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TOTAL FLOAT MANAGEMENT TECHNIQUE UNDER THE FLOAT AND RESOURCE LOADING

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Abstract – *Schedule delays in construction projects are a common occurrence and have a significant impact on the overall project duration. Plentiful delay analysis techniques have been proposed and utilized to resolve these issues. The total float management method is widely accepted and considered the most fundamental approach as it effectively resolves four major delay issues and measures float consumption. However, current delay analysis techniques have often overlooked the allocation of float and resources, which can remarkably affect the determination of delay responsibilities for involved parties. This study aims to enhance the total float management approach by intensively incorporating float and resource loading considerations before delay analysis implementation. The research methodology includes an extensive literature review, identification of crucial issues related to schedule delays arising from the lack of resource and total float allocation, and the application of enhanced total float management under float and resource loading through a case study for test validation. The research findings provide transparent insights into delay liability considering both time delays and float consumption and emphasize the importance of float and resource allocation in the early stages of construction projects for a consensus before analyzing and assigning delay responsibilities. Future studies could focus on legalizing the procedural considerations of float ownership and resource allocation in contract agreements.*

Keywords: delay responsibilities, enhanced total float management technique, total float and resource allocation.

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I. INTRODUCTION

An indispensable measure of accomplishment in managing construction projects is completing the project within a specified duration and budgeted cost. It is, therefore, a challenging and perplexing task for project managers, owners, and contractors due to the inextricable entanglement of construction projects and risk-taking behaviors from stakeholders. Properly assessing the impact of schedule delays is often one of the most contentious matters in construction claims. A wide variety of delay analysis methods have been developed by delay analysts to resolve schedule delays, but there is no perfect delay analysis technique since they all include a set of hypothetical assumptions, the application of personal experience and insights, and analytical expectation [1]. Many recent studies have focused extensively on two key issues, including enhancing the delay techniques, finding ways to prevent disputes before they arise [2] and exclusively considering addressing particular delay issues while partly ignoring others [3–7]. Specifically, the analysis of schedule delays becomes even more complex when dealing with concurrent delays and determining float ownership [8] and resource allocation [9]. Therefore, selecting a proper delay analysis method depends gradually upon the availability of scheduling data, the familiarity of the analyst with the capabilities of the software used in the project, and explicit specifications stipulated in the contract agreement [8]. Currently, there are over ten existing approaches to float ownership, each addressing different aspects of the six related issues [10]. While many delay methods tackle one or more delay matters, they often indirectly ignore other important issues. Of primary importance, the available analysis approaches seem to lack the incorporation of total float and resource loading for a comprehensive and legally sound analysis and apportionment of delay responsibilities. Furthermore, handling concurrent delay, float ownership, and resource allocation is of the utmost importance when it comes to the likelihood of successful claim resolutions [8, 9, 11].

The total float management (TFM) method has proven effective in resolving the four main delay problems, including real-time delay, concurrent delay, acceleration and pacing delay, and float consumption. This approach has been complemented by window delay analysis and its secondary derivatives, which enhance the accuracy of the analysis process [4, 11–13]. However, the current approach lacks consideration for resource allocation and fails to properly allocate float ownership and calculate the entitlement associated with float consumption during the delay analysis process. This impracticality in project schedules arises from the inadequate availability of resources for specific construction tasks and the potential shifting of total float from non-critical to critical activities [14]. To carefully resolve these key challenges, this study aims to adopt the TFM approach under total float and resource loading at the early stages of construction projects before analyzing for delay claims resolution. By doing so, it seeks to develop an effective and efficient technique for analyzing and apportioning delay liabilities among project parties.

