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DELAY ANALYSIS TECHNIQUES IN CONSTRUCTION PROJECTS

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Abstract: Delays are a common and major concern in most, if not all, construction projects. They often give rise to claims which could potentially lead to disputes. Therefore, it is crucial to be able to analyze the effect of delays on projects, in terms of both time and cost. A number of studies have been conducted to identify and formalize the root causes of delays in the construction industry; however, there is not an agreement on a specific delay analysis technique that each party should use when assessing time-related claims. Thus, the objective of this paper is to identify and critique the most commonly delay analysis techniques used by each party in construction and to recommend the appropriate techniques to be used in different project situations. A number of surveys and structured interviews were conducted on a pool of different project parties to identify and assess the industry commonly used techniques when assessing time-related claims and to highlight the leverages and limitations of each technique in the different situations. Thus, this research not only recognizes the most common delay analysis techniques used in the construction industry, but also explains the reasoning behind the choice of analysis technique by each party to the project. Finally, it supports decision-makers in selecting the most appropriate technique to be applied based on the project's circumstances.

1 Introduction

A "Delay" in the construction industry is the time overrun beyond either the agreed upon project completion date or the date of contractual milestones due to unanticipated events (Stumpf, 2000). These delays tend to be the most common problem that construction projects face and thus they usually give rise to claims and disputes (Hosny et al, 2018).

When a delay event takes place, its impact on the project's duration has to be studied, analyzed and quantified. This analysis is done using various Delay Analysis Techniques (DATs). Given that there are different DATs, each technique may give a different result from the other, and this is one of the main reasons why different projects parties use different DATs, as some techniques produce more favorable results than others in each party's point of view. Also, different techniques require different documentation, which will be further discussed. Their applicability depends on the time the delay event took place, the available project documentation at the time and their reliability.

Another crucial aspect to the assessment of the delay is the identification of the type of delay, some delays are attributable to the Contractor, some to the Employer and others are out of both parties' control. This then helps in recognizing whether the results of the analysis are to be further transferred into an Extension of Time (EOT) for the Contractor, alongside any associated and culpable costs, or Liquated Damages for which the Contractor is liable to pay the Employer.

In case the Contractor believes that he is entitled to an EOT, a claim for EOT has to be prepared, where the Contractor has to first deploy one of the available DATs to analyze the effects of the delay events that took place. This claim is then submitted to the Employer (or the Employer's Engineer) for further assessment where the Engineer deploys either the same DAT presented by the Contractor or a different DAT to study the impact of the presented delay events.

In some cases, these delay claims give rise to major disputes in the project. There are multiple documents in literature that provide guides for handling of delay claims which aim to reach an amicable solution without disputes being borne into the project. Out of these documents, is the “Delay and Disruption Protocol” which was published by the UK’s Society of Construction Law (SCL) originally in 2002 and then a later, more enhanced edition, was published in 2017, and also the AACE International (Association for the Advancement of Cost Engineering Int.) Recommended Practice No. 29R-03 titled “Forensic Schedule Analysis” (2017). The protocols are not to be considered as contract documents but are rather meant to provide the preferable means to deal with delay claims to avoid disputes and thus attempt to reduce projects costs as a result of such undesirable disputes.

Despite the existence of such documents, there still seems to be a gap in the current literature, where there are no guides or documents that aid decision-makers or practitioners in choosing the most appropriate DAT depending on the project’s situation.

2 Literature Review

Alkass et al. (1996) presented and discussed the various delay analysis techniques that at the time were deployed by practitioners in the industry. The techniques identified were global impact technique, net impact technique, adjusted as-built CPM technique, ‘but for’ or collapsing technique, snapshot technique, time impact technique, and also a new DAT which was developed in that research called Isolated Delay Type (IDT). Alkass et al. (1996) then implemented these techniques on a case study and the results were compared and used to highlight the strengths and weaknesses of the different techniques. It was found that there were 3 main issues that needed to be addressed during the analysis to ensure that the results of the analysis are as reliable as they could be, these issues were: proper categorization of the delays according to their type (excusable compensable, excusable non-compensable, non-excusable), concurrency of delays, and real time Critical Path Method (CPM) analysis. Comparison of the different DATs is presented in Table 1.

