

Article

Good Practice Guidance for Selecting Delay Analysis Methods

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Abstract

The appropriateness of delay analysis methods (DAMs) has been at the core of disagreements over delay assessments during the past decades. Delay experts continue to disagree over their suitability while not offering best or good practice guidance. Scholars are critical of their performance while not proposing pragmatically superior DAMs. Judges do not deal with this issue while insisting that the parties should accept the DAMs and indicating that the DAMs should be accurate, effective, and harmonized with contracts. However, the parties are heavily reliant on expert advice and model agreements, which do not offer adequate delay analysis terms, although contract terms are not only well-established legal instruments but also a requisite for clear risk allocation and certainty. While the need for an effective DAM selection model in this context is obvious, such a model has not been offered. Instead, guidance on a set of endorsed DAMs has been provided, but legal systems continue to generate disputes over delay assessments. This paper evaluates published literature and contributes to the fulfilment of this knowledge gap by offering a DAM selection model that is based on six recognized DAMs and is instrument-based, precision-oriented, impartial, effective, and coordinated with legal systems and construction contracts.

Keywords: construction contracts; delay analysis; dispute avoidance; risk allocation

1. Introduction

1.1. Background and Research Rationale

Construction delay disputes are expensive, widespread, and persistent [1–3]. This issue is particularly common in large projects [4]. Such disputes involve disagreements over points of law, facts, and technical matters, including delay assessments. Disagreements over delay assessments, although often described as ‘technical’, include factual and technical aspects. The former relates to the availability and reliability of material evidence and documents, including the agreed plan to complete the works (or baseline programme and planned resources) and contemporaneously logged project data showing the actual progress of the works (or as-built records and actual resources). The latter involves the selection and use of delay analysis methods (DAMs) and delay quantification techniques such as the critical path method (CPM). DAMs are systematic techniques used by delay analysts (or experts) to identify the causes, extent, and responsibility for project delays [5]. The literature suggests that, notwithstanding the initial conceptualization of DAMs and delay analysis tools, the field remains complex, laborious, and contested [6]. Although the unavailability and/or inadequacy of project records are reasons for disagreements over delay assessments, arguments over the selection and application of DAMs are at the core of such disagreements. This is a relatively recent finding mainly because most construction disputes are resolved privately through dispute resolution methods that



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guarantee the confidentiality of the parties, legal teams, and documents, including the produced programming (or scheduling, or delay analysis) reports [7,8]. Disputes over delay assessments affect the productivity of construction projects, as, *inter alia*, resources are allocated to facilitate their management rather than focusing on the project works [9,10]. Furthermore, such disputes are typically funded by taxpayers in public projects [11]. Although this issue has been identified and commitments have been made to improve it by facilitating early settlements of such disagreements to avoid and manage disputes more effectively, the problem persists [3,12].

Early settlement refers to the settlement of disagreements via, e.g., contract claims procedures, as opposed to dispute resolution methods that are relatively more costly and time-consuming. This is significant as, *inter alia*, construction delays are not only anticipated but typically accommodated by legal systems and construction contracts. For example, ‘time of the essence’ clauses, which are characteristic for commercial agreements, are replaced by extension of time (EOT) mechanisms and claims procedures that provide opportunities to introduce changes (or events) that cause project delays without terminating the contracts and assess and agree on the impact of delays during contract administration to prevent the escalation of such claims into disputes [13]. However, the issues persist as far as disagreements over delay assessments are concerned. The literature indicates that arguments over the selection and application of DAMs are at the core of such escalations, and the costs of those escalations to the employers (or clients) are high [8,9]. The main reason for this is that, although attempts have been made to offer DAM selection models, those recommendations focus on categories of DAMs, e.g., dynamic, static, additive, or subtractive, and/or do not offer a selection approach that is (i) founded on an instrument-based analysis; (ii) coordinated with legal systems, laws, and construction contracts; and thus (iii) effective in enabling early settlements of disagreements over delay assessments [14]. It is argued in this article that points (i) and (ii) are essential in facilitating early acceptance of the DAMs and dispute avoidance. While guidance has been offered by the Society of Construction Law (SCL) and the American Association of Civil Engineering (AACE), those guides do not offer ‘best’ or ‘good’ practice guidance. In fact, the SCL made an unambiguous statement in the second edition of its Delay and Disruption Protocol to that effect [5]. In this context, the main contributions of this study are:

- To offer good practice guidance on the selection and application of DAMs that is instrument-based, precision-oriented, impartial, effective, and coordinated with legal systems and construction contracts.
- To recommend ideas and principles that can be used to verify the effectiveness of innovative DAMs.

These contributions are significant as, *inter alia*, currently, one of the main reasons for disagreements over delay assessments is the lack of best or good practice guidance on the selection of DAMs. Although legal systems indicate that it is up to the parties to construction contracts to select and apply DAMs, they have not offered such guidance. The identified case law indicates that the selection of DAMs is a contentious matter, and the parties to construction agreements fail to achieve early agreements on delay analysis methodology [15,16]. Moreover, the available guidance (or grey literature) does not offer a DAM selection model. Instead, it recommends a set of DAMs that often produce conflicting delay assessments because the endorsed DAMs tend to rely on different delay analysis tools and different assumptions [5]. This leads to escalations of disagreements over delay assessments from contract claims into disputes, which, as indicated above, are expensive and time-consuming.

Therefore, this article focuses on solving an aspect of a systemic problem related to the escalation of disagreements over delay assessments from contract claims into disputes,

the main aspects of which are: (i) legal systems create laws that leave it to the parties to select the DAMs; (ii) unavailability of best or good practice guidance; (iii) if the parties do not select the DAMs on an *ex-ante* basis or before the delay assessments, it is up to the delay experts to select and apply the DAMs, which results in escalations of contract claims into disputes; and (iv) a lack of harmonization (or coordination) of the DAM selection rationale with construction contracts [15,16]. Specifically, the article offers a DAM selection model, or good practice guidance for the selection of DAMs, that is based on a review of the key principles identified from the published academic and grey literature and case law and coordinates the DAM with the contracts, the law, and relevant governmental policy objectives.

The key DAM selection principles offered in this article are influenced by (i) government policy objectives, namely proactive and early settlement of disagreements in public projects, including disagreements over assessments of construction delays, and early agreements on the impact of such delays [12], and (ii) established construction project management practice; specifically, the approach to planning of contractors is generally based on forecasts rather than hindsight [17]. This paper offers a novel DAM selection approach that is proactive, impartial, effective, instrument-based, precision-oriented, and therefore acceptable by parties to construction contracts, delay experts, and judges. The arguments in this paper are set out in the context of the main propositions; namely (i) the selection of DAM must be acceptable by the parties and the law; (ii) impartiality and accuracy of delay assessments will facilitate a clear risk allocation mechanism and thus improve the acceptability of DAMs and contractual certainty; and (iii) contractual certainty is typically achieved in legal systems by the application of well-established legal principles and contract law. In this article, the term accurate refers to the precision of the EOT entitlement, whilst the term effective refers to the likely acceptance of the DAMs by parties, delay experts, and decision-makers.

A discussion of the key principles that govern the selection of DAMs is offered next. The structure of this section includes discussions of legal principles and contract law, construction contracts, six DAMs, and delay quantification techniques.

