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The Evolution of Forensic Delay Analysis: A Literature Review Investigating Changes and Progress in Project Management Approaches to Delay Measurement

Authors

Grzegorz Grzeszczyk Ph.D.
School of Civil Engineering
University of Leeds
Woodhouse, Leeds LS2 9JT
United Kingdom
ORCID: 0000-0003-3020-8833
cngg@leeds.ac.uk

Tristano Sainati Ph.D.
School of Civil Engineering
University of Leeds
Woodhouse, Leeds LS2 9JT
United Kingdom
ORCID: 0000-0003-0846-8348

Christine Unterhitzenberger Ph.D
School of Civil Engineering
University of Leeds
Woodhouse, Leeds LS2 9JT
United Kingdom
ORCID: 0000-0001-5815-9127

Abstract

This literature review explores the topic of Forensic Delay Analysis (FDA), highlighting recent advances and key themes currently attracting research interest within the area. Project delays in every context can have significant financial and non-financial impacts, so it is crucial to accurately identify and assess their influence. Our analysis shows that despite the initial conceptualisation of FDA methods and tools, the field remains complex and laborious, and its credibility is often contested due to . The findings suggest that FDA has received insufficient research attention compared to other project management domains and has made limited progress since its inception. Furthermore, there is no consistent approach to measuring delays, despite their prevalence, severity and global persistence. Although a wide range of publications acknowledge the continuing interest in FDA, most confirm its limited applicability and inadequate standardisation. The literature also highlights lack of progress in this area of knowledge predominantly due to lack of innovative perspectives, tools and understanding. In order to improve the credibility and reliability of FDA and DATs, it is therefore essential to embrace and promote alternative and innovative knowledge. This paper will appeal to a wide audience, including academics and practitioners, who wish to explore the limitations of FDA and the knowledge gaps identified in the existing literature.

Key words: *schedule delays, delay analysis, project controls, construction claims, project management, contract administration*

Introduction

The scientific literature emphasises the relevance of delays for projects (Durdyev and Hosseini 2019). For instance, delays are frequent in projects (Flyvbjerg 2014), particularly large ones (Park 2021),

and they have a detrimental impact on their performance (Eizakshiri et al. 2015), both directly (Siemiatycki 2018) and indirectly (Braimah 2013). Given the relevance, and frequency of delays in projects, appropriate methods have been developed, in particular the so-called Delay Analysis Techniques (DATs), sometimes denoted by various alternative terms (Kabre and Kumar 2019). DATs comprise an array of quantitative methods to assess the impact of delays on projects and stakeholders (Braimah 2013; Yang and Kao 2009). There are two main approaches for DATs, namely prospective and retrospective analysis (Keane and Caletka 2015). Prospective DATs assess the impact of past and current delays into the future, typically to evaluate their effect on the project's completion date. Prospective DATs are performed periodically during delivery (Nemr et al 2019) and involve a theoretical contemporaneous ascertainment of delay's criticality and impact on the basis of what is known within the project at that moment. They are thus forward-looking and aim to foresee the future. Conversely, the retrospective DAT benefits from hindsight and looks backward, usually to trace back the cause of the delay (Parry 2015). Both approaches are applied in practice and have been endorsed by practitioners and industry (Braimah 2013, Braimah and Ndekugri 2008, Gorse et al. 2006). Each approach has developed its own DAT methods, which already have been extensively exemplified by other publications (D'Onofrio and Dale 2015) and the judiciary[1] (Hess and Bailey 2015, Fenwick Elliot 2012, Garner 2007). Many jurisdictions developed unique interpretation of FDA and DATs principles too (D'Onofrio et al. 2018).