Table 1: Comparison of the different DATs

DAT	Differentiates delay types	Addresses concurrent delays	Uses Real Time CPM
Global Impact	-	-	-
Net impact	-	Yes	-
Adjusted as-built CPM	-	Yes	-
‘But for’ or collapse	Yes	Yes	-
Snapshot	-	Yes	Yes
Time impact	-	-	Yes
Isolated delay type	Yes	Yes	Yes

Thus, the authors recommended that the IDT technique is the most accurate out of all the techniques as it deals with the 3 major concerns of the delay analysis process. However, according to later literature this technique did not become very popular alongside some of the other techniques, while other newer more reliable techniques were developed Alkass et al. (1996).

On the other hand, Stumpf (2000) focused on 4 of the techniques that he mentioned that they were the most commonly used during that time, these techniques were as-planned versus as-built (adjusted as-built CPM), impacted as-planned, collapsed as-built (but for) and contemporaneous period analysis (snapshot, window analysis). Delays were first identified as independent delays, concurrent, serial and then were categorized as according to Alkass et al (1996).

Stumpf (2000) also aimed to identify the strengths and weaknesses of each of these techniques by applying them on a case study and providing a comparative analysis of their results. A summary of the results is shown in Table 2.

Table 2: Comparison of the different DATs (Stumpf, 2000)

DAT	Strengths	Weaknesses
As-planned versus as-built	• Technically simple to perform if as-built schedule is available.	• Doesn't identify criticality or concurrency of delays • Assumes accurate baseline schedule logic
Impacted as-planned	• Easy and quick to prepare	• Assumes a perfect baseline schedule that was followed accordingly without any changes. • Results in magnified delays due to simplified scheduling planners usually make.
Collapsed as-built	• Easy and quick to prepare if there is a reliable as-built schedule.	• Analyst has to identify the as-built critical path. • Analyst has to make adjustments and insert logical ties as delays are removed.
Contemporaneous period analysis	• Highly accurate, causes the least controversy. • Uses schedule updates so gives a more realistic effect of the delay	• Time consuming to perform. • Requires sufficient project documentation

In 2002 the Society of Civil Law (SCL Protocol, 2002) developed a protocol entitled: "Delay and Disruption Protocol", that intended to provide a simple guideline to the process of dealing with time-related claims, and to avoid potential disputes in the project. The protocol discusses the implementation of 4 of the mentioned techniques which are as-planned versus as-built, impacted as-planned, collapsed as-built and Time Impact Analysis (TIA). SCL categorizes the techniques as either being prospective or retrospective techniques as shown in Figure 1, based on whether the impact of the delay is determined before or after the delay event has taken place. As for the TIA and the window analysis techniques, they could be used both retrospectively and prospectively as this relies on the availability of project updates right before the event took place. It also states that the choice of a DAT depends mainly on: the particular conditions of the contract, the type of delay event, the available documentation and time, the size of the dispute, the availability of schedule information and the scheduler's level of skill. Moreover, the protocol also highlights the appropriateness of deploying each of these techniques in certain project situations based on the availability and/or reliability of the project documentation, and the time and cost associated with each of the techniques (SCL Protocol, 2002).

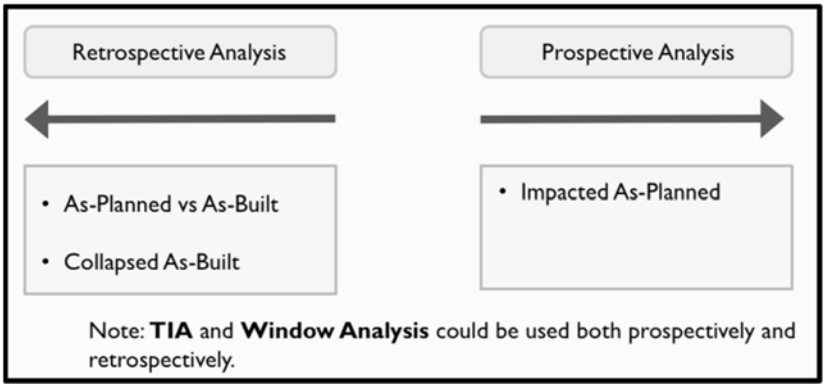

Figure 1: Categorization of Delay Analysis Techniques

The AACE International Recommended Practice No. 29R-03 titled "Forensic Schedule Analysis" (2011) also aimed to provide a similar guideline to that of SCL's protocol, however the categorization of the analysis