1.2. Legal Principles and Contract Law

The arguments in this paper are set out in the context of well-established legal principles, concepts, and contract law, including the principles of freedom and sanctity of contracts [18,19]; the existence of effective contract terms [20]; the standardization of contract terms [21]; the rules of interpretation utilized by, among others, decision-makers, judges, arbitrators, and adjudicators when testing the meaning of standard and bespoke contract terms [22]; the transparency achieved by the publication of judicial decisions [23]; and the certainty of judicial decisions attained by binding precedents which ensure that, generally, law courts are bound by the decisions of higher courts and/or their own decisions [20,24]. In summary, the goal is to facilitate trade by providing predictable and stable legal frameworks [19]. It is argued in this article that, although parties to construction agreements are generally free to contract, when the cost of the dispute is funded by taxpayers, contracts should ensure that such costs are minimized. In other words, the freedom of contract should be limited, particularly if, as a direct result of exercising it, the aforementioned well-established legal principles that ensure contractual certainty are not followed and, as a result, the costs of disputes are maximized through unclear risk allocation for the measurement of construction delays and contractual uncertainty and such costs are funded by third parties. A context-specific application of the aforementioned principles is offered in Section 4. In this context, the term contractual certainty refers to the

existence of clear, complete, and legally enforceable contract terms that ensure accurate, acceptable (by delay experts and decision-makers), and thus effective delay assessments.

Legal rules and principles take precedence over construction contract conditions. This means that for a contract to be the governing body of terms, it must align with such rules. There are four main types of construction delays that are governed by two sets of legal rules when it comes to contractual risk allocation, namely (i) principles governing delays caused by employer-risk, contractor-risk, and neutral events (e.g., adverse weather conditions) and (ii) legal rules governing concurrent delays. Although the focus of this study is construction contracts, specifically, the measurement and management of delays, it may be useful to offer examples of the legal rules that govern those two categories of delays [25]. For example, the prevention principle governs employer risk delays in the UK. According to it, an employer cannot hold a contractor to a specified completion date if the employer has, by act or omission, prevented the contractor from completing the construction project (or a section of it) by that date. All construction contracts should align with this principle. Referring to the second category of delays, there are several definitions of the term concurrent delay. One of the definitions was ‘a period of project overrun which is caused by two or more effective causes of delay which are of approximately equal causative potency’ [26]. Therefore, it is generally accepted that the effect of an employer risk event and a contractor risk event must be simultaneous for a delay to be classified as concurrent. The allocation of liability for concurrent delays differs in different jurisdictions. For example, in England and Wales, contractors are entitled to EOT but not entitled to compensation for loss and expense [27]. In Scotland, the delay is apportioned [28].

Although the legal system of England and Wales is the focus of this paper, observations are made on relevant case law from other common law (and some civil law) jurisdictions, including those of Scotland, Northern Ireland, and North American jurisdictions. This is because, *inter alia*, the principles, rules, and concepts that govern construction delays in those common law systems are similar; the judicial decisions offer comparable guidance; arguments presented in case law can be used to persuade judges and other decision-makers; and the disagreements over delay assessments are similar across many jurisdictions, including civil law jurisdictions as, among other things, (i) legal systems leave it to the parties to construction contracts to select and apply the DAMs and (ii) standard contracts like the New Engineering Contracts (NEC) and the Fédération Internationale des Ingénieurs-Conseils (FIDIC) contracts and the endorsed DAMs are used in both types of jurisdictions [29]. For example, since 1993, the NEC suite of model agreements has been used for infrastructure and engineering projects in varied jurisdictions, such as Australia, New Zealand, Peru, Belgium, France, Germany, the Netherlands, and the Philippines. Moreover, the UK, South Africa, and Hong Kong maintain the NEC as the default suite of contracts for infrastructure and engineering projects in their territories [29,30]. The FIDIC suite of contracts is the most popular engineering and infrastructure standard form of contract globally, as evidenced by the increasing number of countries that use those model agreements, which amount to circa 100 [31]. However, those two model agreements do not offer standardized (compulsory or optional) delay analysis terms, which is problematic in the aforementioned context, lacking widely accepted guidance on delay analysis methods. This indicates the universal significance of the issue, which is the selection and application of DAMs.

1.3. Construction Contracts

It is outside the scope of this paper to argue the advantages of standard contracts over bespoke agreements. This is effectively dealt with elsewhere [20,21,32,33]. However, by common consent, one of the main advantages of standard contracts over bespoke

agreements is the increased certainty of the interpretation of terms [32]. The legal principles facilitating certainty were noted above.

The standard construction contracts used across the globe include the JCT Standard Building Contract, standard contracts developed by the Joint Contracts Tribunal (JCT) for the construction sector (predominantly for building projects in the UK), and the fourth iteration of the New Engineering Contract (NEC4) developed (predominantly for UK and international infrastructure and engineering projects) by the Institution of Civil Engineers [1]. The key difference between NEC and JCT, as far as harmonization with DAMs is concerned, is that the former has a proactive approach to the assessment of the impact of delays, while the latter's approach is neutral. For example, Clause 2.27 of JCT Standard Building Contract with Quantities 2024 states that the contractor should give a notice to the contract administrator 'whenever it becomes reasonably apparent', indicating a flexible approach to the resolution of EOT claims. In other words, this contract lacks a time bar provision (used in NEC4) that specifies a period within which the relevant event/compensation event should be notified. In this comparison, JCT provides a flexible approach to the assessment of the impact of delays, and contractors and/or delay analysts may decide to 'wait and see' if retrospective assessments produce more desirable results. Such flexibilities provide opportunities for disagreements over delay assessments, which are at the core of the escalation of construction delay claims into disputes [34]. The difficulties with retrospective assessments in this context include the following: (i) contractors do not have the benefit of hindsight during the planning and contract administration processes in construction, as such processes involve forecasting based on evidence and/or experience [17]; (ii) practitioners discourage the 'wait and see' approach to claims management, as it often leads to accumulations of delay claims which, in turn, makes delay assessments more difficult and contentious [34,35]; (iii) standard contracts, developed to address contemporary challenges of the construction sector, advocate proactive and prospective claims administration, including assessments of EOT entitlements during the contract administration process that are likely to reduce the number of disagreements over such assessments and prevent their escalations into disputes [36,37], as long as such contracts include an agreed delay analysis protocol as a contract document [15,16]; and (iv) governments are the drivers of this model of work in public works, projects, and programmes (or schedules) [12]. Furthermore, JCT is deficient in provisions that require the production of relatively more precise delay analysis tools, such as frequently and regularly updated programmes and as-built data (included in NEC4), which eliminates the possibility of using some of the most accurate DAMs and requires relatively more assumptions than NEC4 to complete the delay assessments [5,35]. However, in the reviewed cases, judges tend to prefer the most accurate and least subjective delay assessments and delay analysis instruments [38,39]. Moreover, contracts like NEC4 and FIDIC typically involve large administration teams, which should, at least in theory, identify and agree on the impact of delays without having to employ a dispute resolution procedure [33]. In summary, construction contracts are deficient in ensuring the most effective delay analysis instruments, even though the law suggests that the only way to ensure the availability of the instruments is by incorporating contract terms. The available guidance is also unhelpful. This is discussed next.