II. LITERATURE REVIEW

A. *Schedule delays*

The Oxford Advanced Learner's Dictionary [15] states 'delay' as 'a period of time when somebody or something has to wait because of a problem that makes something slow or late; a situation in which something does not happen when it should, and as the act of delaying.' In the project management context, most researchers agree that a delay is considered an action or event which extends the time required to perform or to complete a part of work or the entire work under the contract [16, 17]. Based on scheduling management, a delay is regarded as an effect on the completion date of the project or the project's critical path(s) [18]. Kartam suggested that schedule delays could be divided into three typical classifications: compensability, timing, and origin [19]. In terms of liability, it can be due to owner-caused delays, contractor-induced delays, and third-party-caused delays. The timing of delay is assorted concurrent delay and non-concurrent delay. Delays are classified by compensability, including excusable delays consisting of excusable compensable (EC) and excusable non-compensable (EN) and non-excusable delays (NE). In the study of Kao and Yang [5], delay classification is presented in different manners. Hence, depending on the specific situation and context in which the terms are being used, all delays might be classified into excusable, compensable, critical, and concurrent [5]. While examining concurrent delays, Arditi and Robinson [20] claimed that for two or more delays to be concurrent and cause delays in the overall project, they must first occur in the same period and they must each have the ability to affect the overall project duration independently of each other. From the aforementioned studies, concurrent delays can be classified according to the liability/responsibility and compensability represented in Figure 1.

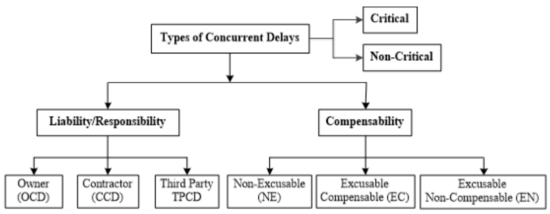

Fig. 1: Classification of concurrent delays

Openly analyzing and apportioning concurrent delays are the most challenging tasks since both owner and contractor aim to employ concurrent delays as a strong defense tool against each other. For instance, owners use them to protect their interest in obtaining liquidated damages, while contractors yield them to neutralize or waive their inexcusable delays and hence avoid damages entitlement [21]. Courts, arbitration boards, practitioners, and researchers are generally inconsistent in terms of the definition, identification, analysis, and apportionment of concurrent delays [22]. Nowadays, for schedule delays in terms of concurrency, it is more legally equitable and reasonable to validly apportion two different rules, which are the so-called Easy Rule (Contributory Negligence) and Fair Rule (Comparative Negligence) [23]. A matrix that summarizes concurrent delay remedy is shown in Table 1. However, if both rules are not reached to the project parties' agreement, the parties may apply an equal liability method (ELM) [24]. The ELM is based on the assumption that all parties are equally liable for the delays they cause, so each party shall be entitled to fair delay damages whenever they are proved specifically as concurrent delays.

Table 1: Remedy for concurrent delays

Concurrent delay type	**Remedy (for critical path)**	
Any delay concurrent with excusable non-compensable	Time extension	
Excusable compensable concurrent with non-excusable non-compensable	Easy Rule	Fair Rule
	Time extension	Appointment

This study focuses on two basic rules to handle concurrent delays based on the original TFM approach to track the changes in total float consumption in which most of the window-based techniques seem to be likely ignored completely. Further discussion of concurrent delays to apply the ELM is beyond the scope of this study.

B. Existing delay analysis techniques

Delay analysis involves the examination of project delays and the assignment of liability to project parties. Various delay methods have been employed for this purpose. However, these tasks are really challenging as they require significant time, resources, and cost loading, and may even involve errors in resolving delay claims. Despite the availability of analysis techniques, there are still notable shortcomings in terms of analyzing delays and resolving delay claims: (1) the critical path method cannot be caught in delay analysis and the fluctuation of the critical path cannot be taken closely; (2) concurrent delays cannot be recognized or computed by some of the available approaches; (3) the float ownership and the relative cost of float consumption are not properly accumulated [25]; (4) the effects of acceleration of most methods focus merely on the delayed activities, ignoring the impact of time-shortened activities on total project duration and pacing delay [12]; (5) loss of productivity [26]; and (6) resource allocation [9]. Accordingly, the existing analysis techniques have only addressed one or two more delay problems because they all consist of subjective assessments, assumptions and theoretical projections [1]. Different results may be obtained by applying current analysis approaches [3, 12, 25, 27–29] and even using the same technique under distinct assumptions may lead to various results. For instance, using a window analysis technique with a varying window size can lead to inconsistent outcomes [30, 31]. For the same token, available analysis techniques yield distinct types of programs, namely as-planned, as-built, adjusted schedule, and entitlement schedules based on several requirements of the method that is very easy to obtain inconsistent analysis outcomes.