techniques is provided in layers, where layer 1 shows: Prospective vs Retrospective, layer 2: Observational vs Modeled, etc. The recommended practice, as well as Braimah (2013), recognizes the 4 techniques discussed by SCL to be the most commonly used techniques by practitioners, in addition to the window analysis technique. Braimah (2013) presented a case study, where he implemented all 5 techniques on the case study and compared the results to be able to depict the limitations of each of the 5 techniques. Some of the limitations were similar to that concluded by Stumpf (2000), however the additional findings were as follows: The as-planned versus as-built, impacted as-planned and collapsed as-built do not consider any changes to the critical path of the project or changes to the schedule logic; the choice of windows affect the results of the analysis for the window analysis technique, and the TIA requires sufficient project records and project periodic updates is time demanding, and could be impractical to use if the project has been subjected to a large number of delay events.

3 Objective

This research aims to depict the most commonly used delay analysis techniques by the different parties in construction, as well as, to understand the logic and factors influencing the selection of which technique to be used in assessing time-related claims.

4 Methodology

To achieve research objectives the first step was to review the literature that is available to date regarding delay analysis. This was done initially to get a collective overview of the various delay analysis techniques that are established in construction.

After gathering the required information from literature, the next step was to conduct a few structured interviews with some construction experts to investigate the techniques they use in analyzing the delays in their projects and the basis for selecting a certain technique over the other. The interviews and the literature review were the basis for designing a survey that was sent out to a number of experts in the industry. The purpose of both, the survey and the interviews, was to identify a pattern or depict the industry's common practice when it comes to each party's choice of delay analysis technique and at which phase in the project these techniques are used.

Another outcome of this step was to get recommendations from the industry's experts with regard to selecting the most appropriate delay analysis technique depending on when the delay event took place during the project's life as some techniques would be unreliable and/or inefficient to implement in certain situations. The recommendations were then used to emphasize the strengths and limitations of using each of the techniques that were acquired from literature.

4.1.1 Interviews

Three structured interviews were carried out with experts in the field, where experts were asked a certain set of questions and the findings from the interviews were summarized and compared against what was found in literature. Also, the results of the interview were then used as a foundation to create the survey to be distributed to construction experts.

4.1.2 Surveys

After the interviews were conducted, the survey was established and 30 surveys were completed by practitioners in the construction field that work for different construction organizations (contractors, consultants, etc.) in different countries.

5 Results and Discussion

5.1.1 Interviews

First, the interviewees were asked to specify the major factors that they believe affect the choice of the DAT. All three of them agreed that if the particular conditions of the contract do not specify a DAT to be used when analyzing time-related claims then, the DAT chosen would be a function of the size and type of the project, the availability of project updates, the reliability of the projects' schedule, the availability of time and cost to carry out the analysis, the time at which the delay event takes place in the project, the level of skill of the team performing the analysis, along with a set of other factors. These factors were similar to those mentioned in the literature specifically in the SCL protocol and the AACEI recommended practice. However, all three experts highlighted a major aspect that affect the choice of the DAT which is the party carrying out the analysis, they state that each party tends to deploy the DAT that most serves its case. In the interviews it was pointed out that the Contractor would most likely prefer to use the impacted as-planned technique as it always exaggerates the delays and does not reflect any delays by the Contractor on site due to low productivity, delayed materials delivery, etc. Whereas the Consultant/Employer would most likely choose to implement the TIA technique as it clearly depicts the delays of the Contractor and differentiates them from any excusable delays to the Contractor. Results from the interviews were then used to construct the survey that was sent out to experts in the field.

5.1.2 Surveys

The surveys include a certain set of questions regarding the factors that affect the choice of DAT and the preference of each party as well as the timing in the project at which the delay event takes place, as these were some of the major aspects that were addressed by the experts in the interviews. Also, the participants were asked about their background in order to test the validity and applicability of the results of the survey. The statistical analysis of the surveys is presented and discussed in this section.

5.1.2.1 Type and Location of Construction Organization

The percentages of the participants from each construction organization and their respective locations are shown in Figures 2 and 3 below.