1.4. Delay Analysis Methods and Primary Delay Analysis Instruments

The available guidance comes from the SCL and the AACE, which endorse six comparable DAMs. A detailed analysis of all available DAMs is outside the scope of this article, as the relative merits of different DAMs have been discussed in the literature [5,14,17,34,40,41]. Instead, this article adopts an instrument-based evaluation of the six endorsed by the SCL DAMs, in the context of their effectiveness (i.e., acceptability by decision-makers) and effi-

ciency (i.e., their cost to clients). In this article, the term primary delay analysis instruments refers to the programmes and as-built data that are relied upon in delay assessments. The six widely recognized/endorsed DAMs were divided into two categories: prospective and retrospective.

The two prospective methods are impacted as-planned analysis and time impact analysis (TIA). In terms of primary delay analysis instruments, the former relies upon a logically linked baseline programme, while the latter also utilizes regularly updated logically linked programmes and progress data. It is therefore logical that the latter method is likely to produce more accurate and effective assessments if the primary delay analysis instruments (i.e., the baseline programme, updated programmes, and progress data) are accurate. In other words, if detailed, logically linked, valid, reliable, and regularly and frequently updated programmes and as-built data are unavailable, the delay assessments will be more theoretical and subjective, as they would rely on relatively more assumptions [5].

The four retrospective methods are collapsed as-built analysis, retrospective longest path analysis, as-planned vs. as-built analysis in windows (windows analysis), and as-planned vs. as-built time slice (time slice) analysis. Like the prospective DAMs, the retrospective methods can be categorized in terms of the same delay analysis tools. In sum, the time slice analysis method requires the greatest number and most accurate tools. Since the law courts are clear that the most accurate and least theoretical DAM should be preferred, the time slice analysis is the most effective retrospective method. Furthermore, the TIA and the time slice analysis are similar in that, conceptually, they rely upon the same ‘types’ of tools, the difference being that the latter relies upon additional logically linked programmes and as-built data. This is an important idea to consider when selecting the DAM because the courts indicate that prospective methods should not be used when the impact of delay is clear at the time of the EOT application. Thus, if a contractor does not conform to the prospective nature of the contract and EOT assessment, it cannot benefit from such an infringement by relying on a theoretical prospective delay assessment after the impact of the delay has materialized and is known. Moreover, the Northern Ireland Housing Executive v Healthy Buildings (Ireland) Limited [2017] NIQB 43 case indicates that it is possible to rely on a retrospective DAM in instances where new information emerges, which entitles the contractor to more time after an EOT entitlement has already been granted [39]. Consequently, this article argues that a contract can provide for both eventualities—to rely upon TIA in the context of proactive contracts like NEC and FIDIC but use time slice analysis if, e.g., contractors fail to punctually produce adequately substantiated prospective delay assessments. In this example, the two DAMs are compatible because they would rely on the same types of tools, referred to in this paper as primary delay analysis instruments. The difference is that the latter DAM would rely on more up-to-date instruments. However, with both DAMs, the critical path should be assessed contemporaneously. Therefore, if conducted promptly and diligently with accurate primary delay analysis instruments and the requisite substantiation, the two assessments should produce identical EOT entitlements unless new essential information in relation to the same delay event emerges at a later stage, in which case the EOT must be reassessed. This is due to the contemporaneous nature of the CPM when used in conjunction with those two DAMs that employ substantiated forecasts. In other words, even if the impact of the delay has materialized, both the TIA and the time slice analysis require prospective assessment of the critical path. Here, the implication is that there could be a difference between the forecast and the actual delay for various reasons. For example, the contractor decides to employ more resources to accelerate the project in order to mitigate a delay to another aspect of the critical path of the project that was caused by the contractor, or the contractor has failed to adequately substantiate the delay forecast.

1.5. Delay Quantification Techniques and Secondary Delay Analysis Instruments

The ongoing debate over delay assessments includes delay quantification techniques, such as the CPM, and delay analysis tools that assist the primary instruments, referred to in this article as secondary (delay analysis) instruments, e.g., analysis of resources, mitigation, acceleration, and descope measures. The objectives of ‘critical path planning and scheduling’ (or the ‘critical path method’) are to form a basis for prediction and planning; evaluate alternative plans for accomplishing the objectives; check progress against current plans and objectives; and form a basis for obtaining the facts so that decisions can be made and the job can be done [42]. The current guidance is clear in that the programme should be based on the CPM where the activities are linked together by appropriate logic (e.g., start to start, start to finish, finish to start, or finish to finish), which demonstrates a constrained critical path that is based on a necessary construction sequence (e.g., foundations to walls or steel frame) unless the critical path is resource-constrained (e.g., where two or more aspects of the works can be progressed in parallel) or the sequencing of the works/activities is preferential (e.g., no constraint is influential) [5]. In other words, this is one of the most critical contextual factors in the DAM selection process because, in the first example, the criticality of delay events (or the causation) is determined on the basis that the event delayed a critical activity (or an activity that is on the critical path of the project). However, the approach to the delay analysis in preferential sequencing and resource-constrained projects is different, as the critical path is either controlled by the allocation of resources or there is no clear critical path through the construction works. For example, even in projects where the CPM is appropriate but there is a near-critical path or a path of programme activities that is nearly as long as the longest (or critical) path and has similar total float. A minor delay on this path can make it become the critical path, directly impacting the completion date (e.g., two buildings of similar size, complexity, and work involved). In this context, the decision on which aspect of the work should be advanced depends on resource allocation. Therefore, the primary delay analysis instruments should be supported by secondary delay analysis instruments, including analyses of resources, mitigation, acceleration, and descope measures, to ensure that EOT estimates are objective, without significant flaws, and consistent with the factual circumstances [5].

This section offers a background to this interdisciplinary problem, the research rationale, and a literature review before the research gap is established. Section 2 discusses the approach to the selection and analysis of the research methods and materials. Section 3 states the research results. Section 4 examines the research results. Section 5 summarizes the discussion, lists research limitations, and recommends further research.

2. Materials and Methods

This research involved the analysis, synthesis, and evaluation of the published academic and grey literature and legal principles identified from case law. The literature search was precipitated by a search for relevant databases. The main criteria for the database search were access, materials included, and database type. Six databases were identified and examined, namely (i) the Association of Researchers in Construction Management research database; (ii) the ICONDA library, or the online repository containing publications relating to the Council for Research and Innovation in Building and Construction; (iii) Google and Google Scholar; (iv) the British Library ‘Ethos’; (v) LexisNexis; and (vi) Westlaw.

The research method was qualitative in that it consisted of two in-depth examinations scrutinizing the published works germane to the issue to determine (i) how delay analysis instruments impact the effectiveness of DAM and (ii) the interplay between the law, legal systems, construction contracts, and DAMs. The first step was to search for legal principles

that establish the criteria for the acceptability of DAMs by the law courts. The second step was to identify construction contract philosophies that, despite the principle of freedom of contract, are typically directed by government policies to enable the coordination of DAMs with contracts in public projects. This was critical because, as aforementioned, legal systems are clear that it is up to the parties to select the DAM, and contract certainty is typically created in legal systems by incorporating terms into contracts. The third step was a review of the published academic and grey literature to identify if those legal principles have been unified in those works in the context of disagreements over delay assessments. In other words, the findings from those exercises were compared to the identified academic and grey literature. The third step not only established the knowledge gap, but it also offered the key aspects of the proposed solution.

The search for published literature was conducted in a manner that targeted the reduction in retrieval and publication bias. For example, keywords (e.g., delay analysis/dispute) and synonyms of the keywords (e.g., scheduling analysis/dispute) were used in addition to the database-specific subject headings to reduce retrieval bias, such as assigning publication types incorrectly or using generic terms, because, *inter alia*, this is a relatively new subject area.