DATs have multiple uses, including enhancing project controls, decision-making and estimating the completion date (Rathod 2016, Alkass et al. 2010). Yet, a subclass of DATs is also used to support formal disputes between contractual stakeholders, i.e. Forensic Delay Analysis (FDA). FDA is used for quantifying the impacts associated with delays and their causes (Braimah 2013). FDA comprises of quantitative assessments, combined with legal and contractual interpretations, for determining economic compensation (i.e. damages) in projects (Kelly and Franczek 2013). The initial development and consolidation of the FDA date back to mid-1960's, as a techno-legal application of scheduling models such as the Critical Path Method (CPM) (Livengood 2016). Shortly after, initial publications attempting to systematise FDA were released (Wickwire and Smith 1974). Presently, CPM remains to be the most used scheduling method for FDA, although there are more recent and sophisticated alternatives (Zack and Collins 2012). Despite the significance of FDA for project-based industries (e.g. construction, although the applicability of FDA extends onto other industries such as manufacturing or IT), project

management scholars devoted limited attention to these techniques, resulting in a narrow and fragmented published research on this area. This paper shows this is one of the core reasons why FDA is still perceived as niche 'dark art' (Barry 2009). To advance research in this critical area of project management, this paper therefore addresses the following research question: What is the current status of FDA in academic and texts and unpublished or non-commercial research materials such as reports, conference proceedings, working papers (the so-called grey literature)?

The paper is organised as follows. This section acts as a concise introduction to the problematic of delays and FDA and briefly depicts its origins and applications. The authors assume basic familiarity of the reader with the topic and its circumstantial positioning, although more elaborate considerations on the topic will be included in the sections below. Section 2 outlines the systematic review process including the identification of sources considered, and the thematic analysis designed and employed to review them. The emergent themes from the systematic review process are then individually presented and discussed in section 3. Section 4 contains the authors' subjective reflections developed and founded on the entire review process, including the contribution of this research to the field of project management. Lastly, summative conclusions are located within section 5.

The review process

Academic Publications

The current status of FDA was assessed with the use of systematic literature review – chosen as the proven method to unfold themes and research gaps (Fisch and Block 2018). The review process (Figure 1) followed a modified protocol designed by Tranfield et al. (2003), progressed by Pickering and Byrne (2014) and refined by Xiao and Watson (2019).