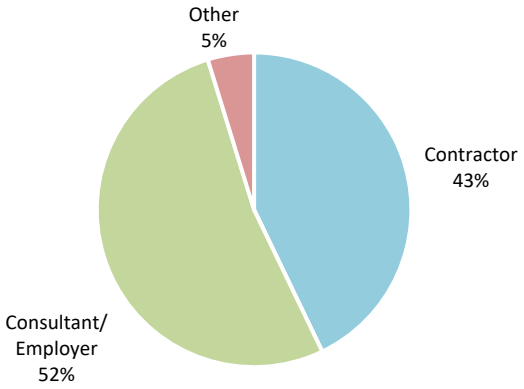

Figure 2: Types of Construction Organizations

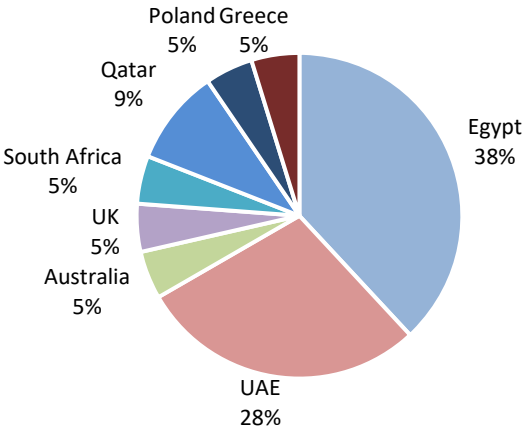

Figure 3: Country of Construction Organizations

5.1.2.2 Role of Participants

The percentages of the positions of the participants from each construction organization are shown in Figure 4. As seen, there is a variety of disciplines in the construction industry and the majority of the contributors were planning engineers, managing consultants and delay analysts, thus their disciplines are highly involved in time-related claims analysis.

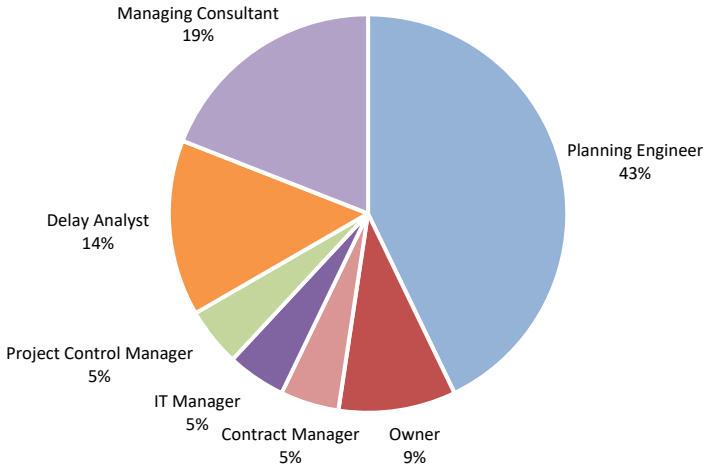

Figure 4: Role of Respondents in the Construction Organizations

5.1.2.3 Years of Experience of Participants

The average number of years of experience of the respondents, which was calculated as a weighted average, is shown in the Figure 4. The lowest number of years of experience is around 10 years, thus indicating that the pool of participants was appropriate which strengths the validity of their responses as it reflects their expertise in dealing and assessing time-related claims.

