5)$$

Step 7. Finding out the coefficient $k_j'$:

$$k_j' = \begin{cases} \bar{T} & \text{if } j = n, \\ 2 - \bar{s}_j^* & \text{if } j > n. \end{cases} \quad (6)$$

Step 8. Finding out the fuzzy weight $\bar{q}_j$:

$$\bar{q}_j = \begin{cases} \bar{T} & \text{if } j = n, \\ \frac{q_{j+1}}{k_j} & \text{if } j > n. \end{cases} \quad (7)$$

Step 9. Finding out the relative weight of the criterion $\bar{w}_j$:

$$\bar{w}_j = \frac{\bar{q}_j}{\sum_{j=1}^{n} \bar{q}_j}. \quad (8)$$

Step 10. To find out the final weights of criteria, it is essentially required to carry out the defuzzification of the fuzzy values $\bar{w}_j$ and $\bar{w}_j'$:

$$\bar{w}_j = \frac{1}{2} (w_j + w_j'). \quad (9)$$

Step 11. Examining the results acquired by using the Spearman and Pearson correlation coefficients.

3. Case Study

3.1. The Road Transport System in the Benin Republic. The Republic of Benin has a relatively well-developed network with a total length of 15,500 km, of which 8,300 km are classified, and 2,100 km are paved [71]. Figure 2 shows Benin’s Republic classified road density of 75 km/100 km² of the land area as it is the highest in the subregion and comparable to the average of 88 km/100 km² for low-income countries. The road development index (RDI), which indicates how well the population is served, is 0.26 for the classified network. Its classified network comprises four main corridors (Figure 2), as can be seen below.

(i) A coastal highway from Lagos to Lomé via Cotonou;

(ii) two north-south corridors from Burkina-Faso border to Cotonou via Porga-Djougou-Savalou and from Niger border to Cotonou via Malanville-Parakou; and

(iii) a transverse road from Nigerian border to Togo border via Chicandou, Nikki, and Djougou.

3.2. Data Collection Methodology. The questionnaire created for use in the survey included 20 delay causes identified in road construction project reports and classified into four categories (see Table 5). A questionnaire survey was prepared for data collection and distributed to three decision-makers representing the engineer working at the Benin Republic’s road transport general directorate (client institution), a consultant who has been inspecting road works, and a contractor who has been engaged in road projects under the road transport general directorate. Because of their professional experience, all three individuals have higher positions (at least over ten years).

3.3. Defining Delays Groups and Causes. Construction plays a critical role in economic growth in West Africa in general and in the Benin Republic in particular. However, due to some delays, infrastructure projects, particularly highways, cannot be completed on time. As shown in Table 5, there are four types of delays: construction-related, managerial-related, financial-related, and technical-related, each with five different types of delays.

The process of constructing something is known as construction. There are three types of construction requirements: prescriptive, performance, and proprietary. The
construction group consists of five subcriteria, of which low labor and equipment productivity (C1) and insufficient equipment (C2) are of the beneficial type (B), whereas delays in relocating utilities (C3), varying or unexpected geotechnical conditions during construction (C4), and the effect of rain on construction activities (C5) are of the cost type (C).

The managerial group or management directs or supervises an organization or a group of people. It is the plan and execution of tasks to achieve a goal. This group contains five subcriteria, the work license (M4) being of the cost type, while the other subcriteria are of the advantageous type. Financial management is the process of managing money and accumulating necessary savings. It has five subcriteria, which are all of the cost types. Technical is the quality of acquiring extraordinary and broadly applicable knowledge, particularly in scientific and mechanical fields. It has five subcriteria, of which the cost type is the persistent design changes requested by the client during construction (T1), misreading of drawings (T2), and reworks due to construction faults (T3). In contrast, a lack of technical personnel (T4) and the consultant’s supervisory staff’s unfamiliarity with or lack of information about new construction methods, materials, and procedures (T5) are of a beneficial type.

4. Assessment of Causes of Delay in the Road Construction Project in the Benin Republic by Using a Fuzzy PIPRECIA Method

A category of 20 subcriteria was formed in the first step, and fuzzy PIPRECIA is used to determine their weights. The main criteria, including construction (C), managerial (M), financial (F), and technical (T), are classified as in the CMFT matrix, not considering their importance. Additionally, in
Tables 6 and 7 indicate the evaluation of the Main Criteria. To assess the criteria, which characterize the establishment of the four main criteria analyses.

4.1. Assessment of the Main Criteria. Tables 6 and 7 indicate the evaluation of the main criteria CMFT matrix for the method used and its inverse by three deciders and an average value (AV), which value is employed to assess additional computation.

According to the estimation of criteria and using equation (1), a matrix is established. Using (2), the subtraction of those values is done from number 2. Based on the rules of effectiveness on fuzzy numbers, the \( k_j \) matrix is gained in the following way:

\[
\begin{align*}
k_1^1 &= (1.000, 1.000, 1.000) \\
k_2^1 &= (2-1.350, 2-1.300, 2-1.200) = (0.650, 0.700, 0.800) \\
k_3^1 &= (2-1.650, 2-1.600, 2-1.400) = (0.350, 0.400, 0.600) \\
k_4^1 &= (2-0.800, 2-0.556, 2-0.429) = (1.200, 1.444, 1.571)
\end{align*}
\]

Based on (3), the values of \( q_j \) are obtained as follows:

\[
\begin{align*}
q_1^1 &= (1.000, 1.000, 1.000) \\
q_2^1 &= (1.000/0.800, 1.000/0.700, 1.000/0.650) = (1.250, 1.429, 1.538) \\
q_3^1 &= (1.250/0.600, 1.429/0.400, 1.538/0.350) = (2.083, 3.573, 4.394) \\
q_4^1 &= (2.083/1.571, 3.571/1.444, 4.396/1.200) = (1.326, 2.473, 3.663)
\end{align*}
\]

Using (4), the corresponding weights are computed as follows:

\[
\begin{align*}
\overline{w_1} &= (1.000/10.597, 1.000/8.473, 1.000/5.659) = (0.094, 0.118, 0.117) \\
\overline{w_2} &= (1.250/10.597, 1.429/8.473, 1.538/5.659) = (0.118, 0.169, 0.272) \\
\overline{w_3} &= (2.083/10.597, 3.571/8.473, 4.396/5.659) = (0.197, 0.422, 0.777) \\
\overline{w_4} &= (1.250/10.597, 2.797/8.473, 3.663/5.659) = (0.125, 0.292, 0.647)
\end{align*}
\]

Table 8 indicates the finalized antecedent calculation, and the defuzzified values of corresponding weights of criteria are shown in the last column.

