INDISPENSABLE DELAY ANALYSIS METHOD SELECTION: AN INTEGRATED AHP-RII APPROACH

Vo Minh Huy¹, Huynh Thi My Dung²*

Abstract – Delay is an inevitable event in construction projects due to their intricacy and dynamic nature, therefore, the project parties frequently come to disputes about which party is liable for schedule delays. Delay analysis methods are gradually evolved and used to steadily determine and apportion delay’s responsibilities. Notwithstanding, courts and arbitrary boards have not legalized any specific standard category of delay analysis technique to evaluate the impact of delay activity(es) on total project duration timely. Also, there is no universal delay analysis method that can be used better than the others under certain circumstances. This research, thus, targets to seek the most appropriate and fundamental delay analysis method for delay claims resolution. The study methodology was adopted by conducting an extensive literature review to identify current delay criteria that have much more impact on the selection of delay analysis method than existing delay analysis method that is also carried out for an efficient discussion with a panel of experts. The Integrated Analytical Hierarchy Process and Relative Importance Index approach are ideally employed to analyze the highest and the most priority delay analysis method along with the critical factor weight influencing detection the most proper type of delay analysis. Study findings are highly authentic because of fairly selecting the best delay analysis method based on reliable delay factors and available delay analysis methods. The researchers and practitioners may yield viable study outputs for incipiently practical preparation of a variety of data and documents that can be publicly supported as active and valid evidence for future claims.

Keywords: construction project, delay analysis method, delay criteria, integrated AHP-RII approach.

I. INTRODUCTION

Successful completion of the project within the schedule, budgeted cost, and quality assurance is considered an arduous task of project management for contracting parties. It is, therefore, very customary for construction project delays, cost overruns, and rework [1–4]. When schedule delays occur, possibly assessing the impact of the delay sometimes takes a long time since the project consists of many involved parties, such as the owner, contractor, consulting parties, and stakeholders. Practically, a variety of potential factors can affect the occurrence of delays and contemporaneous studies have been devoted and made a great effort to delay causes all over the world [4–7]. Sometimes, the party’s responsibility is the owner-caused delay, some caused by the contractor or by neither both parties. For the employer-caused delays (excusable, compensable), an extension of time shall be entitled to the contractor and cost compensation while the contractor shall be fully liable due to his caused delays (non-excusable) as well as the third party caused delays (non-compensable). Along with identifying the causes of delays and apportioning the responsibility for delays, analyzing schedule delays and evaluating the impact on the project participants are not simplistic and easy work because it is time-consuming, resources, cost loading, and misconception in delay claims resolution. Currently, a lot of different delay analysis methods (DAMs) have been developed in the construction industry with different strengths.
and weaknesses. Each approach has a distinct procedure and analytical application process for analyzing schedule delays. In the wake of naturally selecting the appropriate method of delay analysis, it seems to be a likely part of where many inherent disputes go wrong. An individual implementing for a typical party can be able to detect historically a particular delay technique providing benefits to the party in a dispute [8, 9]. By have seen expressly that the delay analysis method (DAM) is commonly sought for arbitrary selection rather than based upon the actual experiences and experts’ capability. Delay factors impacted on the selection of DAM have been widely studied in the literature review. For instance, Arditi et al. [10] pointed out that the selection of the proper analysis method depends upon a variety of factors, including information available, time of analysis, capabilities of the methodology, and time, funds, and effort allocated to the analysis. Then Adhikari et al. [11] employed the outcomes of the results to apply the analytical hierarchy process (AHP) approach to detect the appropriate DAM for the construction industry. Later study, the simple additive weighting method (SAW) was utilized for the selection of the optimum technique of delay analysis for construction projects [12]. However, these studies have adopted both inherently limited delay factors (criteria) and DAMs (alternatives) that cannot be capable of seeking a greatly appropriated DAM. More recently, the fuzzy VIKOR (VIsekriterijumska optimizacija i KOmpromisno Resenje) approach was conducted by considering the detected selection criteria and the most common DAMs for mega airport projects [13]. The research typically reached the gaps in the literature by paying much attention to selecting the most fundamental DAM and considering the project type and size in the selection of delay analysis techniques will provide more reliable outcomes. On the one hand, the authors had a conclusion of 27 delay criteria in which only 16 factors were used for application. On the other hand, several fruitful DAMs have been gradually proposed in the literature, however, the studied limitation of alternatives has firstly made it incompletely reliable for the construction industry. Secondly, a single approach (fuzzy VIKOR) remains its inherent problem. In essence, it is in the hour of need for further study that aims to develop the novel and indispensable DAM selection for analyzing schedule delays by applying an integrated approach.