Besides academic publications, the literature search included grey literature and case law to reduce publication bias. The three types of literature were comparatively analyzed, but the ideas presented in case law and academic literature were typically given more weight than the ideas presented in professional (or grey) literature (e.g., the SCL Protocol), if there were clashes of ideas or principles. For example, the identified academic and grey literature gives an undue weight to the economic efficiency of DAMs, whilst legal systems are mainly concerned with their effectiveness.

The case law was mainly identified through the search criteria of Westlaw and Lexis-Nexis. All decisions of the relevant court (e.g., the Technology and Construction Court) were detected. The guidance offered on the selection and application of primary and secondary delay analysis instruments was the main search criterion. The judicial decisions were qualitatively analyzed. The case law was grouped into themes based on the identified legal principles. Case law that did not refer to such principles was excluded. For example, principles discussing the legal aspects of concurrent delay were excluded from the sample. Although the UK legal systems are at the core of the findings, case law from other jurisdictions was used to (i) corroborate the similarities between different legal systems and (ii) supplement the research results because, e.g., some of those legal systems offer legal precedents that have not been created in the UK legal jurisdictions. For example, the Australian law courts are clear that the selection of the DAMs is a contractual matter. The results from the case law analysis are presented next.

3. Results

The findings from the literature review were divided into two categories. Firstly, a summary of key findings from the identified case law is offered in Section 3.1. Then, a synthesis of key findings from the identified academic and grey literature is presented in Section 3.2. Based on those findings, Section 3.3 offers recommendations and evidence-supported conclusions.

3.1. Case Law

The findings from the review of the case law are provided next, in Table 1.

Table 1. A summary of key findings from the review of case law.

Entry	Judicial Decision	Case Citation
1	Detailed, valid, reliable, fully logically linked, regularly and frequently updated programmes, and as-built data are the primary instruments required for the determination of the impact of construction delays. If a contractor and an employer formed a contract that requires proactive resolution of claims and then do not conform to the prospective nature of the contract and the delay assessments, the infringing party should not benefit from such an infringement by relying on a theoretical prospective delay assessment after the impact of the delay has materialized and is known.	The Royal Brompton Hospital NHS Trust v Frederick Alexander Hammond and Others (No. 7) (2001) EWHC Technology 39, 76 Con LR 148; George Sollitt Constr. Co. v. United States, 64 Fed. Cl. 229, 238 n. 8 (2005); Kane Constructions Pty Ltd. v Sopov (2005) VSC (30 June 2005); Northern Ireland Housing Executive v Healthy Buildings (Ireland) Limited [2017] NIQB 43; SCL, (2017).
2	The DAMs that rely upon the use of such programmes produce relatively more accurate results as long as (a) the updated programmes are contemporaneously validated against the as-built data and concurrently verified by both parties to ensure that, <i>inter alia</i> , the facts do not collide with the programme logic; (b) the analysis is conducted in an objective, logical, and detailed way; (c) the programmes include all works and are produced at regular and reasonably short intervals; and (d) the programmes and the analysis incorporate the effect of all operative delays but exclude significant errors and are supported by additional studies (e.g., analysis of resources).	Skanska Construction UK Ltd. v Egger (Barony) Ltd. (2004) EWHC 1748 (TCC); John Barker Construction Limited v. Portman Hotel Limited (1996) 83 BLR; Balfour Beatty Construction Limited v The Mayor and Burgesses of the London Borough of Lambeth (2002) BLR 288; George Sollitt Constr. Co. v. United States, 64 Fed. Cl. 229, 238 n. 8 (2005); Mirant Asia-Pacific Construction (Hong Kong) Ltd. v Ove Arup Partners International Ltd. & Anor [2007] EWHC 918 (TCC).
3	As far as the regularity of the programme updates is concerned, it is accepted that one month is a reasonable interval. However, the as-built data should be produced more frequently, for example, on a daily or a weekly basis, when, e.g., such data is likely to be required to assess the criticality of the works.	Walter Lilly & Company Ltd. v Mackay and Anor (2012) EWHC 1773 (TCC).
4	Generally, the delay must exceed the total float in the programme to demonstrate a loss and recover damages. Only delays on the critical path of a construction project (or a section of a project) can affect the completion/section completion date of that project.	Blackhawk Heating & Plumbing Co., GSCBA No. 2432, 75-1 BCA ¶ 11,261 (1975); Ascon Contracting Ltd. v Alfred McAlpine Construction Isle of Man Ltd. (1999) 66 Con.
5	Whether the DAM relied upon for the assessment of construction delays is prospective or retrospective is dictated by the contract type and terms.	Built Qld Pty Ltd. v Pro-Invest Hospitality Opportunity (ST) Pty Ltd. [2021] QSC 224 and John Holland Pty Ltd. v The Minister for Works [2021] WASC 312.
6	It is important to consider, evaluate, and demonstrate the impact of activities and events on near-critical paths, as well as the critical path, to understand their potential impact on construction projects and the completion/section completion dates.	Skanska Construction UK Ltd. v Egger (Barony) Ltd. (2004) EWHC 1748 (TCC).
7	A valid critical path must be established both initially and at regular intervals, as well as all material points, because the critical path can change throughout construction projects.	Balfour Beatty Construction Limited v The Mayor and Burgesses of the London Borough of Lambeth (2002) BLR 288.

Table 1. Cont.

Entry	Judicial Decision	Case Citation
8	Only delays on the critical path can affect completion; specifically, what must be demonstrated is: (a) a delay to an activity on the critical path must occur (which is of a certain number of days) and (b) that delay, in fact, delayed the completion date at the end of the project (or one or more section completion dates) by a given number of days after taking account of any mitigation or acceleration measures and/or descope of construction projects. Resources, mitigation, or acceleration measures must be taken into account when EOT claims are prepared and assessed. The analysis must include the interrelationship between all the operative delays/events from the start to the finish of a project.	Santa Fe, Inc., VABCA No. 1943–1946, 84-2 BCA ¶ 17,341 (1984); Henry Boot Construction (UK) Ltd. v Malmaison Hotel (Manchester) Ltd. (1999) 70 Con LR 33; Morrison Knudsen Corp. v. Fireman’s Fund Insurance Co., 175 F.3rd 1221 (10th Cir. 1999); Motherwell Bridge Construction Ltd. v Micafil Vakuumtechnik (2002) 81 ConLR 44; Mirant Asia-Pacific Construction (Hong Kong) Ltd. v Ove Arup Partners International Ltd. & Anor [2007] EWHC 918 (TCC); Costain Ltd. v Charles Haswell & Partners Ltd. (2009) EWHC 3140 (TCC); City Inn Ltd. v Shepherd Construction Ltd. [2010] ScotCS CSIH 68.
9	Although it is accepted that the interpretation (e.g., prospective or retrospective) of the critical path should be dictated by the contract, contemporaneous critical path assessments are recommended for preparation, assessment, and award of EOT entitlements because, among other things, contractors typically use forecasts to identify the planned/projected critical paths of construction projects and rarely have the benefit of hindsight.	UK Petrochemicals Ltd. v Punj Lloyd Ltd. [2013] EWHC 2916 (TCC); Van Oord UK Ltd. & Anor v Allseas UK Ltd. [2015] EWHC 3074 (TCC).
10	Analyses of resources, mitigation, and acceleration measures are essential in the determination of the impact of delays.	Vivergo Fuels Ltd. v Redhall Engineering Solutions Ltd. [2013] EWHC 4030 (TCC).
11	There are no legal rules that prevent parties to contracts from selecting, drafting, and/or amending construction contracts in such ways to incorporate protocols for the assessment of construction delays that specify, <i>inter alia</i> , the DAMs, the way criticality will be calculated, and the programmes and as-built data required to complete the delay analysis, including each step that delay analysts should undertake to complete such assessments and how the as-built data will be acquired, stored, and shared between all parties, including the frequency of as-built data updates.	Built Qld Pty Ltd. v Pro-Invest Hospitality Opportunity (ST) Pty Ltd. [2021] QSC 224; John Holland Pty Ltd. v The Minister for Works [2021] WASC 312.
12	Unilaterally modified DAMs are likely to cause disagreements over delay assessments.	Thomas Barnes & Sons Plc v Blackburn with Darwen Borough Council [2022] EWHC 2598 (TCC).