To obtain the final weights of criteria, it is essential to use equations (5-9), particularly the inverse fuzzy PIPRECIA method. According to the evaluation conducted by the deciders and using an average value (AV), the obtaining of \( s_j \) is done:

\[
\begin{align*}
s_1^j &= (0.411, 0.522, 0.722) \\
s_2^j &= (0.290, 0.340, 0.411) \\
s_3^j &= (1.200, 1.300, 1.350)
\end{align*}
\]

The coming values are got through the usage of (7):

\[
\begin{align*}
qu_1^j &= (1.000, 1.000, 1.000) \\
qu_2^j &= (1.000/0.800, 1.000/0.700, 1.000/0.650) = (1.250, 1.429, 1.538) \\
qu_3^j &= (1.250/1.710, 1.429/1.660, 1.538/1.589) = (0.731, 0.860, 0.968) \\
qu_4^j &= (0.731/1.589, 0.860/1.478, 0.968/1.278) = (0.460, 0.582, 0.758)
\end{align*}
\]

Next, it is indispensable to use equation (8) to get the final weights for the fuzzy inverse PIPRECIA approach.
follows:

The weights of the managerial criteria elements are as follows:  $w_{1M} = 0.170, w_{2M} = 0.178, w_{3M} = 0.193, w_{4M} = 0.292,$ and $w_{5M} = 0.195.$

5. Sensitivity Analysis and Discussion of Results

The estimation of Spearman coefficient correlation for the classification obtained by the fuzzy PIPRECIA method and its inverse fuzzy variant was used in the sensitivity analysis. A Pearson correlation coefficient was also determined for the derived weights of CMFT matrix components from both variants of the developed approach. Tables 17 to 21 show the classification as well as the correlation coefficients.

As shown in Table 17, the most significant group of delays is related to the financial aspect, with a value of 0.406. Five subcriteria linked with the financial delay group have been identified and can be resolved by allocating sufficient funds to the project, controlling price escalation, accelerating indemnity of reimbursement, and making the payment procedure supported by the client very quickly. The construction category is the least important source of delay. Furthermore, Table 17 shows the classifications that are identical when applying the fuzzy PIPRECIA and inverse fuzzy PIPRECIA techniques, indicating that the classifications have a complete correlation (SCC = 1.000). The Pearson correlation coefficient of 0.967 validated the higher reliability of the data obtained.

The study looked at five subfactors in the construction delay category, with the second being the most important, which is insufficient equipment (Table 18). Our findings are consistent with previous studies by Al-Najjar [72] and Mahamid, Bruland, and Dmaidi [73], which conclude that a lack of equipment is one of the most significant factors

| PIPR. | C | M | F | T |
|-------|---|---|---|---|
| DM1   | 1.100 | 1.150 | 1.200 | 1.300 | 1.450 | 1.500 | 0.500 | 0.667 | 1.000 |
| DM2   | 1.200 | 1.300 | 1.350 | 1.400 | 1.600 | 1.650 | 0.500 | 0.667 | 1.000 |
| DM3   | 1.300 | 1.450 | 1.500 | 1.500 | 1.750 | 1.800 | 0.286 | 0.333 | 0.400 |
| AV    | 1.200 | 1.300 | 1.350 | 1.400 | 1.600 | 1.650 | 0.429 | 0.556 | 0.800 |

Table 6: Assessment of the main criteria by three deciders for the fuzzy PIPRECIA method.

| P. | s_i | k_j | q_j | w_j | Df |
|----|-----|-----|-----|-----|----|
| C  | 1.200 | 1.300 | 1.350 | 0.650 | 0.700 | 0.800 | 1.250 | 1.429 | 1.538 | 0.118 | 0.117 | 0.124 |
| M  | 1.400 | 1.600 | 1.650 | 0.350 | 0.400 | 0.600 | 2.083 | 3.573 | 4.394 | 0.197 | 0.422 | 0.777 | 0.443 |
| F  | 0.429 | 0.556 | 0.800 | 1.200 | 1.444 | 1.571 | 1.326 | 2.473 | 3.663 | 0.125 | 0.292 | 0.647 | 0.323 |
| SU | 5.659 | 8.473 | 10.597 |

Note. P stands for PIPRECIA; SU stands for SUM.

The weights of the technical criteria elements are as follows: $w_{1T} = 0.186, w_{2T} = 0.266, w_{3T} = 0.218, w_{4T} = 0.198,$ and $w_{5T} = 0.159.$

4.2. Assessment of the Causes of Delay Related to the Four Groups of Delays. The computation of components of all CMFT matrix categories was carried out identically. Tables 9–16 indicate computations and outcomes for all elements of the CMFT matrix. The weights of the construction criteria elements are as follows: $w_{1C} = 0.190, w_{2C} = 0.256, w_{3C} = 0.236, w_{4C} = 0.165,$ and $w_{5C} = 0.181.$

The weights of the managerial criteria elements are as follows: $w_{1M} = 0.221, w_{2M} = 0.253, w_{3M} = 0.202, w_{4M} = 0.179,$ and $w_{5M} = 0.166.$

The weights of the financial criteria elements are as follows: $w_{1F} = 0.186, w_{2F} = 0.266, w_{3F} = 0.218, w_{4F} = 0.198,$ and $w_{5F} = 0.159.$
### Table 9: Assessment of construction delay causes by three deciders for the fuzzy PIPRECIA and inverse fuzzy PIPRECIA.

| PIPR | C1   | C2   | C3   | C4   | C5   | C1   | C2   | C3   | C4   | C5   |
|------|------|------|------|------|------|------|------|------|------|------|
| DM1  | 1.300| 1.450| 1.500| 0.667| 1.000| 1.000| 0.333| 0.400| 0.500| 1.000|
| DM2  | 1.100| 1.150| 1.200| 0.667| 1.000| 1.000| 0.500| 0.667| 1.000| 0.500|
| DM3  | 1.100| 1.150| 1.200| 0.500| 0.667| 1.000| 0.400| 0.500| 0.667| 1.300|
| AV   | 1.167| 1.250| 1.300| 0.611| 0.889| 1.000| 0.411| 0.522| 0.722| 0.933|

### Table 10: Computation and results of the utilization of fuzzy PIPRECIA and inverse fuzzy PIPRECIA for construction delay causes.

| PIPRECIA | sj | kj | qj | wj | Df |
|----------|----|----|----|----|----|
| C1       | 1.167 | 1.250 | 1.300 | 1.000 | 1.000 | 1.000 | 1.000 | 0.158 | 0.193 |
| C2       | 0.611 | 0.889 | 1.000 | 0.700 | 0.750 | 0.833 | 1.200 | 1.333 | 1.429 |
| C3       | 0.411 | 0.522 | 0.722 | 1.000 | 1.111 | 1.389 | 0.864 | 1.200 | 1.429 |
| C4       | 0.933 | 1.039 | 1.183 | 1.278 | 1.478 | 1.589 | 0.544 | 1.200 | 1.429 |
| C5       | 0.817 | 0.961 | 1.067 | 0.510 | 0.845 | 1.369 | 0.080 | 0.163 | 0.332 |
| SUM      | 4.118 | 5.190 | 6.344 | 4.118 | 5.190 | 6.344 | 4.118 | 5.190 | 6.344 |