The study method starts by conducting an in-depth literature review in terms of delay factors and existing DAMs. These criteria and alternatives were identified succinctly in compliance with the Association of the Advancement of Cost Engineering International (“AACEI”) published its Recommended Practice No. 29R-03 (RP) in June 2007. This RP was revised twice, with the latest revision in April 2011 (AACE RP 29R-03, 2011) [14] and the Society of Construction Law (SCL) delay and disruption protocol (SCL, 2002), its second edition (SCL, 2017) [15]. By the same year, in 2017, the American Society of Civil Engineers (ASCE) Construction Institute Schedule Delay Analysis Standards Committee published consensus industry standard guidelines for schedule delay analysis in the United States by the American National Standards Institute (ANSI) under the designation ANSI/ASCE/CI 67-17 Schedule Delay Analysis (the ASCE Standard, 2017) [16]. A focus group discussion (FGD) with a panel of 10 experts, dispute resolvers, and analysts who have at least a 5-year experience in delay claims resolution shall be materially performed. More importantly, the combined analytical hierarchy process - relative importance index (AHP-RII) approach has been analyzed to find out the best DAM in the given delay factors and conditions for construction projects. As a basic tool for decision-making, the AHP is the most widely used, simplest, and most accurate method [13, 17]. Its integration with the RII approach in this study ensures that the results are reliable, highly accurate, credible, and consistent, making them exceptionally valuable in practical applications [18].
II. LITERATURE REVIEW AND RESEARCH MODEL

A. Delay criteria

Previous studies have revealed a wide range of underlying criteria impacting the selection of the best DAMs. Taking into first consideration by Braimad et al. [19], a total of 18 potential factors were determined through literature review and pilot surveys and then ranked on their relative importance based on data collected in a nationwide survey of UK construction organizations. The study research concluded six latent features: project characteristics, contractual requirements, availability of baseline schedule, cost proportionality, the timing of the analysis, and record availability. Additionally, DAM proper selection was subject to a wide number of factors, including availability of information data, time of analysis, capabilities of methodologies, and time and funds available for analysis [10]. Particularly, Yang et al. [8] developed a delay analysis selection model for construction projects that identified the optimum delay analysis type for a given objective circumstance in which 26 attributes were investigated and grouped into seven categories. Then the attribute weights and categories were computed by the entropy method. Following the validation, Perera et al. [12] proposed a decision-making model (DMM) to support concerning parties in the domain. By applying the SAW approach, seven key factors in the level 2 and 23 attributes in level 3 of developed DMM were analyzed in terms of significant index and important index, respectively, and the validation of DMM is applied via a series of case studies and a professional panel. Furthermore, the study by Cevikbas et al. [13] was conducted through an intensive literature review and a 12-expert panel to detect the further factors impacting the selection of DAM, a total of 26 criteria were grouped into six categories and analyzed via the Fuzzy VIKOZ method for the selection of the appropriate delay analysis approach for mega airport projects. Notwithstanding, since projects are one-of-a-kind by nature, the DAM alone shall not be the best for all project circumstances under certain conditions. Thus, concerning numerous studies that have been developed by scholars for the appropriate selection of DAM, the inherent problems of delay analysis still exist and are one of the primary domains of scientific study currently in construction projects. The previous studies have included constant limitations with criteria and alternatives which seems to be likely in confusion to the practitioners and researchers. Instantly, the SCL (2017), AACE RP 29R-03 (2011), and ASCE Standard (2007) are the most recognized documents that provide sufficient guidance on selection factors, delay analysis types that arise on a project in evaluating extensions of time or compensation for delay. More than that, they also provide more guidance on general applications subject to the specific contract and legal jurisdiction of the matter. However, they are not legal bidding unless incorporated into the contract but have been used in the UK and US as well as internationally instructive in approaching common delay and disruption matters. Contrastingly, probably lacks practicality on how such factors influence and application of DAMs. Both the SCL and ASCE standards are highly intended to be balanced among the contracting parties and present the interests of all parties in construction delay claims and disputes.