Table 1 includes a synthesis of the key principles established from the review of the case law that, according to judges, should guide the selection of DAMs. The overarching findings are that (i) judges prioritize the accuracy and reliability of delay assessments over their efficiency; (ii) if a party to a construction agreement does not follow the spirit of it should not benefit from its infringement at the expense of others, including an agreement to use a prospective DAM; (iii) if important new information emerges after the contractor was granted an EOT, which entitles the contractor to more time, new EOT assessment should be conducted; and (iv) the parties should accept all matters relating to delay assessments on an *ex ante* basis. In relation to point (i), as indicated in Table 1, the programmes should be detailed, logically linked, reliable (i.e., validated against accurate progress data), and

regularly and frequently updated, even though the reliance on such tools, in theory, is likely to be relatively more costly. Therefore, the term primary delay analysis instruments refers to the availability and quality of programmes and as-built data. If new instruments emerge, they have to comply with the legal requirements described above. As indicated by the identified case law, the use of *ex ante* agreements (or contract terms) facilitates the acceptance of delay analysis methodology. The aim is to prevent disagreements, which typically escalate from contract claims into disputes. For example, if the application of the CPM is agreed to be contemporaneous, delay experts would not be allowed to apply it retrospectively because that would breach the contract term.

In terms of the principles identified from the case law, those were divided into 12 categories that reflect statements of the law made by judges in multiple common law jurisdictions. All principles offer guidance on the selection and application of DAMs, including the likely effectiveness of delay analysis instruments. For example, the first set of principles, namely Entry 1, offers some judicial guidance on, *inter alia*, the effectiveness of programmes as an evidential delay analysis instrument; specifically, programmes should be detailed, valid, reliable, fully logically linked, and regularly and frequently updated. This offers guidance on the acceptability of delay analysis instruments by the law courts.

3.2. Academic and Grey Literature

The overarching findings from the review of academic and grey literature are that (i) although the academic literature is highly critical of the endorsed (by the SCL) six DAMs and delay quantification techniques, including the CPM, it has failed to offer a superior legally enforceable alternative and (ii) when it comes to the DAM selection principles, the academic and grey works unjustifiably and thus misleadingly prioritize the context and the economic efficiency of DAMs over their accuracy and effectiveness. In relation to key finding (i), although the acceptability of the CPM by the courts in common law (and civil law) jurisdictions is growing, the CPM is not without its critics [43]. In relation to key finding (ii), as far as the academic and grey literature is concerned, the selection of DAMs depends upon the context; specifically, the factors that influence the selection of the most appropriate DAMs can be divided into five groups, namely, project characteristics; requirements of the contract; characteristics of the baseline programme; cost proportionality; timing of the analysis; and availability of contemporaneous as-built records/data [5,40].

3.3. DAM Selection Guidelines

Based on the analysis, synthesis, and evaluation of the identified literature and case law, as well as the novel arguments presented above, a DAM selection model was designed, the key principles of which are illustrated in Figure 1.

The DAM selection model incorporates the main requirements for identifying an accurate and effective DAM in contexts where CPM analysis is or is not appropriate. Although, as per the literature review findings discussed in the previous sections, many of the principles that govern the selection of DAMs are evidence-based, some are recommendations, namely (i) the coordination of DAMs with contracts and the aims of governments and legal systems and (ii) the instrument-based analysis of DAMs. Even though those ideas are not founded on individual statements identified from literature (e.g., judicial decisions or arguments made in academic literature), as argued in this article, they have strong foundations. For example, the recommendations were based on the following findings: (i) the introduction of the NEC suite of contracts to the UK construction sector indicates a drive for proactive and collaborative resolution of delay claims; (ii) the Construction Playbook 2022 clearly states that early settlements of construction disputes in public projects is a goal of the UK Government; (iii) the fact that construction contractors use forecasts

in their planning procedures indicates that prospective DAMs should be used, save for the exceptional circumstances discussed in case law; (iv) the SCL Protocol endorses only two prospective DAMs and indicates that the TIA is the relatively more accurate one from those two DAMs, and the academic literature does not offer DAMs that are likely to produce more accurate and effective delay assessments; (v) although legal systems do not offer best or good practice guidance, there are indications as to the need to supplement primary delay analysis instruments with secondary instruments in certain circumstances; and (vi) the DAMs should produce accurate delay assessments and should be incorporated in construction contracts. In this context, it is rational to recommend that the selection of DAMs should be coordinated with the aforementioned realities and that the DAM selection should be instrument-based. For instance, a prospective DAM should be designated, in the offered example, but a retrospective DAM should be selected in case the exceptional circumstances discussed in the case law materialize. The key aspects of the proposed DAM selection model are discussed next.

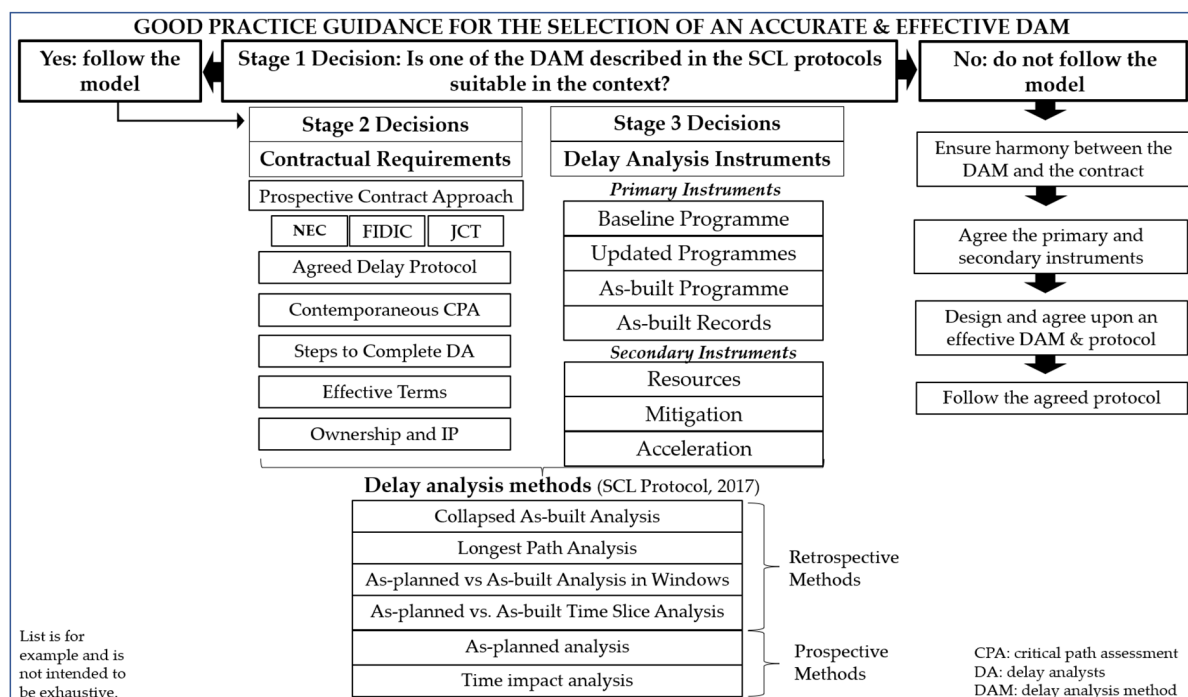


Figure 1. DAM selection model [5].