### Table 11: Assessment of managerial delay causes by three deciders for the fuzzy PIPRECIA and inverse fuzzy PIPRECIA.

| PIPR | M1 | M2 | M3 | M4 | M5 |
|------|----|----|----|----|----|
| DM1  | 1.100| 1.150| 1.200| 0.400| 0.500| 0.667| 0.400| 0.500| 0.667|
| DM2  | 1.100| 1.150| 1.200| 0.400| 0.500| 0.667| 1.200| 1.333| 1.429|
| DM3  | 1.000| 1.050| 1.100| 0.900| 0.950| 0.967| 1.021| 1.367| 1.628|
| AV   | 1.067| 1.100| 1.150| 0.633| 0.717| 0.844| 0.866| 0.972| 0.956|

### Table 12: Computation and results of the utilization of fuzzy PIPRECIA and inverse fuzzy PIPRECIA for managerial delay causes.

| PIPRECIA | sj | kj | qj | wj | Df |
|----------|----|----|----|----|----|
| M1       | 1.067| 1.100| 1.150| 0.850| 0.900| 0.933| 1.071| 1.111| 1.176|
| M2       | 0.633| 0.717| 0.844| 1.156| 1.283| 1.367| 0.784| 0.866| 1.018|
| M3       | 0.667| 0.772| 0.956| 1.044| 1.228| 1.333| 0.588| 0.705| 0.975|
| M4       | 0.611| 0.889| 1.000| 1.000| 1.111| 1.389| 0.423| 0.635| 0.975|
| SUM      | 3.867| 4.317| 5.144| 3.867| 4.317| 5.144| 3.867| 4.317| 5.144|

### Table 13: Computation and results of the utilization of fuzzy PIPRECIA and inverse fuzzy PIPRECIA for other causes.

| PIPRECIA | sj | kj | qj | wj | Df |
|----------|----|----|----|----|----|
| M1       | 0.556| 0.778| 1.000| 1.000| 1.222| 1.444| 0.687| 1.120| 1.775|
| M2       | 1.022| 1.200| 1.233| 0.767| 0.800| 0.978| 0.992| 1.369| 1.775|
| M3       | 0.933| 1.039| 1.183| 0.817| 0.961| 1.067| 0.970| 1.095| 1.361|
| M4       | 1.033| 1.050| 1.110| 0.900| 0.950| 0.967| 1.034| 1.053| 1.111|
| M5       | 1.000| 1.000| 1.000| 1.000| 1.000| 1.000| 1.000| 1.000| 1.000|
| SUM      | 4.684| 5.637| 7.021| 4.684| 5.637| 7.021| 4.684| 5.637| 7.021|
Table 13: Assessment of financial delay causes by three deciders for the fuzzy PIPRECIA and inverse fuzzy PIPRECIA.

| PIPR. | F1   | F2   | F3   | F4   | F5   |
|-------|------|------|------|------|------|
| DM1   | 1.300| 1.450| 1.500| 0.400| 0.500| 0.667| 1.200| 1.300| 1.350| 0.286| 0.333| 0.400|
| DM2   | 1.200| 1.300| 1.350| 0.500| 0.667| 1.000| 1.000| 0.500| 0.667| 1.000| 1.000| 1.000|
| DM3   | 1.100| 1.150| 1.200| 0.667| 1.000| 1.000| 0.400| 0.500| 0.667| 1.000| 1.000| 1.000|
| AV    | 1.200| 1.300| 1.350| 0.522| 0.722| 0.889| 0.700| 0.822| 1.006| 0.540| 0.778| 0.800|

Table 14: Computation and results of the utilization of fuzzy PIPRECIA and inverse fuzzy PIPRECIA for financial delay causes.

| PIPRECIA | \(s_j\) | \(k_j\) | \(q_j\) | \(w_j\) | Df |
|----------|--------|--------|--------|--------|----|
| F1       | 1.000  | 1.000  | 1.000  | 1.000  | 1.000 |
| F2       | 0.700  | 0.949  | 0.949  | 0.949  | 0.949 |
| F3       | 0.540  | 0.777  | 0.777  | 0.777  | 0.777 |
| F4       | 1.412  | 5.273  | 5.273  | 5.273  | 5.273 |
| F5       | 0.411  | 0.522  | 0.522  | 0.522  | 0.522 |
| SUM      | 4.192  | 5.273  | 5.273  | 5.273  | 5.273 |

Table 15: Assessment of technical delay causes by three deciders for the fuzzy PIPRECIA and inverse fuzzy PIPRECIA.

| PIPR. | T1   | T2   | T3   | T4   | T5   |
|-------|------|------|------|------|------|
| DM1   | 1.100| 1.150| 1.200| 1.000| 1.000|
| DM2   | 0.667| 1.000| 1.000| 1.100| 1.100|
| DM3   | 0.667| 1.000| 1.000| 1.000| 1.000|
| AV    | 0.811| 1.050| 1.067| 1.033| 1.050|
| PIPR-I| T5   | T4   | T3   | T2   | T1   |
| DM1   | 1.400| 1.600| 1.650| 0.333| 0.400|
| DM2   | 1.200| 1.300| 1.350| 0.500| 0.667|
| DM3   | 1.100| 1.150| 1.200| 0.333| 0.400|
| AV    | 1.233| 1.350| 1.400| 0.389| 0.489|
| SUM   | 5.194| 6.116| 7.064| 1.311| 1.500|

Table 16: Computation and results of the utilization of fuzzy PIPRECIA and inverse fuzzy PIPRECIA for technical delay causes.

| PIPRECIA | \(s_j\) | \(k_j\) | \(q_j\) | \(w_j\) | Df |
|----------|--------|--------|--------|--------|----|
| T1       | 0.811  | 1.050  | 1.067  | 0.933  | 0.950  | 1.189  | 0.841  | 1.053  | 1.071  | 0.124  | 0.175  | 0.235  | 0.177 |
| T2       | 1.033  | 1.050  | 1.050  | 0.900  | 0.950  | 0.967  | 0.870  | 1.108  | 1.190  | 0.129  | 0.185  | 0.261  | 0.188 |
| T3       | 1.233  | 1.350  | 1.400  | 0.600  | 0.650  | 0.767  | 1.135  | 1.705  | 1.984  | 0.168  | 0.284  | 0.436  | 0.290 |
| T4       | 0.395  | 0.500  | 0.689  | 1.311  | 1.500  | 1.655  | 0.707  | 1.136  | 1.513  | 0.105  | 0.189  | 0.332  | 0.199 |
| SUM      | 4.553  | 6.002  | 6.759  | 0.500  | 0.667  | 1.000  | 0.707  | 1.136  | 1.513  | 0.105  | 0.189  | 0.332  | 0.199 |