Plenty of analysis approaches pay very little attention to the effects of total float and resource allocation such as Global Impact, Net Impact, As-Planned, But-For, Time Impact Analysis, Window But-For, Window and Effect-based Delay Analysis, Isolated Daily Window Analysis to the original TFM technique. In the study of William and Nguyen [9], the authors applied traditional and enhanced window analysis to track the changes in schedule delays under the effects of resource allocation. The proposed method intensely considered the impacts of resource allocation that are embedded into the delay analysis technique. Conversely, several limitations of window delay analysis methods are listed out as major concerns. Firstly, it is crucial to address the issue of total float changes and how to handle situations where one party consumes the float that belongs to another party's entitlement. Secondly, concurrent delays could not resolve during the progress of the delay analysis application. Ultimately, the contractor and the owner should have a unanimous legal agreement on resource allocation that is convenient resource availability under schedule progress and resources' mobilization to officially avoid 'phantom float' before schedule delay analysis. Along with the TFM technique, the enhanced window analysis and isolated daily window analysis methods also require much more information and data collection, such as daily logs, weather, and delays, to receive crucially proper documents for analyzing delays.

Birgonul et al. [32] proposed an integrated approach to overcome 17 identified drawbacks of current delay analysis techniques, and their method is helpful for further researchers and practitioners to apply as a set of proposed rules since it scrutinizes all different phases of construction projects, specifically hypothetical case studies. Their method can be further applied for gradual evaluation of usability, credibility, and acceptability before being used as a tool of project management practice. Conversely, further developed delay analysis techniques seem to be likely overlooked resource allocation. In some instances, the Enhanced Daily Windows Delay-Analysis (EDWDA) method has been proposed to effectively combine the ability of the Daily Window Analysis Method to take into account all critical path fluctuation, and the ability of the modified but-for method to analyze concurrent delays and accelerations [11]. Also, a novel delay analysis approach, the so-called Modified Schedule versus Modified Updated Schedule (MSvs-MUS), was developed by Çevikbaş et al. [7] to overcome several downsides of existing DAMs in terms of lacking detailed numerical procedures, ignoring some types of activity relationships, actual improvements and further delays accelerated by the contractor. Notwithstanding, a number of DAMs continue to be developed by the researchersbecause the topic is a primary domain of scientific study due to the impact of delays on schedule and budget cost in construction projects.

C. The float and resource allocation

One of the most controversial issues in the litigation of delay claims is the ownership of float [4]. Float, sometimes called slack, is defined as the amount of time that an activity can be delayed without affecting the completion date of the project, and total float (TF) is calculated based on the difference between the early start and late start or early finish and late finish of activity [33]. Since the float does not always affect the overall project completion date, the project parties would like to use the float to manage their own risks. The larger question is 'Who owns the float?', and its consumption should be highly embedded in the contract with the objectives to minimize potential project disputes [8, 10, 34]. Several concepts have been proposed in the last several decades to resolve float ownership issues. According to Al-Gahtani [10], each approach actually represents a viewpoint on how to appropriately respond to each of six existing issues, particularly allowing flexibility for resource leveling, allowing flexibility to include change order, preventing disentitled float consumption, preventing schedule games, ability to distribute total float among project parties and solve total float change issues associated with float ownership. Notwithstanding, none of the available float ownership concepts has been accepted widely by project participants, arbitrators, and stakeholders in the light of different assumptions which can lead to distinct results. Therefore, the issues of float ownership shall be addressed in well-thought-out contract provisions to legally minimize the official arguments when project delays occur. The current contract articles primarily overlook and ignore float ownership stipulations. The project participants enter disputes after schedule delays, particularly due to the total float consumption on non-critical activity(ies) and the non-critical path(s) becoming critical then delaying the project completion date. Thus, at the very beginning of project preparation, the parties must consider legally and officially embedding the floating article into a contract agreement which defines the float ownership and its consumption. The concept of float ownership should be fully recognized, and if the total float is consumed beyond the party's allowable entitlement, the party should bear responsibility for any resulting delays and damages. The total float can be treated as a valuable commodity that has the potential for trade.