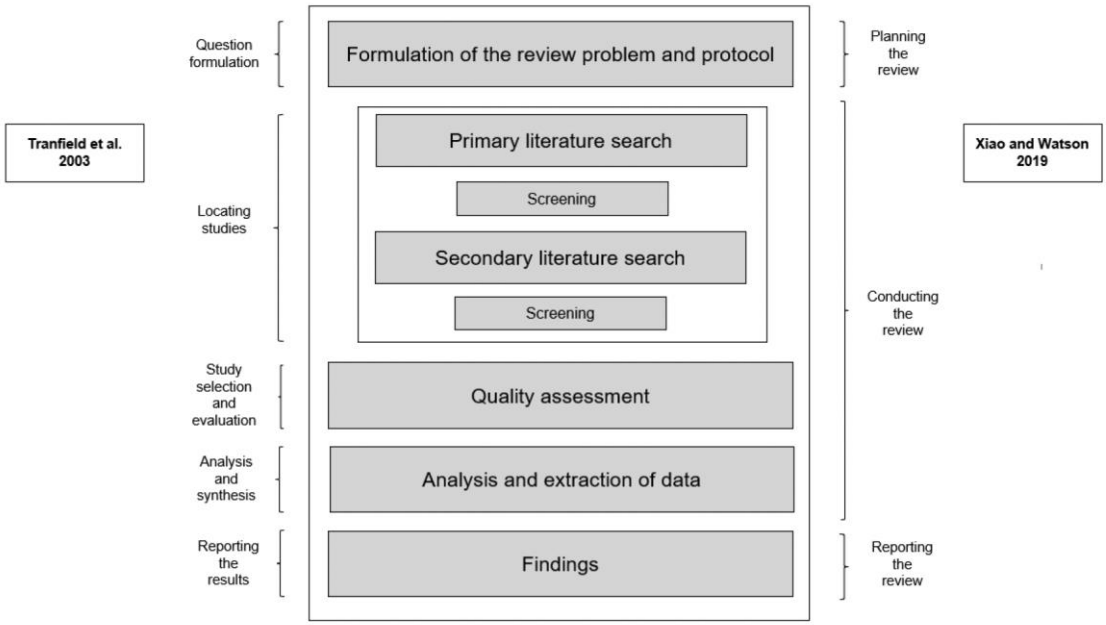

Figure 1. The applied literature review process

The objective was an equilibrium between inclusivity and precision (Wanden-Berghe and Sanz-Valero 2012). This necessitated restriction of the search to the 'forensic delay analysis' noting the presence of 'delay analysis' in transport modelling, electronic engineering and other domains far-distanced from the researched topic. However, to ensure a breadth of metonyms of common terms applicable to FDA other words were used. Bibliographic information was gathered from Scopus database and restricted to texts published in full text in English between 2002 and 2021, and within the following areas: Engineering, Chemical Engineering, Multidisciplinary, Energy, Business, Decision Sciences. The authors considered exclusively journal articles and conference proceedings (only from reputable organisations and leading scholars on the topic). This resulted in the following search string:

TITLE-ABS-KEY ("forensic") AND TITLE-ABS-KEY ("delay*" OR "clai*" OR "tim*" OR "CPM" OR "program*" OR "critical pat*" OR "schedul*" OR "slippag*" OR "overrun*") AND ALL (("analys*" OR "management" OR "evaluation*" OR "assessment*" OR "quantificat*")) AND ALL ("projec*" OR "programm*" OR "megaprojec*" OR "major projec*") AND (LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "DECI") OR LIMIT-TO (SUBJAREA , "CENG") OR LIMIT-TO (SUBJAREA , "ENER") OR LIMIT-TO (SUBJAREA , "BUSI"))

The initial literature screening resulted in 845 sources. The authors reviewed first the title, abstract and keywords, and later entire manuscripts to identify the relevant papers, which are 37.

Non-academic publications

Given the limited number of relevant academic publications, the authors decided to seek additional references in the final set of papers and to explore the thematic grey literature, which includes unpublished or non-commercial research materials such as reports, conference proceedings and working papers. These sources may also be referred to as non-peer-reviewed literature, unindexed documents or semi-published materials. The references were assessed for the same criteria as in academic papers. Additional modifications, however, were made to the sources available online. Here the search was conducted with the use of Google search engine and limited to full-text publications released between 2002-2021 by professional bodies (SCL,[2] ASCE,[3] AACEI,[4] RICS,[5] CIOB,[6] CICES,[7] ICE,[8] PMI,[9] APM[10]), leading market organisations (e.g. HKA, Arcadis, Kroll, Ankura, Secretariat, Berkeley Research, FTI Consultants, Driver Group, Systech), and leading law firms (e.g. Fenwick Elliot, Clifford Chance Corbett, CMS, Jones Day, Eversheds Sutherland, Pinsent Masons, Keating Chambers, Atkin Chambers, KL Gates) sought through a series of strings in the following format: “forensic” AND “delay” AND “analysis” AND “<entity name> “AND “.pdf”. Once this stage was complete – to add coverage– the final run was completed with a three-part string in the following format: “forensic” AND “delay” AND “analysis” AND “.pdf”. No other Google Power Search options were used. Each output was run until the last search output page was reached or when no new relevant references were provided (Levy and Ellis 2006). All main organisational websites, if such functionality was offered, were additionally searched for content containing “delay”. The results meeting the search variables were assessed against the primary search exclusion and inclusion criteria above. The screening process also mimicked the previous one. This resulted in 84 sources.