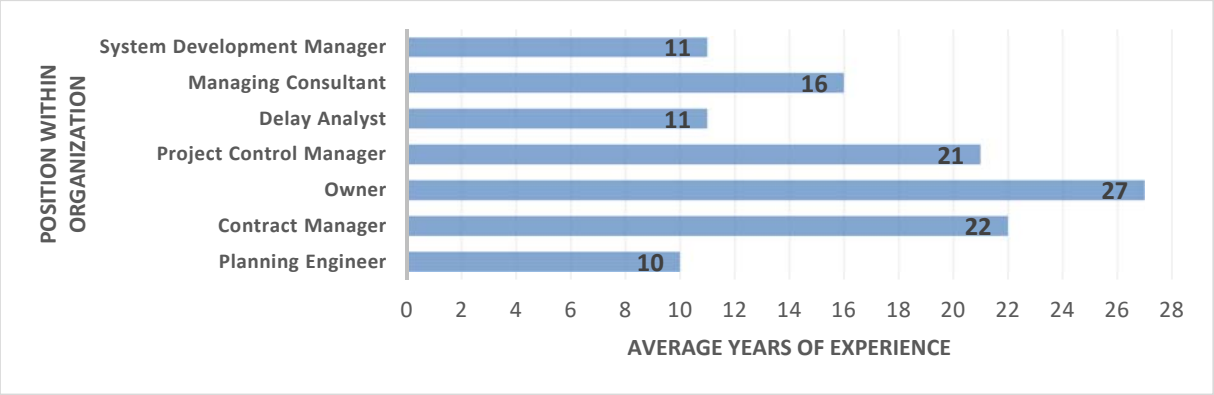

Figure 4: Average Years of Experience of Participants in Each Role

5.1.2.4 Issues Dictating Choice of DAT

The participants were asked to list the top 5 issues that usually dictate the choice of the DAT by any of the parties involved in construction projects, this is done to highlight the suitability of the available DATs in certain situations. As seen in Table 3, the major factors that contribute to the choice of DAT of any of the parties are: the contract's particular conditions, project documentation/regular periodic updates, project type (size, location & complexity), party carrying out the analysis, number of delay events and size of delay. These factors match-up with those stated by experts in the interviews that were conducted, as well as the findings from literature. This means that, if for example no proper project documentation is available, techniques such as TIA and window analysis would not be very efficient if they are to be used to assess the delay, as their implementation might add unnecessary cost and time and will also yield inaccurate impacts of the delay as the they are not performed using the proper required information for them to be reliable.

Table 3: Issues that Majorly Affect Choice of DAT by Parties

Issue	Percentage of Responses	Ranking
Project type (size, location & complexity)	16.81%	**3**
Project duration	0.88%	11
Delay type	3.54%	8
Project documentation/ Regular periodic updates	19.47%	**2**
Contract particular conditions	20.35%	**1**
Time of delay occurrence	7.08%	6
Number of delay events and size of delay impact	7.96%	**5**
Reasons behind delay	0.88%	11
Reliability of project schedules	3.54%	8
Party carrying out the analysis	11.50%	**4**
Time & cost accompanied required to carry out the analysis	4.42%	7
Materialization of delay impact	0.88%	11
Concurrency of delay events	0.88%	11
Skills of team carrying out the analysis	1.77%	10

5.1.2.5 Common DAT Choices of Each Party

Given that which party is carrying out the analysis is a factor that highly contributes to the decision of DAT according to the results of the survey. To depict the regular choice of DAT by the different parties, the

participants were also asked to choose from the 5 above-mentioned DATs, which one they think is most commonly used by the Contractor and by the Consultant/Employer, stating their reason for choosing that specific method.

Table 4: DAT Most Commonly used by Contractor

DAT	Percentage of Responses	Ranking
As-planned versus As-built	20.83%	3
Impacted As-planned	45.83%	1
Collapsed As-built	0.00%	5
Window analysis	4.17%	4
Time Impact Analysis	29.17%	2

Table 5: DAT Most Commonly used by Consultant/Employer

DAT	Percentage of Responses	Ranking
As-planned versus As-built	22.73%	3
Impacted As-planned	13.64%	4
Collapsed As-built	4.55%	5
Window analysis	27.27%	2
Time Impact Analysis	31.82%	1

From the results, it can be noticed that the contractors' typical choice of DAT to be used, is the ***impacted as-planned***, almost all those who responded with this choice of DAT, state that the reasons the Contractor prefers the impacted as-planned method is because firstly, it is not reflective of his own delays, it rather magnifies and highlights those delays that are excusable, and also it does not require regular updates as it only uses the approved baseline schedule and so is the quickest to implement.

Some respondents state that the second most commonly deployed DAT by the Contractor is the ***TIA*** technique with the reason being that it is widely accepted by the parties in the construction industry as it gives the most accurate results, as it considers concurrency of delays, when properly implemented and causes the least debate out of all methods.

Those who responded with the ***as-planned vs as-built technique***, referred to a new method developed by the SCL known as ***as-planned vs as-built window analysis***, this method then combines the ease of implementation of the as-planned vs as-built technique with the accuracy of the window analysis, thus eliminating the limitation of having to use the as-planned vs as-built only at the end of the project, as it uses the as-built schedules for the project windows.