| PIPRECIA-I | \(s_j\) | \(k_j\) | \(q_j\) | \(w_j\) | Df |
|------------|--------|--------|--------|--------|----|
| T1         | 0.833  | 0.889  | 1.033  | 0.967  | 1.111  | 1.167  | 0.500  | 0.825  | 1.293  | 0.077  | 0.156  | 0.308  | 0.168 |
| T2         | 0.611  | 0.889  | 1.000  | 1.000  | 1.111  | 1.389  | 0.583  | 0.916  | 1.250  | 0.090  | 0.173  | 0.298  | 0.180 |
| T3         | 0.389  | 0.489  | 0.667  | 1.333  | 1.511  | 1.611  | 0.810  | 1.018  | 1.250  | 0.125  | 0.192  | 0.298  | 0.199 |
| T4         | 1.233  | 1.350  | 1.400  | 0.600  | 0.650  | 0.767  | 1.304  | 1.538  | 1.667  | 0.202  | 0.290  | 0.397  | 0.293 |
| T5         | 0.899  | 1.000  | 1.000  | 1.000  | 1.000  | 1.000  | 0.155  | 0.189  | 0.238  | 0.191  |
causing time delays in building construction projects in the Gaza Strip and road construction projects in the West Bank of Palestine, respectively. The unpredicted geotechnical situation during construction is the least prominent sub-criteria in the construction delay category. A perfect correlation has been observed for the correlation coefficients relating to classifications, whereas a nearly complete correlation has been recorded for the weight elements.

Five subcriteria relating to the managerial group of delays were investigated. The most significant managerial delay factor is insufficiency in planning and scheduling (Table 19). Our findings are consistent with prior studies of Sambasivan and Soon [74] and Khalid [75], which identified improper scheduling/planning as one of the most major delay factors. The least significant managerial delay factor is poor communication and cooperation by the client and other partners. The correlation coefficients show a perfect correlation for the classification and an near-complete connection for the weight elements.

The financial category of delay includes five subcriteria, of which the problems associated with funding projects are the most significant (Table 20). Our findings are in agreement with previous studies by Bounthiphasert et al. [76] and Soliman [77] which put the financial concerns among the main factors driving road construction delays in Laos and Kuwait, respectively. The least dominant subcriteria remain an of financial motivation for contractors to complete the work. The correlation of classifications in the financial delay group is full with a value of 0.973 for the Pearson correlation coefficient.

The technical delay group comprises five elements of which the scarcity of professional personnel is the most significant delay subcriterion (Table 21). Our findings are in agreement with the study of Al-Kharashi and Skitmore [78], which showed that the most affecting delay causes remain the scarcity of experienced and qualified personnel regarding a significant quantity of immense, innovating construction projects and related present deficiencies of personnel in the industry in Saudi Arabia. The following two subcriteria comprising the shortage of knowledge by the consultant’s guidance staff and the redraft due to mistakes during the construction are relatively close based on their weight calculation results. The same remark is observed with the last two subcriteria: the misconception of designs and the persistent variation in design demanded by the client. Concerning the classification correlations, it is not complete (SCC = 0.900) due to the variation in the classification of the third and the fifth elements that shift their places by employing fuzzy PIPRECIA and inverse fuzzy PIPRECIA approaches. Concerning weight correlation, it is higher than the correlation of classifications, and it is PCC = 0.990.

When considering full sensitivity analysis, the results acquired through the established model are assumed to be steady. The classifications within the established method and the values of weights elements are disposed to correspond completely. Table 22 indicates the accomplished integrated results of the fuzzy PIPRECIA method that describe the local and global importance of elements of each aspect separately and the global classifications of elements.

| Table 17: Classification and weight values of the principal delay groups of CMFT matrix. |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Rank | Rank | d | d^2 | I | II | w_j |
| C | 4 | 4 | 0 | 0 | 0.124 | 0.155 | 0.139 | 4 |
| M | 3 | 3 | 0 | 0 | 0.177 | 0.224 | 0.201 | 3 |
| F | 1 | 1 | 0 | 0 | 0.443 | 0.369 | 0.406 | 1 |
| T | 2 | 2 | 0 | 0 | 0.323 | 0.260 | 0.292 | 2 |
| SCC | 1.000 |
| PCC | 0.967 |

| Table 18: Classification and weight values of construction delay group. |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Rank | Rank | d | d^2 | I | II | w_j |
| C1 | 3 | 3 | 0 | 0 | 0.195 | 0.185 | 0.190 | 3 |
| C2 | 1 | 1 | 0 | 0 | 0.261 | 0.252 | 0.256 | 1 |
| C3 | 2 | 2 | 0 | 0 | 0.235 | 0.237 | 0.236 | 2 |
| C4 | 5 | 5 | 0 | 0 | 0.164 | 0.166 | 0.165 | 5 |
| C5 | 4 | 4 | 0 | 0 | 0.177 | 0.184 | 0.181 | 4 |
| SCC | 1.000 |
| PCC | 0.985 |

| Table 19: Classification and weight values of the managerial delay group. |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Rank | Rank | d | d^2 | I | II | w_j |
| M1 | 2 | 2 | 0 | 0 | 0.230 | 0.212 | 0.221 | 2 |
| M2 | 1 | 1 | 0 | 0 | 0.257 | 0.249 | 0.253 | 1 |
| M3 | 3 | 3 | 0 | 0 | 0.203 | 0.201 | 0.202 | 3 |
| M4 | 4 | 4 | 0 | 0 | 0.170 | 0.189 | 0.179 | 4 |
| M5 | 5 | 5 | 0 | 0 | 0.154 | 0.178 | 0.166 | 5 |
| SCC | 1.000 |
| PCC | 0.959 |

| Table 20: Classification and weight values of the financial delay group. |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Rank | Rank | d | d^2 | I | II | w_j |
| F1 | 4 | 4 | 0 | 0 | 0.192 | 0.181 | 0.186 | 4 |
| F2 | 1 | 1 | 0 | 0 | 0.274 | 0.259 | 0.266 | 1 |
| F3 | 2 | 2 | 0 | 0 | 0.218 | 0.218 | 0.218 | 2 |
| F4 | 3 | 3 | 0 | 0 | 0.192 | 0.204 | 0.198 | 3 |
| F5 | 5 | 5 | 0 | 0 | 0.156 | 0.163 | 0.159 | 5 |
| SCC | 1.000 |
| PCC | 0.973 |

| Table 21: Classification and weight values of the technical delay group. |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Rank | Rank | d | d^2 | I | II | w_j |
| T1 | 5 | 5 | 0 | 0 | 0.172 | 0.168 | 0.170 | 5 |
| T2 | 4 | 4 | 0 | 0 | 0.177 | 0.180 | 0.178 | 4 |
| T3 | 3 | 2 | 0 | 0 | 0.188 | 0.199 | 0.193 | 3 |
| T4 | 1 | 1 | 0 | 0 | 0.290 | 0.293 | 0.292 | 1 |
| T5 | 2 | 3 | 0 | 0 | 0.199 | 0.191 | 0.195 | 2 |
| SCC | 0.900 |
| PCC | 0.990 |
As previously stated, the study looked at 20 delay variables that were divided into four categories, with the financial delay category having the most important subfactors. The five most major causes of delays, according to Table 20, are the projects’ financial issues, slowness during the client-endorsed payment procedure, scarcity of professional people, delay in indemnifying reimbursement (land-owners), and price escalation. As a result, the formulation of strategies to mitigate delays in road construction projects in the Benin Republic is necessary.