Qualitative assessment and theme identification

The primary and secondary search outputs – 122 in total – were aggregated and qualitatively assessed on the basis of a scoring matrix, guided by the considerations posed by Templier and Paré (2015) and Flick (2007) and factors recommended by University of California (Berkeley) Library and the evaluation frameworks created by Farace and Schöpfel (2010), Pyrczak (2016) and Petticrew and Roberts (2006). The matrix rested on a three-tiered scale – *low*, *medium* and *high* – for seven quality criteria: relevance, objectivity, credibility of the content, credibility of the author, credibility of the source, validity of references and currency of the information. Although it is accepted in the literature that the quality evaluation of the identified sources does not have to lead to their exclusion from the review (Okoli and Schabram 2010), the authors decided to subjectively factor out sources that were of unsatisfactory standard or were deemed irrelevant. Accordingly, publications with a cumulative 'low' rating were excluded from thematic analysis. On this basis 29 publications were excluded, leaving 93 papers for evaluation.

The remaining sources were subjected to a thematic analysis based on a process proposed by Braun and Clarke (2017) and supported by insights from Kyngäs et al. (2020) and Thomas and Harden (2008). This entailed a detailed read of each paper, clustering and search for patterns to construct themes. The initial run revealed trends in the thematic area and highlighted a series of questions, contradictions and proposals. Patterns were also clear within theoretical and practical underpinnings of FDA and DATs. The thematic analysis resulted in eight main themes clustering eighteen codes, as shown in Figure 2. The main themes are presented individually in the following sections.