As for the Consultant/Employer, the prevalent DAT identified to be used by this party, is the ***TIA***, with the most frequently mentioned reasons to be that it allows for the team to thoroughly examine any changes (delays) to the non-impacted schedule and/or the impacted schedule, regardless of the delay event being which party's fault, since it uses regular and periodic updates, and so it creates the least conflict.

A close second choice is the ***window analysis*** technique, as it is quite similar to the TIA however is more efficient to carry out when there is a large number of delays in the project.

Again, when these results are compared against those from the interviews and literature, major similarities are highlighted in both the choice and the reason behind the choice of DAT by each party.

Moreover, the participants were asked to choose which DAT is most applicable when the delay event takes place at certain times in the projects' life.

Table 6: Most Appropriate DAT to be used at Certain Times in the Project's Life

DAT	Number of Responses					
	Beginning of Project		Throughout Project		End of Project	
	Percentage of Responses	Ranking	Percentage of Responses	Ranking	Percentage of Responses	Ranking
As-planned versus as-built	4.55%	3	4.55%	4	19.05%	3
Impacted as-planned	59.09%	1	9.09%	3	0.00%	4
Collapsed as-built	0.00%	4	0.00%	5	19.05%	3
Window analysis	4.55%	3	40.91%	2	23.81%	2
Time Impact Analysis	31.82%	2	45.45%	1	38.10%	1

Results from the survey show that, at the beginning of the project, it would be best to use the ***impacted as-planned*** technique as at the beginning it is unlikely that the project schedule would have deviated tremendously from the approved baseline, meaning this technique is most likely to give accurate results and would be the easiest and fastest to implement, as it does not require project updates or as-built schedules which would most likely be unavailable at early stages of the project. Those who chose the ***TIA*** technique, define their reasoning to be that in case of major deviations at the beginning, this technique should then be implemented instead. Also, some respondents referred to the ***as-planned vs as-built window analysis technique***, as at the beginning if some as-built data is available, this technique would also be quite fast to implement and will consider the minor deviations in the schedules as well.

Throughout the project, it would be more appropriate to use either ***TIA*** or ***window analysis***, as these techniques consider any changes that have been made to the schedule just before the delay event takes place, as during the project more information regarding the project progress is available, and so they would be able to identify the impact of the delay as accurately as possible. Also, both techniques can be implemented either prospectively or retrospectively meaning they can be used regardless of whether the impact of the delay event has materialized or not.

Finally, towards the end of the project, the ***TIA*** or ***window analysis*** would also still be more appropriate to implement for reasons similar to those mentioned above. Even though it would be expected that the techniques that require as-built schedules would be easier to use due to the existence of as-built schedules, yet the downfalls of these retrospective methods still seem to outweigh their ease of implementation according to the results of the survey. However, the percentages of responses for the ***collapsed as-built*** and the ***as-planned vs as-built*** are higher than in the other 2 situations and this is just because as mentioned above, at this point in the project they would be quite fast to implement as as-built schedules would be readily available.

6 Conclusion

The choice of a fitting delay analysis technique, from all of those available in the industry, is of high complexity. Making the appropriate choice is influenced by a number of factors as analyzed from literature. This paper aims to identify the preferable method of analysis that is implemented by each of the parties, as this is considered to be one of the main factors that affect the choice of DAT. The research also identifies the appropriateness of the available techniques in certain project situations. This was done through conducting structured interviews as well as distributing a number of surveys to several experts in the field.

Firstly, interviews were conducted to identify which major topics to address and to provide a guideline for the nature of the questions that shall be included in the survey. The results of the interviews and the surveys were presented and analyzed. The results included the identification of the major factors, according to industry experts, that dictate the choice of DAT by any of the project parties. Moreover, the results depicted the industries' norm for the preferred choice of DAT by the different project parties and provided the reasoning behind each parties' preferences. Finally, the suitability of each of the techniques at different project stages was determined showing which of the available DATs is most suitable at the beginning of the project, throughput the project construction, and at the end of the project. Reasons were also provided for the techniques' suitability at certain phases in the project. The findings of this research support provide decision makers in selecting the DAT to be implemented when handling time-related claims and provide them with a knowledgeable tool to refer to regarding which techniques are best to use depending on the projects' circumstances. However, this research does not extensively cover all of the factors that affect the choice of DAT, and future research would include building a model that could account for as many, if not all, of the influential factors, to be able to optimize the choice of DAT in the different project circumstances.

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