Therefore, this targeted study heavily focuses on 3 types of aforementioned documents to detect the most indispensable factors which affect the severe selection of DAM, along with conducting an in-depth literature review and an expert panel to eventually squeeze out the criteria and alternatives weight. The following group of key delay factors (which are almost covering a wide range of sub-delay factors in schedule delays of the construction projects) are from AACE RP 29R-03 (2011) for an FGD such as Contractual requirements, Purpose of analysis, Source data availability and reliability, Size of the dispute, Complexity of the dispute, Budget for forensic schedule analysis, Time allowed for forensic schedule analysis, Expertise of the forensic schedule analyst and resources available, Forum for resolution and audience, Legal or procedural
requirements, Custom and usage of methods on the project or the case and adding other matters (if any) because it is not possible to create an exhaustive list of all the factors to consider when selecting and implementing the delay analysis approach. This is probably true because each project is unique by nature. Therefore, the delay analyst should apply analytical skills and professional judgment on how to analyze and categorize the delays based on the above specific matters.

B. Available delay analysis methods

Plentiful delay analysis techniques have been gradually proposed and used for analyzing schedule delays and related problems. Selecting the proper DAM is a contentious task in resolving delay claims. Kao et al. [20], reviewed 18 delay analysis techniques, and compared in detail three process-based dynamic analysis methods, namely, the snapshot analysis method, the Windows analysis method, and the isolated delay type method, and proposed six useful suggestions for developing an ideal DAM. By assessing currently related studies, two main directions of research areas were identified in the construction industry, so-called, improving the DAMs and resolving the delay disputes before they happen, by the same token. Cevikbas et al. [21] presented an innovative DAM, namely modified schedule versus modified updated schedule (MSvsMUS), was created to overcome the latent weaknesses, detail numerically mathematical statement, and variation between MS and MUS including real dragnet periodically is considered for developed method. On the one hand, these methods can be able to solve most of the schedule delay-related problems such as changes of the critical path(s), actual progress data, concurrent delays, pacing delays, acceleration, considering several types of activity relationships, and so on. On the other hand, it is impossible to apply those techniques in a real-world case practice, in specific, a mega project including a thousand items and work activities, the innovative technique should be incorporated into popular commercial scheduling software. Currently, there is no universal scheduling software available to provide satisfaction for delay analysts and end-users.

In the contemporary construction sector, there are numerous proposed DAMs. However, both AACE RP 29R-03 (2011) and SCL (2017), provide very good guidance on the suitable delay analysis techniques. The researchers and practitioners frequently have called the developed method with variously different names compared to existing delay analysis techniques. For instance, several method names refer to the same ‘Impacted As-Planned Method’ such as As Planned Impacted, Impacted Baseline, After-the-fact, and What-if. These are several secondary derivatives of the original one. By understanding all current DAMs also extracted from SCL and highlighting the equivalent method in AACE RP 29R-03, six primary DAMs were recommended in this study, namely, The Impacted As-Planned Method, The Time Impact Analysis Method, and The Time Slice Windows Analysis, The As-Planned versus As-Built Windows Analysis, The Retrospective Longest Path Analysis, and The Collapsed As-Built Analysis. Details of the discussion for method description, requirements, implementation process, and limitations can be seen in SCL and AACE RP 29R-03 [14, 15].

III. RESEARCH METHODOLOGY

Research methodology is applied through a combination of AHP and RII approaches, this subsection provides an overview of both methods separately before being integrated into the application of the study.

A. Analytical hierarchy process (AHP)

The AHP is a method performed with three levels. It is chosen by many business managers to assist in decision-making in many different areas [17]. Applying the AHP model is to decide and develop supporting tools to detect the appropriate delay analysis approach in construction projects. Intrinsic factors are the extreme impact of the selection of DAM (thorough an in-depth literature review first and then a questionnaire survey or FGD coming after) and current delay
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analysis techniques (many original DAMs and second derivatives instead of only given some in previous studies). The three-level model of the AHP method is shown in Figure 1. Level 1 is to define the project problem statement. The delay factors (criteria) are introduced at level 2 of this method. And finally, level 3 is a DAM (alternatives).