In the scheduling network, the calculation of activities' duration and project completion date often assumes all the resources needed for the available project schedule. This assumption, however, may not always hold true for construction projects, as the schedule may not be realistic when schedule delays occur, and the existing delay analysis techniques do not account for analyzing delays [9, 32] under resource loading and constraints. In order to deal with such particular problems, available resources are embedded into a proper technique to analyze schedule delays sufficiently. Given the finite nature of resource availability, such as machines, on-site space restrictions, skilled labor, materials, and even financial matters, there should be demand for resource loading over the total project duration. Underlying resources are severely crucial and must be taken into deep consideration for resource schedule loading and the delay analysis process. Thus, if a project is resource constrained, the availability of those resources will be limited. A proper delay analysis technique should include resource loading, and scheduler and delay analysts should pay great attention to resource overloading during delay analysis application [32]. In this study, the most important and expensive resources are closely considered and specified in terms of the number of units.

III. METHODOLOTY

A. Methodology development of the initial TFM technique

The primary methodology used in the initial technique is an Isolated Daily Window Analysis that considers float consumption after a delay or acceleration event. This technique is considered the most ideal and accurate compared to currently available window techniques. It effectively addresses the four general delay issues on a daily basis. It provides a good alternative for resolving most delay issues, analyzing float ownership, and apportioning concurrent delays based on the Fair Rule and Easy Rule. A large amount of collected information, however, used in this technique and using a day-by-day window analysis necessitates much effort to analyze schedule delays explicitly in the case of productivity loss, so this technique cannot address such potential problems. The original TFM technique involves four basic steps: (1) listing all delay/acceleration events in the as-built schedule, (2) establishing the baseline schedule and distributing initial total float entitlement, (3) implementing analysis after each delay/acceleration event while applying the rules of concurrency, and (4) determining delay responsibility between the owner and contractor based on the time of delay and total float consumption [12]. The difference between actual project delays and the combination of project delays and the entitlement of total float loss is used to allocate delay liability to the contractor or owner. For further discussion of the initial TFM approach, refer to other sources [12, 35].

B. Enhanced TFM technique under the float and resource loading

According to Mohan et al. [4] an ideal approach should encompass various types of delays, accelerations, pacing delays, and concurrent delays, making it practical for resource loading. Additionally, the delay analysis technique is conducted on a daily basis to monitor changes in both critical and non-critical activities within the project schedule. In this regard, if a delay occurs in either non-critical or critical tasks, it will have an impact on the total float of other activities in the schedule network, leading to either a decrease or an increase in the float changes. It is necessary to analyze the responsibility for delays and the utilization of float on a daily basis throughout the delay analysis process in order to effectively prepare and assess delay claims. The question of float ownership is an important consideration, especially if it is specified in the contract provisions. While the total float may not always affect the overall project duration, the parties involved primarily utilize it to manage their individual risks.

The flowchart of enhanced TFM technique under total float and resource allocation is shown in Figure 2.

Concerning total float as a valuable asset and loading resources practice, to improve the original TFM technique for delay claims preparation the project parties must achieve a unanimous agreement on the float at the very start of the project and resource allocation before performing delay analysis to ensure the baseline schedule is officially legalized under total float and resource loading. A systematic delay analysis procedure to enhance the original TFM technique with five basic steps in Figure 2.