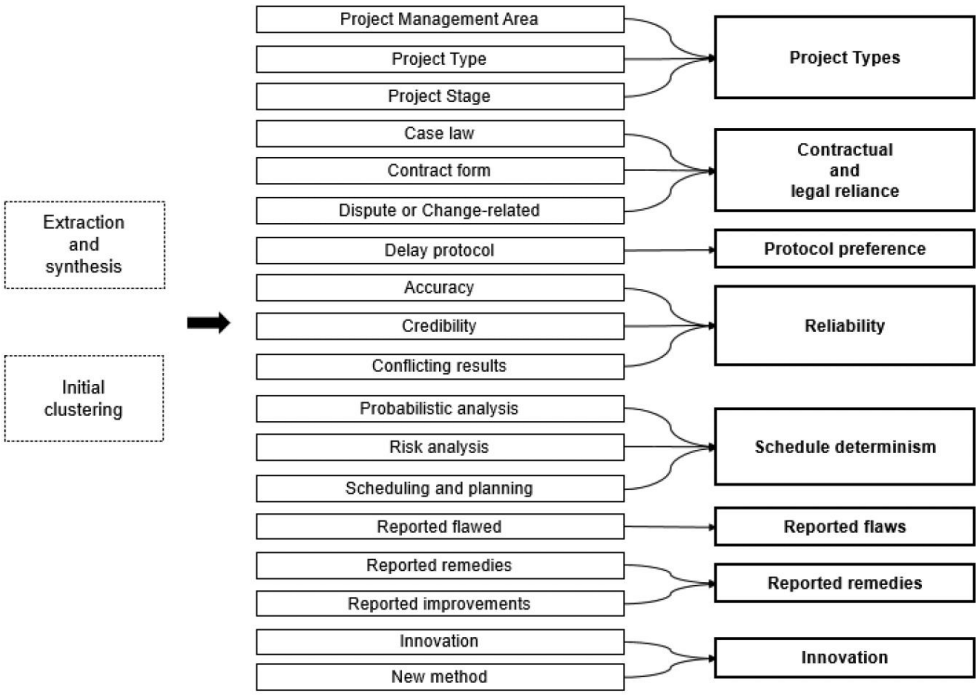

Figure 2. Theme extraction and synthesis

Findings

Theme: Project characteristics

Noting the level of effort required to conduct FDA, it is applied to projects with specific characteristics. Otherwise, the cost of proceeding with a formalised and structured analysis, engaging expert witnesses and delay analysts may outweigh its benefits (Braimah 2009). Projects can be classed in line with a number of arbitrary criteria driving their uniqueness (Safa et al. 2015). Accordingly, the literature review sought to identify the categories of projects where FDA is applied or desirable. Few of the papers, however, exhibited that the demand for FDA is created within large projects, due to their complexity and economic size, which justify the need for a formal delay analysis (Mohammady and Gibson 2020; Guida and Sacco 2019; Mehany and Grigg 2016; Muhammad 2015; Fawzy and El-Adaway 2012; Abd El-Razek et al. 2008). Some texts also included propositions that the need for its application is connected to the undertakings notoriously experiencing schedule overruns, Extensions of Time (EOTs) or apportionment of liabilities (Fawzy et al. 2018; Linnet et al. 2014). In practice, these characteristics are synonymic with construction and engineering sectors. Many identified papers make a direct reference to these areas (Jagannathan and Delhi 2020; Braiham 2013, Magdy and Georgy 2019; Ndekugri et al.

2008). Sometimes this attachment is not explicit but it can be inferred based on the textual analysis or the journal type (Carvalho 2021, Kim et al. 2016). A proportion of the texts was supported by case studies, which stipulate the classes of projects where FDA is typically utilised (Muhammad et al. 2016; Abd El-Razek et al. 2008; Lo et al. 2006). Most of these, however, are concise and descriptive. Other sources position deliberations on FDA in a general context (Guida and Sacco 2019, Ackermann and Eden 2008, Pickavance 2008).

As shown in Table 1, the findings of the review also indicate that FDA and DATs are topics that are rarely considered from the perspective of a particular geography. From the pool of identified sources only seven papers made an explicit mention of location (Mohammady and Gibson 2020, Abdelhadi 2016; Muhamad et al. 2015; Parry 2015; Abd El-Razek et al. 2008; Abdul-Rahman et al. 2006; Lo et al. 2006). A detailed read of texts permits, however, to infer specific settings. This is observed, as expected, within the grey literature and papers released by professional organisations (e.g., SCL and AACEI). Several publications describe FDA and DAT applications in a manner which permits to clearly associated their application to publicly-funded undertakings – with most referring to or being related with large public infrastructural works.

Theme: Contractual and legal references

FDA is framed in the legal context (Pulket and Arditi 2008). Most principles driving the FDA methodologies, including DATs, are driven by principles attributable, for example, to the law of negligence. It is also dependant on the contractual and jurisdictional settings, which set frameworks for recovery of losses related to prolongation costs (Nash 2002). Due to the probative value of FDA, the courts, regardless of jurisdiction, often express their preferences with regard to the overall FDA approach (Munvar et al. 2019) or particular method of analysis. FDA is also a product of legal interventionism, as its development was and is steered by the manner in which the courts perceive liability for delays (Whaley 2021; Marshall 2016). For example, in Australia, in *Alstom Limited v Yokogawa Australia Pty Ltd* (no.7) [2012] SASC 49 one of DATs applied by an expert was rejected as being 'not recognised within the engineering profession'. In the UK, in *Adyard Abu Dhabi V Sd Marine Services* [2011] EWHC 848 (Comm) the court followed a specific interpretation of contractual provision as to what type of FDA should be employed to determine EOT. The judiciary in the USA (e.g., *Law Co., Inc. v. Mohawk Const.*

177 *Supply Co.*), Hong Kong (e.g. *Leighton Contractors (Asia) Limited v Stelux Holdings Ltd*), or elsewhere
178 follow the same mantra. Influence on FDA had also ADR methods, particularly adjudication and
179 arbitration (Saraswat 2020) what is underlined well by Balfour Beatty Construction Ltd v Lambeth in
180 the UK.