6. Strategy Formulation to Mitigate Delay in Road Construction Projects

Based on the findings, this study showed the saying, “More wisdom exists in an older person than in an intelligent one,” implying that using construction professionals is a step that the construction industry could take to avoid the most common causes of delays in road construction projects. Their knowledge and understanding of the building sector, as well as their competence, will help them achieve their goals quickly. Following an examination of the study’s findings, the following solutions have been developed to alleviate the causes of delays in road construction in the Benin Republic.

The lack of equipment is the biggest difficulty in road projects in African countries since contractors do not sufficiently analyze equipment for the construction during the procurement stage. Further investigations are also not performed to discover whether the equipment is dedicated to other contractor projects. Consequently, it is proposed that the inspectors or controllers monitor an appropriate examination of the undertaking equipment during the achievement time of the procurement phase.

Inadequate planning and operation during the construction project could lead to a variety of adverse project results. Due to scheduling constraints and construction delays, a successful adventure is turning into a defeat. As a result, effective project management and thorough pre-project planning should be performed to reduce or eliminate these delays as they are critical success factors for completing the construction project.

A project’s proper guidance and work are based on a schedule, which is an important aspect of primarily employing available resources and labor. Extensive technical knowledge, the sequential order of building works, and an accurate rational relationship between the works and assets required for each activity are all essential in scheduling. Due to an ineffective project timetable, important project assets will be diverted to nonessential operations. As a result, key activities will be hampered, and delays will occur during the construction phase. To lessen or avoid scheduling challenges, the scheduler must have a strong technical understanding background that applies to the project. The scheduler should also be able to grasp the job’s dimensions correctly.

According to the results of our research, the major financial-related causes of project delays are issues linked to project funding and delays during the payment procedure endorsed by the client. To reduce cash flow concerns for project clients, banks should provide end-financing. Banks should also speed up the delivery of loans to customers once all conditions have been met. In terms of payment, the client should make a timely payment to the main contractor. In terms of legislation, it should be updated to provide a clear understanding of the refund and payment processes for both clients and contractors.

Highly skilled resource persons are vital for the socio-economic growth of a country, to which education is one of the primary elements. The shortage of professionals is identified to be the major technical-related cause leading to road project delays. Consequent supply of suitable education and professional training is important to enhance national capability and assist high-quality human resources with technical skills.

7. Conclusions

The fuzzy PIPRECIA approach is used in this study to examine the causes of delays in road construction projects in the Benin Republic. A total of 20 causes for delays were investigated, and they were divided into four categories: construction, managerial, financial, and technical. Three decision-makers are included in the survey. The findings revealed the top five reasons for road construction project delays in the Benin Republic, four of which are financial and one being technical. The most significant causes of delays in the construction, managerial, financial, and technical groups, respectively, are a lack of equipment, improper scheduling/planning, finding challenges, and a lack of experienced and competent staff.
The financial aspect is the most significant delay group, with a weight value of 0.406, followed by the technical aspect \((w=0.292)\), and the management aspect \((w=0.201)\), according to the classification and weight values of delay groups. With a score of 0.139, the construction category is the least significant among the delay groups. A sensitivity analysis based on the estimate of Spearman and Pearson coefficients was used to confirm the findings of this study. Given the detrimental consequences of delays in specific road construction projects, it is recommended that strategies based on the study’s findings be developed to control and mitigate delays during the road construction project. These strategies can assist project managers in the Benin Republic in reducing road construction delays. Furthermore, this research is useful for both academic institutions and road construction practitioners since it enables efficient and detailed analysis of a road construction project’s progress to facilitate and achieve a competitive level of time, cost, and quality for successful road construction.

This is the first study of its kind in the Benin Republic, involving the use of multicriteria decision-making to examine the causes of the delay. The implemented methodology demonstrated how the criteria were examined without first classifying them in order of critical importance and how subjectivity and uncertainty can be reduced in the decision-making process. As a result, the applied methodology may be useful in different decision-making scenarios. The method’s greatest shortcoming is that researchers can only utilize the scales provided for the assessment and no others. In addition, for the entire procedure, including the steps of the fuzzy PIPRECI A and the inverse fuzzy PIPRECI A, fuzzy PIPRECI A necessitates a very exact assessment of decision-makers. In future studies, the adopted method can be applied to objective data to demonstrate and prove all of the approach’s benefits. The study’s shortcoming is that it only considers four types of delays and the perspectives of only three decision-makers: one consultant, one contractor, and one client. Other types, such as personnel and equipment, materials, projects, and externally connected delays, may be considered in future studies. In addition, the number of decision-makers needs to be increased. In terms of the methodology to be implemented, certain classic methodologies [79–85] or new newly established methods [86–97] can be used to assess the causes of the delay.