![Fig. 1: Construction of structural hierarchy [17]](image)

From Figure 1, the top level is related to the objective, the second level contains the criteria for ranking and the final level includes alternatives. In addition, a pairwise comparison evaluation ranking from 1 to 9 for criteria at level 2 is shown in Table 1.

Table 1: The relative significance scale suggested by Saaty [17]

<table>
<thead>
<tr>
<th>Scale</th>
<th>Numerical Rating</th>
<th>Reciprocal</th>
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<tbody>
<tr>
<td>Extremely preferred</td>
<td>9</td>
<td>1/9</td>
</tr>
<tr>
<td>Very strong to extremely</td>
<td>8</td>
<td>1/8</td>
</tr>
<tr>
<td>Very strong preferred</td>
<td>7</td>
<td>1/7</td>
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<tr>
<td>Strongly to very strongly</td>
<td>6</td>
<td>1/6</td>
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<tr>
<td>Strongly preferred</td>
<td>5</td>
<td>1/5</td>
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<tr>
<td>Moderately to strongly</td>
<td>4</td>
<td>1/4</td>
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<tr>
<td>Moderately preferred</td>
<td>3</td>
<td>1/3</td>
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<tr>
<td>Equally to moderately</td>
<td>2</td>
<td>1/2</td>
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<tr>
<td>Equally preferred</td>
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For example, the Local Weight associated with criterion 1 is the AHP which allows each alternative to be evaluated on the importance of one alternative over another by reference to a common factor. The comparison matrix has been designed to support expert judgment since the AHP has the advantage of determining priority, that is, generating the best local priorities from a pairwise comparison matrix or a group of pairwise comparison matrices.

Table 2: Pairwise comparison matrix for criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>1</th>
<th>2</th>
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A pairwise comparison evaluation scaling ranking from 1 to 9 at the level 2.

\[
A = \begin{bmatrix}
    a_{11} & a_{12} & \cdots & a_{1n} \\
    a_{21} & a_{22} & \cdots & a_{2n} \\
    \vdots & \vdots & \ddots & \vdots \\
    a_{n1} & a_{n2} & \cdots & a_{nn}
\end{bmatrix}
\]

(1)

Where:

\[
a_{ij} = \begin{cases} 
    a_{ij} & \text{if } a_{ij} > 0 \\
    \frac{1}{a_{ij}} & \text{if } a_{ij} = 0
\end{cases}
\]

If assuming ‘n’ number(s) are given for pairwise comparison, then AHP will do the above procedure to determine the weight of the criteria. Where, A = n x n, ‘A’ represents the alternatives, and a11-aij, ‘n’ represents the comparison number of variables, and the others in the equation represent pairwise comparison. The variables related to the diagonal of the matrix are all equal to 1. For instance, a_{ij} = 1. Hinge on the given equation, it is possible for a preference to be assumed as reciprocal and can be represented as below a_{ij} = \frac{1}{a_{ij}} then, i \neq j. For example, if i-th
variable is, X times more favorable than the j-th variable, then, \( A_{ij} = x \), at this point it is assumed that j-th variable(s) is 1/x, as important between i-th variable \( a_{ij} = \frac{1}{x} \) and/or \( a_{ij} = \frac{1}{a_{ij}} \).

Level 3, a pairwise comparison evaluation scaling ranking from 1 to 9 for all alternatives is the same as the calculation in level 2.

Through the standard normalization procedure to determine the weights, the criterion weights and the local weights of the alternatives from the pairwise comparison matrix, each value in column ‘j’ is divided by the sum of values in column ‘j’. The sum of the values of the columns in the matrix must be 1. The equation representation below is a normalization of the pairwise comparison matrix.

\[
A_{W} = \frac{\sum a_{ij}}{\sum a_{ij}} \quad \left( 2 \right)
\]

Through aggregating the local weights, the global weights of the alternatives are obtained. The way to determine the eigenvector of matrix A is to compute Ci as the mean and then Ci as the mean in row ‘i’ of the Aw matrix which will be computed for the column vector C where the value Ci represents relative importance.