In summary, the stages in the selection of an accurate and effective DAM are three: stage 1: identify that at least one of the DAMs endorsed by the SCL Protocol is suitable to measure the impact of delays in a specific context; stage 2: select a standard construction contract that adopts a proactive and prospective approach to the assessment of the impact of delays (e.g., NEC or FIDIC), and stage 3: ensure that the contract (i) requires the use of all primary and secondary delay analysis instruments that are essential in the accurate and effective identification of the impact of delays and (ii) stipulates each step that is required to complete those assessments, the data recording rate, and the clear consequences of non-compliance with the agreed contract terms that govern the measurement of the impact of delays. The numbering of stages 2 and 3 does not indicate sequence, as they can be conducted concurrently. Figure 1 contextualizes the three standard contracts discussed in this paper.

In theory, the selection of a retrospective DAM is possible, but such a method would require a standard contract that adopts a strictly retrospective approach to the assessment of the impact of delays and a government policy that approves such a method of work.

This paper does not discuss such contracts, and the legal systems considered here do not advocate such an approach. However, as argued above, the DAM selection model should identify a retrospective DAM that relies on the same types of (but more up-to-date) primary delay analysis instruments in cases where contractors do not conform to the prospective nature of contracts and delay assessments or important new information in relation to a specific delay event emerges after an EOT entitlement was granted for that delay event, e.g., the TIA and time slice analysis. For example, as discussed in Sections 1 and 3, in England and Wales, the legal system advocates for proactive and prospective resolution of delay claims. As a result, among other things, the NEC suite of contracts was introduced. However, those contracts do not include (compulsory or optional) delay analysis terms. Furthermore, the SCL Protocol recommends six DAMs, only two of which are prospective. One of those two DAMs relies on significantly more accurate and effective primary delay analysis instruments, namely the TIA. The only retrospective DAM is the time slice analysis. Consequently, one of the NECs can be selected, and the TIA and the time slice analysis DAM should be selected, accepted, and applied to measure the delays. The NEC contract should be amended to incorporate delay analysis terms required to measure the delays accurately and effectively. Those terms should state clearly the contractual requirements, the delay analysis instruments, and the DAM and stipulate, *inter alia*, each step of the delay analysis, including the limited circumstances under which the time slice analysis DAM would be used. It is therefore recommended in this article that all standard forms of internationally used construction contracts should offer standardized delay analysis terms, particularly if (i) a legal system had similar aims to England and Wales and (ii) the cost of delay disagreements is funded by third parties such as the taxpayers.

Figure 1 also offers the key principles that should be followed by the parties if none of the DAMs endorsed by the SCL Protocol are suitable in specific contexts or if academics invent new DAMs that will be used in legal systems to substantiate EOT claims. Those principles are: (i) ensure coordination of (a) the DAMs and the construction contract and (b) the contract and the legal system that governs the contract; (ii) agree on accurate and effective requisite delay analysis instruments to avoid the use of assumptions; (iii) design and agree on an effective DAM and delay assessment protocol including each step that is required to complete the delay assessments and the consequences of non-compliance with the agreed protocol/model of work and/or the prospective nature of the contract; and (iv) follow the agreed protocol. If those principles are not followed, disagreements over delay assessments are likely to continue, escalating from construction claims into disputes. This is mainly because, currently, common law (and civil law) legal systems typically rely upon the principles of transparency and legal precedent, and the construction sector uses standard contract terms to, *inter alia*, create contractual certainty and allocate risks [20,21,24]. Ultimately, the parties should accept a ‘best of the rest’ DAM [5,14,43].

Moreover, construction contracts should align with this methodology when used in public projects to reduce the cost of disputes, which includes the cost of reduced productivity due to the allocation of resources to deal with disputes. In other words, an early settlement of disagreements is facilitated through the prevention of the escalation of disagreements over delay assessments from contract claims into disputes through contractual certainty and a clear risk allocation, which are facilitated by the principles discussed above. For example, the JCT, NEC, and FIDIC forms, among other contracts, should use the DAMs employing the most accurate and effective (primary and secondary) delay analysis instruments; the prospective and retrospective DAMs should employ identical instruments, save for the more up-to-date programmes and as-built data, which the latter would rely on. The critical path should always be assessed contemporaneously, and the impact of delay should be calculated prospectively unless one of the exceptions discussed above

applies. When an exception applies, the retrospective method should be selected based on the principles identified in this article. This method of work ensures dispute avoidance through agreement and selection of the most accurate and effective DAM and a reduction in project costs through alignment of delay assessments with construction contracts and government objectives and the interests of the taxpayers.

Although the proposed guidance and its principles ensure the accurate and effective identification of the impact of employer risk, contractor risk, and neutral and concurrent delays, as explained in Section 1, concurrent delays are governed by the relevant law. Consequently, the legal principles of the relevant legal jurisdiction should be applied.

4. Discussion

This section offers a discussion of the main findings of this paper in the context of the identified academic and grey literature and case law, as well as the offered DAM selection model, specifically, (i) criticism of the endorsed by the SCL DAM, including the CPM; (ii) legal and contractual issues with the offered to date DAM selection principles; and (iii) the proposed legal enforcement of the DAM selection model, namely the compliance of the model with well-established legal principles and contract law. The discussion ends with a synthesis of the offered novel DAM selection principles and ideas.

Although academic literature is typically highly critical of the six endorsed by the SCL DAM and delay quantification techniques, including the CPM, it has not offered a superior, legally enforceable alternative. Academics argued that, among other things, the CPM outputs are complex, widely misunderstood, and a poor means of communication, as such outputs can result in very large and complicated networks [44,45]. Additionally, it was contended that the CPM characterizes projects in a deterministic manner, which requires the participants to mentally associate the conceptual information that the programmes represent with the physical works [46]. Further limitations of the CPM include the following: (i) it assumes unlimited resource availability [47] and (ii) it is unable to consider the variety of parameters that construction operations have (e.g., special information and weather conditions) [48]. However, the critics have not proposed more efficient, legally effective, and viable alternatives. For example, a fuzzy logic solution was suggested to remedy the uncertainty associated with, among other things, the interdependence of logically linked tasks and resources. This solution relates to prospective assessments of delays [49]. More recently, an approach to delay analysis involving the TIA method and quantitative schedule risk analysis was also recommended, but this suggestion has similar limitations in terms of its prospective nature [50]. As argued in this article, this is problematic because, in the aforementioned exceptional circumstances, the parties may have to use a retrospective DAM. Moreover, the use of simulation models was recommended, but the implications of all the disadvantages of this technique were not disclosed [48]. Furthermore, it was argued that the advantages the CPM offers outweigh its disadvantages, which results in a wide acceptance of the CPM in, among other common law (and civil law) jurisdictions, the UK and US; specifically, the benefits of well-constructed programmes, including estimated activity durations, logic, and constraints, are seen as useful by both project management teams and the judicial systems discussed in this article [51]. Additionally, many standard construction contracts require the use of such programmes. Consequently, the CPM and related techniques have become a commonly accepted basis for the quantitative forensic analysis of construction programmes [5,52,53]. In terms of identifying a trend, the acceptability of the CPM by the UK and US courts is high [43,54]. Moreover, CPM assessments do not have to rely solely on construction programmes. The accuracy and reliability of their results can be improved by, among other things, the use of other primary delay analysis instruments such as as-built data and the aforementioned secondary delay analysis instru-

ments. In other words, the disadvantages of the CPM can be mitigated. Plus, all DAMs that are endorsed by the SCL recommend the use of the CPM if this delay quantification technique is contextually appropriate [5].