Data Availability

The data used to support the findings of this study are included within this article. However, more details on the data can be made available upon request to the corresponding author.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] C. Kaliba, M. Muya, and K. Mumba, “Cost escalation and schedule delays in road construction projects in Zambia,” International Journal of Project Management, vol. 27, no. 5, pp. 522–531, 2009.
[2] C. T. Amoatey and A. N. O. Ankrah, “Exploring critical road project delay factors in Ghana,” Journal of Facilities Management, vol. 15, 2017.
[3] R. F. Aziz and A. A. Abdel-Hakam, “Exploring delay causes of road construction projects in Egypt,” Alexandria Engineering Journal, vol. 55, no. 2, pp. 1515–1539, 2016.
[4] H. Derakhshian, J. J. Ochoa, K. Krytopoulos, W. Mayer, and V. W. Tam, “Construction delay risk taxonomy, associations and regional contexts: a systematic review and meta-analysis,” Construction and Architectural Management, vol. 26, 2019.
[5] Y. Xenidis and E. Stavarakas, “Risk based budgeting of infrastructure projects,” Procedia - Social and Behavioral Sciences, vol. 74, pp. 478–487, 2013.
[6] E. Viles, N. C. Rudeli, and A. Santilli, “Causes of delay in construction projects: a quantitative analysis, Engineering,” Construction and Architectural Management, vol. 27, 2019.
[7] M. O. Sanni-Anibire, R. Mohamad Zin, and S. O. Olatunji, “Causes of delay in the global construction industry: a meta analytical review,” International Journal of Construction Management, pp. 1–13, 2020.
[8] S. Durdyev and M. R. Hosseini, “Causes of delays on construction projects: a comprehensive list,” International Journal of Managing Projects in Business, vol. 13, 2019.
[9] Z. Rachid, B. Toufik, and B. Mohammed, “Causes of schedule delays in construction projects in Algeria,” International Journal of Construction Management, vol. 19, no. 5, pp. 371–381, 2019.
[10] A. Alfakhir, I. Ismail, A. Muhamad, I. Arhad, and H. Irtema, “A conceptual model of delay factors affecting road construction projects in Libya,” Journal of Engineering Science & Technology, vol. 12, pp. 3286–3298, 2017.
[11] F. Leo-Olagbaye and H. A. Odeyinka, “An Assessment of Risk Impact on Road Projects in Osun State, Nigeria,” Built Environment Project and Asset Management, vol. 10, 2020.
[12] M. Kamanga and W. V. D. M Steyn, “Causes of delay in road construction projects in Malawi,” Journal of the South African Institution of Civil Engineering, Joernal van die Suid-Afrikanse Instituut van Siviele Ingenieurswese, vol. 55, pp. 79–85, 2013.
[13] K. Khair, Z. Mohamed, R. Mohammad, H. Farouk, and M. E. Ahmed, “A management framework to reduce delays in road construction projects in Sudan,” Arabian Journal for Science and Engineering, vol. 43, no. 4, pp. 1925–1940, 2018.
[14] Y. F. Kassa, “Determinants of infrastructure project delays and cost escalations: the cases of federal road and railway construction projects in Ethiopia,” American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS), vol. 63, pp. 102–136, 2020.
[15] M. Atibu, “An Investigation into Factors Causing Delays in Road Construction Projects in Kenya,” American Journal of Civil Engineering, vol. 3, 2015.
[16] A. S. Ezeldin and M. Abdel-Ghany, “Causes of construction delays for engineering projects: an Egyptian perspective,” in Proceedings of the AEI 2013: Building Solutions for Architectural Engineering, pp. 54–63, Pennsylvania, PA, USA, April 2013.
[17] H. Alinaitwe, R. Apolot, and D. Tindiwensi, “Investigation into the causes of delays and cost overruns in Uganda’s public sector construction projects,” Journal of Construction in Developing Countries, vol. 18, p. 33, 2013.

[18] N. Chileshe, P. D. Berko, and T. Haupt, “Causes of project cost overruns within the Ghanaian road construction sector,” in Proceedings of the Association of Schools of Schools of Construction of Southern Africa, Durban, South Africa, July 2010.

[19] Z. Stević, Ž. Stepanović, Z. Božičković, D. K. Das, and D. Stanujkic, “Assessment of conditions for implementing information technology in a warehouse system: a novel fuzzy piprecia method,” Symmetry, vol. 10, p. 586, 2018.

[20] M. Książek, P. Nowak, J. Rosłon, and T. Wieczorek, “Multicriteria assessment of selected solutions for the building structural walls,” Procedia Engineering, vol. 91, pp. 406–411, 2014.

[21] M. V. Książek, P. O. Nowak, S. Kivtrak, J. H. Rosłon, and L. Ustinovichius, “Computer-aided decision-making in construction project development,” Journal of Civil Engineering and Management, vol. 21, pp. 248–259, 2015.

[22] T. Trzaskalik, Metody Wielokryterjalne Na Polskim Rynku Finansowym, PWE, Warszawa, Poland, 2006.

[23] M.-H. Ha, Z. Yang, and J. S. L. Lam, “Port performance in container transport logistics: a multi-stakeholder perspective,” Transport Policy, vol. 73, pp. 25–40, 2019.

[24] I. Gokasar, M. Deveci, and O. Kalan, “CO2 Emission based prioritization of bridge maintenance projects using neutrosophic fuzzy sets based decision making approach,” Research in Transportation Economics, Article ID 101029, 2021.

[25] D. Pamucar, F. Ecer, and M. Deveci, “Assessment of alternative fuel vehicles for sustainable road transportation of United States using integrated fuzzy FUCOM and neutrosophic fuzzy MARCOS methodology,” The Science of the Total Environment, vol. 788, Article ID 147763, 2021.

[26] R. Krishankumar, D. Pamucar, M. Deveci, and K. S. Ravichandran, “Prioritization of zero-carbon measures for sustainable urban mobility using integrated double hierarchy decision framework and EDAS approach,” The Science of the Total Environment, vol. 797, Article ID 149068, 2021.

[27] D. Pamucar, M. Deveci, I. Gokasar, and M. Popovic, “Fuzzy Hamacher WASPAS Decision-Making Model for Advantage Prioritization of Sustainable Supply Chain of Electric Ferry Implementation in Public Transportation,” Environment, Development and Sustainability, pp. 1–40, 2021.

[28] I. Z. Akyurt, D. Pamucar, M. Deveci, O. Kalan, and Y. Kuvvetli, “A Flight Base Selection for Flight Academy Using a Rough MACBETH and RAIFS Based Decision-Making Analysis,” IEEE Transactions on Engineering Management, 2021.

[29] M. B. Bouraima, Z. Stević, I. Tanackov, and Y. Qiu, “Assessing the performance of Sub-Saharan African (SSA) railways based on an integrated Entropy-MARCOS approach,” Operational Research in Engineering Sciences: Theory and Applications, vol. 4, pp. 13–35, 2021.

[30] M. B. Bouraima, Y. Qiu, B. Yusupov, and C. M. Ndjegevwe, “A study on the development strategy of the railway transportation system in the West African Economic and Monetary Union (WAEMU) based on the SWOT/AHP technique,” Scientific African, vol. 8, Article ID e00388, 2020.

[31] B. Karlešuša, N. Dragičević, and A. Deluka-Tibiljaš, Review of Multicriteria-Analysis Methods Application in Decision Making about Transport Infrastructure, vol. 65, no. 7, pp. 619–631, 2013, Građevinar.

[32] T. L. Saaty, “How to make a decision: the analytic hierarchy process,” European Journal of Operational Research, vol. 48, pp. 9–26, 1990.

[33] G. Yannis, A. Kopsachilis, A. Dragomanovits, and V. Petraki, “State-of-the-art review on multi-criteria decision-making in the transport sector,” Journal of Traffic and Transportation Engineering, vol. 7, 2020.

[34] P. Razi, M. Ali, and N. Ramli, “AHP-based analysis of the risk assessment delay case study of public road construction project: an empirical study,” Journal of Engineering Science & Technology, vol. 14, pp. 875–891, 2019.

[35] M. Wagale and A. P. Singh, “The application of adaptive neuro-fuzzy inference system and fuzzy Delphi technique to assess socio-economic impacts of construction of rural roads,” Transport and Telecommunication, vol. 20, pp. 325–345, 2019.

[36] M. V. S. Phogat and A. P. Singh, “Selection of equipment for construction of a hilly road using multi criteria approach,” Procedia-Social and Behavioral Sciences, vol. 104, pp. 282–291, 2013.