\[
C = \frac{\begin{bmatrix} \sum a_{11} / n \\ \sum a_{12} / n \\ \vdots \\ \sum a_{n1} / n \\ \sum a_{12} / n \\ \vdots \\ \sum a_{nn} / n \end{bmatrix}}{\lambda_{max}} \quad \left( 3 \right)
\]

To get the second approximation, which is calculated by multiplying A and C, best for eigenvectors.

\[
A \times C = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \begin{bmatrix} C_{1} \\ C_{2} \\ \vdots \\ C_{n} \end{bmatrix} = \begin{bmatrix} x_{1} \\ x_{2} \\ \vdots \\ x_{n} \end{bmatrix} \quad \left( 4 \right)
\]

Then an estimation is denoted, it will be calculated by below formula:

\[
\lambda_{max} = \sum_{n=1}^{n} \frac{X_{i}}{C_{i}} \quad \left( 5 \right)
\]

Where \( \lambda_{max} \) is the eigenvalue of the pair-wise comparison matrix, then approximation to the consistency index (CI) will be calculated. Finally, the consistency judgment for appropriate value of n by CR must be checked in order to ensure the consistency of pair-wise comparison matrix, as indicated in the representation below.

\[
CI = \frac{\lambda_{max} - n}{n - 1} \quad \text{and} \quad CR = \frac{CI}{RI} \quad \left( 6 \right)
\]

Range of RI is the length of the sequence of (0.00, 0.00, 0.58, 0.09, 1.12, 1.24, 1.32, 1.41, 1.45, 1.49); where RI represents the random consistency index and RI value for different numbers of n from 1 to 10. If CR is 0.10 (10%) the degree of consistency is satisfactory; but if CR is > 0.10 then, there is an indication of serious inconsistencies.

**Local weight related to criteria:** the AHP can be able to evaluate each alternative based on the importance of an alternative over another, a pairwise comparison matrix or a group of pairwise comparison matrices. It is noted that the corresponding priority vectors (for the individual criteria) and consistency are also allocated.

**Global weight for each alternative:** Based on the weight of the alternative calculation that is the same way as the criteria, the priority vectors of each criterion, and the weight of the alternative, global weight will be achieved for the next calculation. Finally, given a decision matrix could result from the final priority according to the original or ideal mode AHP, the selection
of the alternative of final priority is determined based on the results of the original/ ideal mode AHP method, the optimum alternative has recommended the best for selection of DAM along with the calculation of relative important index.

B. Relative importance index (RII)

Based upon the delay factors (criteria) and alternatives (current DAMs), the questionnaire was formed by assigning values to the factors ranging from 1 (very low important) to 5 (very high important) considering their relative importance. Then

\[
RII = \frac{\sum W}{(A \times N)}
\]  

(7)

Where RII = relative importance index; W = weighting given to each factor by respondents (ranging from 1 to 5); A = highest weight and N = total number of respondents.

The factor with the highest rank indicates that it has the maximum frequency of occurrence while the factor with the lowest rank indicates that it has the least frequency of occurrence in terms of delay factors (criteria) and alternatives.

C. An integrated AHP-RII approach

As represented severally above, the combined AHP and RII methods can be able to greatly detect the most appropriate DAM for international construction projects efficiently. The flowchart of the proposed method has been illustrated in Figure 3. The application of its procedures may include several detailed steps. Firstly, an identification of study problems along with the adopted methodology to gather data in terms of delay factors and alternatives are conducted via an intensive literature review. Secondly, an FGD shall perform via an official seminar with a panel of 10 experts or a questionnaire survey as soonest to make a close discussion for a fair pairwise comparison of criteria and alternatives, concurrently with a proper determination of ranking different delay factors. It is vitally important to note that delay analysts, experts, and dispute resolvers should comprehend not only academic knowledge but also the experience in practice required to be able to make reasonable professional assessments on the issues in question. The project planners and schedulers’ capabilities normally are performing scheduling and control management well versed, and they are also aware of truly explaining the delays as the impacts of delays on the critical path and non-critical path of the project as well. Usually, in the previous studies [12, 13], the authors adopted many professionals whose jobs were in project planning, controlling, technical office, commercial, and contract managers and those are highly unsuitable identification.