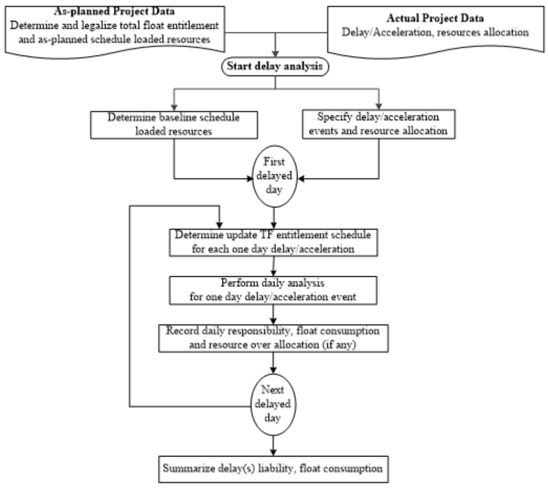

Fig. 2: The flowchart of enhanced TFM technique under the float and resource allocation

- Step 1: To prepare a contract document embedded in the float officially responding to the question ‘who owns the float’ and which party is accredited entitlement of total float.

- Step 2: To specify the as-planned schedule loading resources achievably for the project, it is so-called the baseline schedule and the contractor and the employer have validly accomplished total float availability based on the certain schedule resource allocation.

- Step 3: To record all site events including a delay/acceleration day and calculate the as-built schedule based on the ending project completion date.

- Step 4: To perform day by day delay analysis and update the baseline schedule after a delay/acceleration event as well as record delay responsibility, total float consumption and resource over allocation (if any).

- Step 5: To summarize details of reliability of project delays’ day(s), total float consumption and resource overloading (if any).

IV. A CASE STUDY ILLUSTRATION AND RESULTS DISCUSSION

A. *A case study illustration*

A case study examination of seven work activities was adopted in very early studies using a resource-constrained CPM schedule and schedule analysis under the effects of resource allocation [9, 36]. The as-planned resource allocation schedule was 13 days with two types of resource availability, namely Type A, with two units, and Type B, with merely one unit, supposing that the total completion days for the project are 16. Both the as-planned and as-built schedules reached resource-constrained units. Figure 3 represents the as-planned schedule loaded with resource allocation-constrained units.

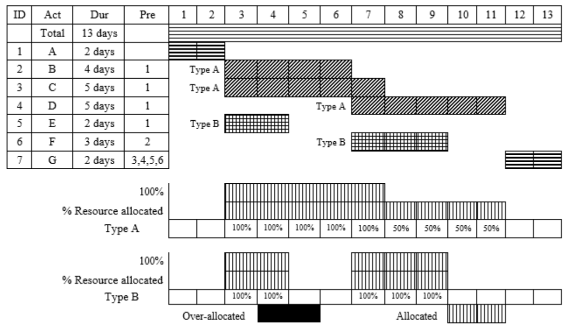

Fig. 3: As-planned schedule with resource allocation – constrained units

After examining the planned schedule, it is evident that Type A resource allocation allows for five days and four days with 100% and 50% allocation, respectively. However, Type A resource loading is restricted to Activities B, C, and D, and these activities cannot start concurrently due to limited resource availability. Consequently, the starting and ending times of these activities may change during the project if resource over-allocation is not resolved. Nonetheless, Activity B is directly linked to Activity F, and thus, resource allocation must be prioritized for Activity B. Activities E and F have Type B resource loading and allow for two days of total float. The project parties must fairly allocate the entitlement to total float following the contract and through an official agreement.

Figure 4 illustrates the as-built schedule with resource allocation-constrained units. Typically, several types of delays are excusably compensable (EC) in Activity B and excusable non-compensable (EN) in Activity C, and non-excusable delays (NE) in both Activity C and D. More particularly, there are several specific changes in the as-built schedule compared with the as-planned schedule in terms of resource allocation and project activity duration. Firstly, Activity B, C, and D have steadily changed the start and finish dates due to project delays and resource overloading to maintain project delays at least. Secondly, Type A resource allocation for the as-built schedule is four days and seven days in line with 100% and 50%, respectively. Simply compared with the as-planned schedule, the Type A resource loading of project completion is determined as one day (50%) longer. On top of that, the duration of Activity D increased by one day from five days to six days excluding six days delayed (NE). This issue may make disputes more severe due to productivity loss in place of NE delays. Nevertheless, the loss of productivity shall be beyond this research.