[37] M. Hasnain, M. J. Thaheem, and F. Ullah, “Best value contractor selection in road construction projects: ANP-based decision support system,” International Journal of Civil Engineering, vol. 16, pp. 695–714, 2018.

[38] F. Yücelgazi and I. Yitmen, “An ANP model for risk assessment in large-scale transport infrastructure projects,” Arabian Journal for Science and Engineering, vol. 44, pp. 4257–4275, 2019.

[39] F. Yücelgazi and I. Yitmen, “An ANP model for risk response assessment in large scale bridge projects,” Civil Engineering and Environmental Systems, vol. 37, pp. 1–27, 2020.

[40] H. Mosalman Yazdi, M. Mosalman Yazdi, and E. Mohammadi, “Delay determination of subway construction project by fuzzy MCDM (case study, karaj subway),” Amirkabir Journal of Civil Engineering, vol. 51, pp. 143–156, 2019.

[41] M. Badalpur and E. Nurbakhsh, “An application of WASPAS method in risk qualitative analysis: a case study of a road construction project in Iran,” International Journal of Construction Management, vol. 21, pp. 1–9, 2019.

[42] E. K. Zavadskas, R. Liias, and Z. Turskis, “Multi-attribute decision-making methods for assessment of quality in bridges and road construction: state-of-the-art surveys,” The Baltic Journal of Road and Bridge Engineering, vol. 3, pp. 152–160, 2008.

[43] G. Khorasani, A. Yadollahi, M. Rahimi, and A. Tatari, “Implementation of MCDM methods in road safety management,” in Proceedings of the International Conference on Transport, Civil, Architecture and Environmental Engineering, pp. 26–27, ICTCAEE’2012, Dubai, December, 2012.

[44] R. Kishore, S. A. M. Dehmourdi, M. G. Naik, and M. Hassanpour, “Designing a framework for Subcontractor’s selection in construction projects using MCDM model,” Operational Research in Engineering Sciences: Theory and Applications, vol. 3, pp. 48–64, 2020.

[45] G. Paredes and R. F. Herrera, “Teaching multi-criteria decision making based on sustainability factors applied to road projects,” Sustainability, vol. 12, p. 8930, 2020.

[46] F. Antoniou, “Delay risk assessment models for road projects,” Systems, vol. 9, p. 70, 2021.

[47] A. Sandra, V. V. Rao, K. Raju, and A. Sarkar, “Prioritization of pavement stretches using fuzzy MCDM approach–A case study,” in Soft Computing in Industrial Applications, pp. 265–278, Springer, Berlin, Germany, 2007.
[48] M. Talebi, B. Majnounian, M. Makhdoom et al., "A GIS-MCDM-based road network planning for tourism development and management in Arasbaran forest, Iran," Environmental Monitoring and Assessment, vol. 191, pp. 1-15, 2019.

[49] D. Nenadić, "Ranking dangerous sections of the road using MCDM model," Decision Making: Applications in Management and Engineering, vol. 2, pp. 115–131, 2019.

[50] M. A. Taş and E. Çakır, "Ranking Triangular and Trapezoidal Fuzzy MARCOS Methods on Road Risk," in Proceedings of the 2021 IEEE Sixth International Forum on Research and Technology for Society and Industry (RTSI), pp. 370–375, IEEE, Naples, Italy, September 2021.

[51] S. Vrtagić, E. Sofić, M. Subotić, Ž. Stević, M. Dordević, and M. Ponjavić, "Ranking road sections based on MCDM model: new improved fuzzy SWARA (IMF SWARA)," Axioms, vol. 10, p. 92, 2021.

[52] E. Liachovičius, V. Skrickij, and A. Podviezko, "MCDM evaluation of asset-based road freight transport companies using key drivers that influence the enterprise value," Sustainability, vol. 12, p. 7259, 2020.

[53] R. Malik, A. Zaidan, B. Zaidan et al., "Novel roadside unit positioning framework in the context of the vehicle-to-infrastructure communication system based on AHP—entropy for weighting and borda—VIKOR for uniform ranking," International Journal of Information Technology and Decision Making, pp. 1–34, 2021.

[54] D. D. Boko-haya, Y. Li, C. Yao, S. Liu, and Q. Xiang, "Road and bridge infrastructure development issues in Benin Republic: analysis and perspectives," American Journal of Civil Engineering, vol. 5, pp. 9–15, 2017.

[55] M. B. Bouraima, Y. Qiu, and B. Yusupov, "A review and analysis of railway transportation system in the economic community of West African States: towards the development of sustainable regional goal," Global Journal of Engineering and Technology Advances, vol. 2, pp. 11–22, 2020.

[56] M. B. Bouraima and Y. Qiu, "Toward innovative solutions for revitalizing Benin republic railway transportation system," in Proceedings of the International Conference on Transportation and Development 2018: Traffic and Freight Operations and Rail and Public Transit, pp. 238–246, American Society of Civil Engineers Reston, Pittsburgh, PA, Pennsylavnia, July 2018.

[57] M. B. Bouraima and Y. Qiu, "Past, present and future development of West African railways," Journal of Sustainable Development of Transport and Logistics, vol. 5, pp. 103–114, 2020.

[58] M. Bouraima and C. Dominique, "Road infrastructure and economic growth in Benin republic," Scholars Bulletin (Civil Engineering), vol. 4, pp. 680–688, 2018.

[59] M. Stanković, Ž. Stević, D. K. Daz, M. Subotić, and D. Pumsara, "A new fuzzy MARCOS method for road traffic risk analysis," Mathematics, vol. 8, p. 457, 2020.

[60] S. Memiş, E. Demir, Ç. Karamasa, and S. Korucuk, "Prioritization of road transportation risks: an application in Giresun province," Operational Research in Engineering Sciences: Theory and Applications, vol. 3, pp. 111–126, 2020.

[61] I. Đalić, Ž. Stević, C. Karamasa, and A. Puška, "A novel integrated fuzzy PIPRECIA–interval rough SAW model: green supplier selection," Decision Making: Applications in Management and Engineering, vol. 3, pp. 126–145, 2020.

[62] S. Veskić, S. Milinković, B. Abramović, and I. Ljubić, "Determining criteria significance in selecting reach stackers by applying the fuzzy PIPRECIA method," Operational Research in Engineering Sciences: Theory and Applications, vol. 3, pp. 72–88, 2020.

[63] S. Veskić, Ž. Stević, D. Karabašević, S. Rajlić, S. Milinković, and G. Stojić, "A new integrated fuzzy approach to selecting the best solution for business balance of passenger rail operator: fuzzy PIPRECIA-fuzzy EDAS model," Symmetry, vol. 12, p. 743, 2020.

[64] A. Blagojević, Ž. Stević, D. Marinković, S. Kasalica, and S. Rajlić, "A novel entropy-fuzzy PIPRECIA-DEA model for safety evaluation of railway traffic," Symmetry, vol. 12, p. 1479, 2020.