In terms of the DAM selection principles, it is argued in this article that some of the academic and grey works unduly and thus unreasonably attach primary importance to some contextual factors, including the economic efficiency of DAM over their accuracy and effectiveness, or at least unduly imply that all contextual variables are of similar importance to the DAM selection process. For example, according to the academic literature, the selection of DAM depends upon the context; specifically, the factors which influence the selection of the most appropriate DAMs were divided into five groups, namely project characteristics; requirements of the contract; characteristics of the baseline programme; cost proportionality; timing of the analysis; and availability of contemporaneous as-built records/data [40]. The availability of as-built data, the quality of the baseline programme, the status of the project, and the time needed to perform the analysis are the primary factors influencing the selection of DAMs, while the appropriateness of using any DAM, in the absence of any contractual requirements, remains at the discretion of delay experts [55]. Although it is accepted that some of the aforementioned contextual factors are important, e.g., the availability of programmes and as-built data, and the characteristics of the contract are primary factors, other factors are of secondary importance. For example, the project characteristics are relevant as far as the critical path is concerned. In other words, the project characteristics are important when they impact the sequence of programme activities, e.g., if the sequence of activities is purely preferential, this would require disruption analysis, rather than an assessment of critical delays [5]. The literature and case law also indicate that the timing of the analysis should be coordinated with the contracts [15,16]; industry practices [17]; other factors, including knowledge of the actual impact of the delay at the time of the EOT application and the emergence of new information after an EOT is granted [39]; government objectives, including early settlements of disputes [12]; and improved productivity of the sector [10]. In terms of the characteristics of the baseline programme, it should be, in all cases, complete, detailed, fully logically linked, reliable, and externally validated [43]. In other words, there should be no need to make any assumptions to fill in information gaps in the baseline programme during EOT assessments. Consequently, some of the academic and grey literature unjustifiably attach similar importance to the identified contextual DAM selection factors. As a result, there has not been much progress in this field over the past decades, and disagreements over delay assessments continue to frequently escalate from contract claims into disputes [6].

Based on the review of the identified academic and grey literature and case law, it is argued in this article that a selection process that is not instrument-based is likely to be ineffective, as judges are likely to prioritize the accuracy and reliability of the delay assessments over their economic efficiency. For example, the available guidance argues that the economic efficiency of DAMs is essential, rather than identifying the requisite tools (or primary and secondary delay analysis instruments) to complete accurate, acceptable, and effective delay assessments, even though there is no empirical evidence in the published literature to suggest that consultancies bill on a basis which considers the DAM, rather than billing on a basis that takes little/no account of the costs associated with using a DAM [5]. In other words, it is unclear if the efficiencies created by using the 'least expensive' DAM are passed by delay experts onto their clients. It has been argued that similar efficiencies in the legal sector have been used to improve the profitability of organizations without accounting for those in billing practices [56]. Furthermore, some of the contributors to the SCL Protocol have access to such information but have not offered it as justification for the statements they have made in that guidance document, which is at least puzzling. Moreover, the

review of the identified case law indicates that other factors, including economic efficiency and cost proportionality, are not considered by decision-makers when evaluating delay assessments. The purportedly most economically efficient DAMs, in the SCL Protocol, are highly likely to produce relatively more theoretical delay assessments, which are anchored on a relatively higher number of assumptions [5]. The case law identified in Section 3 indicates that assumptions are much more likely to be disputed than the facts and also more likely to lead to poor judicial decisions, because such decisions would involve a degree of guesswork by the decision-makers in the absence of the facts. Consequently, the contract risk for the parties would be greater and the contract certainty would be absent when such a DAM is relied upon. This is because, among other things, this article argues that the statement in *Walter Lilly & Company Ltd. v Mackay & Anor* [2012] EWHC 1773 suggests that the selection of a DAM should be immaterial; specifically, experts accept that different DAMs should produce identical results is incorrect. Firstly, it is accepted that this is not always the case [57]. Secondly, this article argues that unless the two DAMs utilize the same types of primary and secondary (or requisite) delay analysis instruments and adopt identical delay quantification techniques (e.g., contemporaneous CPM), it is highly unlikely that the delay assessment would be identical, as, *inter alia*, delay experts would be required to make assumptions that are often subjective or unsubstantiated [8]. Even if the same types of requisite delay analysis instruments are used by one prospective and one retrospective DAM, the EOT assessments are likely to be different because, *inter alia*, the prospective DAM would be based on more assumptions than the retrospective DAM, as the latter relies on more up to date facts, unless, e.g., the CPM is applied contemporaneously and the EOTs are substantiated properly in both cases, which is the case, at least in theory, with the TIA and time slice analysis [5].

In terms of the contractual status of the DAM, the overarching argument presented in this article is that certainty is achieved through the use of effective contract terms that are agreed upon by the parties to construction agreements, which is supported by the literature [20]. Contract terms are required to ensure that judges exercise the principle of sanctity of contracts, avoid interfering with the intentions of parties, and ensure that they are held accountable for their promises. The aim is to facilitate commercial activities by providing predictable and stable legal frameworks [19]. The contract terms should be, whenever appropriate, standardized to increase the consistency of their interpretations, which are recorded in judicial precedents that are published and made available to the public [21–23]. The applications of those principles in judicial precedents will advise or bind decision-makers in future disputes and inform delay experts and parties to construction contracts of their legal positions [20,24]. For example, the Australian courts indicate that the DAM is not a matter for expert evidence, but it is dictated by and depends on the proper construction of the contract [15]. Consequently, delay experts will stop interfering with construction contracts and discontinue claiming that, in such contexts, the DAM selection is a matter of expert evidence. In terms of freedom of contract, although parties to construction agreements are generally free to contract [18], when the cost of the dispute is funded by taxpayers, contracts should ensure that such costs are minimized. In other words, it is argued in this article that the freedom of contract should be limited, particularly if, as a direct result of exercising it, the costs of disputes are maximized, and such costs are paid by third parties, namely the taxpayers.