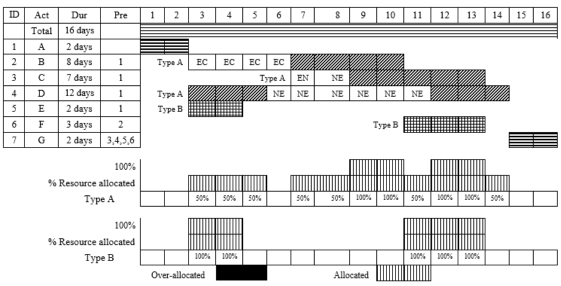

Fig. 4: As-built schedule with resource allocation – constrained units

B. Results discussion

The difference in three delayed days between the as-planned schedule and as-built schedule caused by the owner (EC), the contractor (NE), and the third party (EN) was analyzed, and apportioned responsibility and total float consumption was also analyzed. At the very beginning of the project, the relevant parties reached a valid agreement for the contractor who was authorized entitlement to total float. The baseline schedule in terms of resource loading was specified and it was officially legal to perform delay analysis. In this research, the as-built schedule was collapsed repeatedly after a delay event because it is practical and the resource allocation is constrained factually. If the as-planned schedule is yielded and impacted after a delay event, the resource over-allocation may be seen elsewhere [9]. In case concurrent delays occur, the Fair Rule shall be applied for an illustrated calculation.

Detail calculation of TFM technique under the float and resource loading will be performed daily delay analysis after a delay event from day 3 to day 11. Thereupon, the final result of a case study examination is represented in Table 2 in which the contractor and the owner are equally responsible for 1.5 delayed days. Of prime importance, the owner consumed a two days of the total float, which is belonged to the contractor entitlement on the Activity F. In comparison with the traditional analysis and enhanced delay analysis approaches, those techniques cannot be able to track and analyze the total float changes, and the issues of float consumption should not be calculated and apportioned expressly [9]. Consequently, the consumption of a two-day entitlement to total float on Activity F should be counted as tradable goods or applied by other float ownership concepts and the owner should be fully responsible. Unfortunately, the enhanced window analysis approach results merely in 2 days and one day for EC and NE, respectively. In contrast, the traditional window analysis technique is one day equal for EC and NE. Such techniques analyze one day of concurrent delays between the contractor and owner in the case study illustration, the result of which is that the contractor is frequently entitled to a time extension. The ideal technique, TFM, results in both rules in case of concurrency in terms of the Fair Rule, the owner, and the contractor are equally liable for 1.5 delayed days. For applying Easy Rule, its result has a one-day time extension for concurrent delays and the third party may be responsible for such delays as shown in Table 3. This study's findings are a more reliable and trustworthy apportionment of delay responsibilities in place of project delay day(s) and TF consumption.

The original as-planed schedule of Activity B is merely five days and the as-built schedule has 12 days including six days of NE delays. During the delay analysis of Day 6 to Day 11 for Activity D, we realize early that the project is solely

Table 2: Summary of the TFM technique under total float and resource allocation (Fair Rule)

Act	TF Impact			Owner entitlement TF		Con-entitlement TF		Project Delay		TF Delay	
	TF_{before}	TF_{after}	ΔTF	$OETF_B$	$OETF_A$	$CETF_B$	$CETF_A$	EC	NE	EC	NE
A	0	0	0	0	0	0	0	0	0	0	0
B	0	0	0	0	0	0	0	-1.5	0	0	0
C	0	0	0	0	0	0	0	0	0	0	0
D	0	0	0	0	0	0	0	0	-1.5	0	0
E	6	6	0	3	3.5	2	2.5	0	0	0	0
F	0	0	0	0	0	0	0	0	0	-2	0
G	0	0	0	0	0	0	0	0	0	0	0