The next step is the performance of the calculation of local, global weight, and frequency of occurrence, respectively. Furthermore, proper determination of final priority is processed for ranking each alternative in the AHP approach, in line with fair a combination of multiple local weight of the AHP approach and frequency of occurrence of the RII method to efficiently address the optimum conclusion statement of the study. From the anticipated findings of the study, decision-makers examine closely further potential benefits and weaknesses of the method to avoid unexpected decision-making for construction projects in the future.

Fig. 2: The flowchart of the integrated AHP-RII approach
IV. RESULTS AND DISCUSSION

A wide range of DAMs has been studied in the last several decades in terms of schedule delays, delay claims and other related issues, this topic research is an ongoing awareness of scientists, practitioners, and researchers. A notable selection of the most ideal DAM to deal with delay issues is incredibly vital, critical, and desirable for the sake of the cutting-edge development in the construction industry. Whereas most construction contracts are not consistent with the provision of analysis methods to resolve time-related disputes, each technique responds to different criteria and procedures. Conversely, selecting the appropriate approach has to be considered reliably under AACE RP 29R-03, the ASCE Standard and SCL given key factors and DAMs throughout the study. By first assumptively evaluating the anticipated FGD discussion and integrated AHP-RII approach calculation, the study highlights several potential aspects for further useful discussion as below.

The AHP has been proven to be a suitable effective approach to solving problems of murky and confusing decision-making processes in the context of criteria and alternative availability. In the wake of its combination, both AHP and RII are applied in line with one study case to demonstrate that the outcomes shall be adequately authentic and valid.

The study findings will be applicable in practice because the reliability of DAMs is only dependent on the current availability of delay factors specified by well-known guidelines and re-affirmation from a panel of experts.

Based on the panel of experts’ discussion, the weight of underlying delay factors and DAMs shall be computed along with the frequency of occurrence to examine the study outputs.

Under certain circumstances and conditions, the most appropriate technique has been addressed and unraveled for the further likelihood of delayed claims resolutions, along with the second and the less accurate DAMs which may be in practice. It is of great value to note that none of the approaches shall provide reliable results if the information obtained from the survey or group discussion is indiscriminate and invalid.

V. CONCLUSIONS AND RECOMMENDATIONS

Contracting parties frequently have uncertainty in the selection of DAMs due partly to a wide quantity of key features such as variables involved and the subjectivity of analyses. Thus, the choice of DAM may be practically and potentially costly, they are thus somehow aware of it. Since the current DAMs have different analytical procedures, capabilities, results accuracy, and time requirements thus making the question to project parties how to figure out the appropriate method under certain conditions is an essential task. Recognizing that AACE RP 29R-03, the ASCE Standard, and SCL provide base knowledge and useful guidance which is already supported full of fascinating insights into time and cost in the construction industry, especially containing several core principles relating to delay, extension of time, and compensation. However, current literature on delay factors to select suitable DAMs seems to be likely overlooked the guidelines that are helpfully suggested by AACE RP 29R-03, the ASCE Standard, and SCL. For the best understanding and base ground of proceeding delay analysis methodologies, this study focuses heavily on the forensic delay analysis protocols both key criteria and alternatives to conduct the FGD which is a very practical basis for a strong statement of the findings. In the existence of delay factors and DAMs along with a thorough and intensive literature review, the integrated AHP-RII approach is highly recommended to further realistic studies as the most feasible for selecting DAMs when analyzing obscure decision-making problems. Since the project is empirically unique by dynamic nature this study provides valuable contributions to notably assess and select the optimum DAMs under certain conditions of promising studies conducted previously. It may fill the gaps in the state-of-the-art construction project domain by focusing on the selection of the best delay analysis technique in the process of delays.
resolution. Moreover, the research shall verify
the consistent integration between AHP and RII
via the FGD and final data calculation then we
come to conclude which technique is the highest
priority for analyzing and detecting the most ap-
propriate DAMs. Scholars and practitioners may
yield the possible study outcomes for incipiently
practical preparation of a variety of data and
documents that can be publicly supported as valid
evidence for future claims thereby saving time
and cost. Further research can be implemented
via real-life project cases to gradually examine
the study results.

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