[65] M. Nedeljković, A. Puška, S. Doljanica et al., "Evaluation of rapeseed varieties using novel integrated fuzzy PIPRECIA–Fuzzy MABAC model," PLoS One, vol. 16, Article ID e0246857, 2021.

[66] M. Tomašević, L. Lapuh, Ž. Stević, D. Stanušić, and D. Karabašević, "Evaluation of criteria for the implementation of high-performance computing (HPC) in Danube Region countries using fuzzy PIPRECIA method," Sustainability, vol. 12, p. 3017, 2020.

[67] D. D. Boko-haya, Y. Li, C. Yao, S. Liu, and Q. Xiang, "Road and bridge infrastructure development issues in Benin Republic: analysis and perspectives," American Journal of Civil Engineering, vol. 5, pp. 9–15, 2017.

[68] I. Đalić, J. Ateljević, Ž. Stević, S. Terzić, "An integrated swot-fuzzy picropi model for analysis of competitiveness in order to improve logistics performances," Facta Universitatis – Series: Mechanical Engineering, vol. 18, pp. 439–451, 2020.

[69] I. Đalić, Ž. Stević, J. Ateljević, Z. Turskis, E. K. Zavadskas, and A. Mardani, "A Novel Integrated MCDM-SWOT-TOWS Model for the Strategic Decision Analysis in Transportation Company," Facta Universitatis, Series: Mechanical Engineering, vol. 19, 2021.

[70] D. D. Boko-haya, Y. Li, C. R. Yao, Y. Gu, B. Qiang, and Q. Q. Xiang, "Development of conceptual model for overcoming the challenges of road and bridge infrastructure development: towards innovative solutions in Benin Republic," in International Journal of Engineering Research in Africa, vol. 26, pp. 161–175, Trans Tech Publ, 2016.

[71] J. M. Al-Najjar, Factors Influencing Time and Cost Overruns on Construction Projects in the Gaza Strip, Master thesis, Faculty of Engineering, The Islamic University, Gaza, State of Palestine, 2008.

[72] I. Mahamid, A. Bruland, and N. Dmaidi, "Causes of delay in road construction projects," Journal of Management in Engineering, vol. 28, pp. 300–310, 2012.

[73] M. Sambasivan and Y. W. Soon, "Causes and effects of delays in Malaysian construction industry," International Journal of Project Management, vol. 25, pp. 517–526, 2007.

[74] F. J. I. Khalid, "The Impact of Poor Planning and Management on the Duration of Construction Projects: A Review," Multi-Knowledge Electronic Comprehensive Journal For Education And Science Publications, vol. 2, pp. 161–181, 2017.

[75] S. Bounthiphasert, N. Shozo, O. Toshihiro, and N. Takafumi, "Causes of delays in road construction projects in Laos," Global Journal of Researches in Engineering, vol. 20, 2020.

[76] E. Soliman, "Delay causes in Kuwait construction projects," in Proceedings of the Seventh Alexandria International Conference on Structural and Geotechnical Engineering, pp. 57–67, AICSGE, Alexandria, Egypt, December 2010.
[78] A. Al-Kharashi and M. Skitmore, “Causes of delays in Saudi Arabian public sector construction projects,” Construction Management & Economics, vol. 27, pp. 3–23, 2009.

[79] Ž. Stević, D. Pamučar, A. Puška, and P. Chatterjee, “Sustainable supplier selection in healthcare industries using a new MCDM method: Measurement of alternatives and ranking according to COmpromise solution (MARCOS),” Computers & Industrial Engineering, vol. 140, Article ID 106231, 2020.

[80] L. Muhammad, I. Badi, A. A. Haruna, and I. Mohammed, “Selecting the best municipal solid waste management techniques in Nigeria using multi criteria decision making techniques,” Reports in Mechanical Engineering, vol. 2, pp. 180–189, 2021.

[81] D. Pamučar and G. Ćirović, “The selection of transport and handling resources in logistics centers using Multi-Attributive Border Approximation area Comparison (MABAC),” Expert Systems with Applications, vol. 42, pp. 3016–3028, 2015.

[82] A. Alosta, O. Elmansuri, and I. Badi, “Resolving a location selection problem by means of an integrated AHP-RAFSI approach,” Reports in Mechanical Engineering, vol. 2, pp. 135–142, 2021.

[83] D. Stanujkić and D. Karabašević, “An extension of the WASPAS method for decision-making problems with intuitionistic fuzzy numbers: a case of website evaluation,” Operational Research in Engineering Sciences: Theory and Applications, vol. 1, pp. 29–39, 2018.

[84] C. Kahraman, M. Keshavarz Ghorabaee, E. K. Zavadskas, S. Cevik Onar, M. Yazdani, and B. Oztaysi, “Intuitionistic fuzzy EDAS method: an application to solid waste disposal site selection,” Journal of Environmental Engineering and Landscape Management, vol. 25, pp. 1–12, 2017.

[85] Ž. Stević, E. Durmić, M. Gajić, D. Pamučar, and A. Puška, “A novel multi-criteria decision-making model: interval rough SAW method for sustainable supplier selection,” Information, vol. 10, p. 292, 2019.

[86] M. Kovač, S. Tadić, M. Krstić, and M. B. Bouraima, “Novel Spherical Fuzzy MARCOS Method for Assessment of Drone-Based City Logistics Concepts,” Complexity, vol. 2021, Article ID 2374955, 17 pages, 2021.

[87] F. Kutlu Gündoğdu and C. Kahraman, “Spherical fuzzy sets and spherical fuzzy TOPSIS method,” Journal of Intelligent & Fuzzy Systems, vol. 36, pp. 337–352, 2020.

[88] F. Kutlu Gündoğdu and C. Kahraman, “A novel fuzzy TOPSIS method using emerging interval-valued spherical fuzzy sets,” Engineering Applications of Artificial Intelligence, vol. 85, pp. 307–323, 2019.

[89] F. Kutlu Gündoğdu and C. Kahraman, “Extension of WASPAS with spherical fuzzy sets,” Informatica, vol. 30, pp. 269–292, 2019.

[90] F. K. Gündoğdu and C. Kahraman, “A novel spherical fuzzy analytic hierarchy process and its renewable energy application,” Soft Computing, vol. 24, pp. 4607–4621, 2020.

[91] F. Kutlu Gündoğdu, “A spherical fuzzy extension of MULTIMOORA method,” Journal of Intelligent and Fuzzy Systems, vol. 38, pp. 963–978, 2020.

[92] F. Kutlu Gündoğdu, C. Kahraman, and H. N. Civan, “A novel hesitant fuzzy EDAS method and its application to hospital selection,” Journal of Intelligent and Fuzzy Systems, vol. 35, pp. 6353–6365, 2018.

[93] F. Kutlu Gündoğdu and C. Kahraman, “A novel VIKOR method using spherical fuzzy sets and its application to warehouse site selection,” Journal of Intelligent and Fuzzy Systems, vol. 37, pp. 1197–1211, 2019.