Consequently, in addition to the laws and contract principles discussed above, the proposed DAM selection model is compliant with the principles identified from the case law. Since those sources do not offer all necessary principles, the article offers novel ideas; specifically, (i) the accuracy and effectiveness of DAMs should be prioritized over their alleged economic efficiency; (ii) the selection process should be instrument-based

and ensure the use of primary and secondary delay analysis instruments in order to, *inter alia*, mitigate the shortcomings of the CPM; (iii) although two DAMs should be selected and both methods should rely on identical primary and secondary delay analysis instruments, the retrospective DAM should only be used in exceptional circumstances, as recommended by the case law discussed in this article. If those principles are applied, the TIA and time slice analysis should be the contractual DAMs, which should be supported by secondary instruments; (iv) all construction contracts within a jurisdiction, particularly model agreements, should align with the government objectives and the law, i.e., the approach should be consistent in public projects; (v) the public interest should override the freedom of contract principle in public projects; and (vi) new DAMs should align with principles discussed in this article and should be as accurate and effective or more accurate and effective than the endorsed by the SCL and AACE DAMs. Moreover, circumstances where the time slice analysis is required should be truly exceptional, and the defaulting party should be legally and contractually disincentivized from such behaviour, e.g., to withhold essential information and offer it after the EOT is granted. This method of work is likely to lead to a reduction in disputes over delay assessments through early settlements of contract claims, which would benefit the construction sector and the wider community in publicly funded construction projects.

5. Conclusions

Disputes over delay assessments are time-consuming, expensive, prevalent, and persistent in many legal systems, including the ones discussed in this article. Although the identified academic literature argues that, among other things, the use of two-dimensional delay analysis instruments is obsolete and problematic, none of those studies offer an alternative that (i) works relatively more effectively in practice; (ii) provides greater delay assessment accuracy and efficiency; and (iii) aligns with governmental policies, including initiatives to achieve early settlements of construction disagreements in public projects and to improve the productivity of the construction sector. Additionally, the identified grey literature and case law offer no comprehensive solutions to resolve this issue. This is unsurprising due to the interdisciplinary nature of the problem and the required solution, which involves in-depth knowledge of multiple professions, including project planning, construction project engineering and management, quantity surveying, dispute resolution, and law. Consequently, this article is internationally significant and contributes to the fulfilment of the aforementioned interdisciplinary knowledge gap.

The arguments presented in this article are set out in the context of a drive for early settlements of construction disagreements; specifically, legal systems should ensure that construction contract claims procedures are effective in preventing the escalation of disagreements over delay assessments from contract claims into disputes in public projects. This is likely to improve the productivity of the construction sector and reduce the costs of disputes to the taxpayers, which include the cost of the disputes and the cost of the reductions in productivity of the construction sector caused by the use of resources to settle disputes instead of using those resources in the design and construction processes. It was argued that such contract claims procedures are currently ineffective in the early settlements of disputes. Reliance on accurate, accepted, and effective delay analysis instruments is required to improve the effectiveness of contract claims procedures. In summary, this article offers a novel solution that incorporates delay analysis tools recognized by the law, namely the requisite (primary and secondary) delay analysis instruments. The legal systems and contract law principles discussed in this article do not prevent the use of such a model of work but facilitate it. Moreover, the judicial decisions offered in this article are clear that judges do not take into account the alleged economic efficiency of DAMs

for contractors and employers; they require accurate evidence and an effective DAM. It was argued in this article that the effectiveness of DAMs is improved by (i) the use of accurate and effective delay analysis instruments and (ii) the coordination of DAMs with government objectives, legal systems, the law, and construction contracts. Therefore, even if more advanced delay analysis tools become available, the need to use the DAM selection and coordination principles offered in this article remains.

The use of accurate and effective DAMs is likely to reduce disagreements over EOT assessments by providing all relevant facts, accepting the technical basis of the used forecasts, and agreeing upon the selection and application approach to delay assessments. This should decrease the number of assumptions that delay experts are required to make and remove disagreements over the 'factual' and 'technical' aspects of their role, including the context-specific selection of DAMs and delay quantification techniques. Such a method of work should lead to impartial, accurate, and effective assessments of EOT entitlements, irrespective of whether EOT claims are issued on a prospective or retrospective basis, mainly because of the acceptability of this system of work by the parties, delay experts, and decision-makers. This can be achieved by following the DAM selection model presented in this article, specifically by ensuring that the chosen DAMs rely upon accurate and reliable primary and secondary delay analysis instruments. The primary instruments are an externally verified baseline programme and contemporaneously updated and validated (against the as-built data) programmes that are detailed, valid, reliable, logically linked, and frequently and regularly accepted/approved/validated by the parties or a third party. The secondary instruments include analyses of resources, mitigation and acceleration measures, and changes to the programmes such as descoping. The critical path should be assessed contemporaneously, and the contemporaneously forecasted impact of delay events should be adequately substantiated to enable the assessment of accurate and impartial EOT entitlements, mainly because legal systems require such reliable evidence, and this method of work contributes to remedying a key issue that is the lack of trust among parties to construction agreements.

If the principles presented in this paper are applied, the TIA and time slice analysis should be selected as the contractual DAMs because (i) they address both prospective and retrospective situations with relatively greater clarity; (ii) both DAMs rely upon the same types of primary instruments which, according to the judicial decisions presented in this article, can be very accurate and effective if applied objectively, particularly if they are supplemented by the use of secondary delay analysis instruments; (iii) both DAMs use contemporaneous CPM assessments; and (iv) more accurate and effective alternatives are unavailable. However, none of the legal systems discussed in this article advocates for the use of a retrospective DAM, including time slice analysis. Therefore, this retrospective DAM should only be used if the impact of the delay event is known at the time of making the EOT application or if important new information emerges after an EOT was granted.

The ideas and principles offered in this article should be used to verify the effectiveness of innovative DAMs and/or delay analysis instruments, including (i) the selection rationale that, *inter alia*, prioritizes the use of requisite delay analysis instruments which deliver accurate and effective EOT assessments, rather than a selection process that gives undue weight to the alleged, and empirically unsubstantiated, economic benefit of DAMs to clients; and (ii) the coordination of DAMs and quantification techniques with construction contracts and legal systems.

In terms of the generalizability of the research findings, although the legal systems of the UK, namely, England and Wales, Scotland, and Northern Ireland, are the focus of this article, observations are made on relevant case law from North American jurisdictions and Australia. Moreover, legal systems typically do not offer best practice guidance on this

subject. In other words, judicial decisions indicate that it is up to the parties to construction agreements to select and apply DAMs. However, none of the contracts discussed in this article offer such standardized (compulsory or optional) delay analysis terms. Consequently, although this study offers strong evidence that the implementability of the offered solution is multinational, further research is recommended before the DAM selection principles offered in this article are implemented in different construction agreements and legal jurisdictions. Empirical validation and testing of the guidance in real-life projects are also recommended. Accordingly, further research is recommended, including the refinement and validation of the DAM selection model through empirical verification and the testing of it in construction contracts, claims, and disputes. An investigation of the barriers to the implementation of the offered solution is another valuable line of enquiry.

Future work should integrate machine learning-based text analytics to operationalize the proposed model. Building on prior studies that apply transformer-based text analysis and graph neural network-driven text classification for defect monitoring [58] and inspection, dispute document bundles [59] could be transformed into structured outputs such as evidence-completeness scores, event chronologies, and dispute-risk indicators.

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Abbreviations

The following abbreviations are used in this manuscript:

AACE	American Association of Cost Engineering
CPM	critical path method
DAM	delay analysis method
EOT	extension of time
FIDIC	Fédération Internationale des Ingénieurs-Conseils
JCT	Joint Contracts Tribunal
NEC	New Engineering Contract
SCL	Society of Construction Law
TCC	Technology and Construction Court
TIA	time impact analysis

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