Table 3: Summary of TFM, enhanced window analysis and existing window analysis

Technique	Delay responsibility				TF consumption	
	EC	NE	EN	Concurrent	Owner	Contractor
Enhanced window analysis	2	1	0	1	*	*
Traditional delay analysis	1	1	0	1	*	*
TFM (Fair Rule)	1.5	1.5	0	1	2	x
TFM (Easy Rule)	1	1	1	1	2	x

delayed two days. Due to the loss of productivity of Activity A, its completed duration increased from five to six days so the total project delay was three days. Whether the delay in activity is NE or due to productivity loss, the Contractor is also responsible entirely for delay(s). In contrast, if EC or EN will primarily delay Activity D instead of the NE, it will cause a constant claim among project parties. Current delay analysis methods could not resolve such productivity loss. The results of this study show close comparisons among the improved TFM method, the original TFM technique, and other available delay methods in several key aspects. The enhanced TFM method successfully addressed the inherent drawbacks of the initial approach by considering float and resource allocation in a legally sound manner, which was previously overlooked. These considerations have a significant impact on the outputs of delay analysis. The original TFM approach, on the one hand, did not allocate resource loading and establish total float through official negotiation and agreement at the beginning. Accordingly, the TFM approach assumed ownership of the float and solely incorporated total float entitlement with time delays after completing the delay analysis [35], which is not reasonable and fair because it inflates the total project delay duration beyond the actual delays. On the other hand, window-based delay methods failed to consider concurrent delays, float ownership, and its consumption [5, 13], and daily window delay analysis and its secondary derivatives have exclusively taken into account concurrent delays and ignored float ownership and float allocation [11, 29, 31, 37, 38]. Recent studies have shed light on the interaction and correlation between float ownership, float allocation, and concurrent delays improperly and inadequately [9, 32]. Therefore, the findings of this study make significant contributions to the construction industry by enhancing existing delay analysis techniques and highlighting potential gaps that still require further improvements. These insights contribute to the ongoing advancement of delay analysis methods in construction projects.

V. CONCLUSIONS AND RECOMMENDATIONS

Existing delay analysis approaches have largely overlooked the effects of float and resource allocation in the delay analysis process for delay claims preparation, which often leads to ongoing disputes among project participants. Only a few recent studies on schedule analysis have considered resource loading and its impact, but total float and its consumption are not properly calculated for the entitlement. The findings of this study provide more authentic, fair, and reliable delay analysis results. The innovative TFM technique not only tracks changes in total float and resolves concurrent delays based on both rules but also accurately identifies project delays concerning float and resource loading. By taking into account float and resource allocation from the beginning of construction projects, a clear and transparent determination of delay liability in terms of time delay and float consumption has been achieved. In addition, concurrent delays have been resolved in both rules in compliance with a fair and equitable manner.

There are multiple stages in the project life cycle, and in order to mitigate and avoid potential arguments and disputes among involved parties, the ownership of float should be legally discussed in the pre-contract negotiation before officially entering into a contract agreement. The determination of the as-planned schedule should also incorporate resource allocation constraints before the application of delay analysis. The research highlights the importance of addressing contemporary concerns regarding float stipulation in the contract agreement and resource loading in the baseline schedule before conducting delay analysis. Practitioners and future scholars should focus on float ownership and resource allocation issues to enhance the legal acceptability and credibility of delay claims preparation. Furthermore, the treatment of concurrent delay issues remains ambiguous in contractual agreements, necessitating careful attention to the definition and procedural considerations to effectively assess concurrent delays within well-defined contract provisions.

Despite the numerous benefits of the innovative TFM technique, this study has also identified several potential limitations that need to be addressed in future research. These shortcomings primarily pertain to the inherent TFM technique itself. Firstly, the TFM method requires a significant amount of data, including delay types and resource constraints, as it analyzes delay events on a daily basis. Therefore, it is recommended to develop a technical tool that supports the recording of daily project data promptly. Secondly, the study results need to be further validated through the examination of real-life cases, ranging from simple to mega projects. This would require great effort to test the TFM method under various float concepts and resource allocation scenarios. Additionally, the integration of the TFM method into management system tools or an integrated expert model can enhance its application for delay analysis in future delay claims. Eventually, while analyzing schedule delays in terms of delay responsibilities and liabilities is crucial, it is also important to include the calculation of delay damages. By considering delay costs, project stakeholders can have a clearer understanding of both project delay durations and the associated financial impacts. These recommendations aim to improve the robustness and applicability of the TFM approach and enhance the overall analysis of schedule delays for future research and practical implementation.

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