181 The role of the contracts or technical documentation cannot be underestimated either. Under
182 most contractual conditions in order to be compensated for delay a party must satisfy, in general, three
183 elements (Bailey 2020; Tieder 2009). Firstly, there must be a proof of liability of the defendant for the
184 delay (Oram 2012). Secondly, the delay must lead to loss of some sort, which in this case, is the delay
185 itself (Axelson 2021). Lastly, there must be evident causation connecting the two previous elements
186 (Axelson 2021; Tieder 2009). The claimant is entitled to a compensation only when these three
187 conditions are satisfied. While liability and losses are not difficult to prove, causation requires elaborate
188 investigation, which involves an evaluation of schedules and DATs.

189 As per Table 2, the sources gathered during the literature review confirm three different
190 approaches to the legalistic ramifications of FDA and DATs. On one hand, some papers focus on the
191 legalistic dimension of the area, which either attempt to exemplify the approach to FDA and DATs
192 exercise in a specific jurisdiction (Tieder 2009, Fenwick Elliot 2012), provide comparative insights into
193 how FDA and DATs are perceived across legal systems (Arif and Moyad 2014, Ibbs et al. 2011) or
194 demonstrate how expert testimony is framed in contentious settings (Hoshino 2003). The literature
195 indicates subtle bias towards common law jurisdictions noting that presentation of the topic in mixed
196 and civil law jurisdictions, with some exceptions (CMS 2020, Cocklin 2013, Garner 2007), was bypassed.
197 On the other hand, more technical papers on FDA and DATs contain references that are partial. For
198 instance, minor references to precedents of the senior courts and legislative authorities were made by
199 Bektas et al. (2021). Other literature within this group depicts the machinery of a delay claims and
200 measurement without providing any jurisdictional, contractual, or case law details (Guévremont and
201 Hammad 2020; Abdul-Malak and Mehdi 2020). Some sources made references to general contractual
202 approaches, but abstained from specifying any standard form of contract or jurisdiction.

203 The review reveals also mixed papers that cover the problem from both – the legal and technical
204 angles, the authors identify two main streams (Munvar et al. 2020, Ibbs et al. 2011, Fawzy et al. 2008,

205 Garner 2007). The first stream focuses on all aspects of FDA and attempt to explain the 'dark arts' process
206 of identifying and evidencing compensable schedule overruns from all angles of interest. In these, the
207 technicalities associated with FDA and DATs take place in parallel to the legal principles steering these
208 aspects. The second stream concern the resolution of a particular technical or legal problem that either
209 requires additional evaluation due to novel interpretative or pragmatic considerations. The majority of
210 mixed papers was published under auspices of professional bodies or organisations such as SCL (Axelson
211 2021).

212 However, the gathered literature remains silent on two issues considerable from the perspective
213 of international projects and the overall utility of FDA in settings other than engineering and technology
214 projects. Sources reveal that relative clarity on the matter is exhibited in relation to common law
215 jurisdictions – for example, Australia, England and United States – and selected standard forms of
216 contract (SFC), little is known about these methodologies elsewhere, even in established civil law systems
217 such as Germany or France with developed construction legislation. Furthermore, there is absence of
218 papers on FDA within projects that operate within multiple jurisdictions and are delivered under bespoke
219 contracts. Consequently, it is unknown whether FDA could be applied in such settings, and if so, how it
220 should be executed. Noting the progressing globalisation and interdependent supply chains these
221 elements deserve further elucidation, what was gently communicated in the topical body of knowledge
222 (Tazelaar and Snijders 2010).

223 ## Theme: Reliability

224 Delay calculation continues to cause controversies. Numerous authors posed in the past that
225 FDA and DATs are incapable of producing reliable results, noting their dependence on fallible
226 assumptions and fluid theoretical basis (Yang and Kao 2012). Simultaneously, they are continuously
227 seen as established concepts useful to support the legal and EOT processes, particularly the cause of
228 delay and its effect (Kelly and Franczek 2013). In these settings, credibility of the expert testimony and
229 evidential weight are factors likely to influence the outcomes of the case. Yet, FDA and DATs continue
230 to be riddled with issues. These include reliability problems with identification of concurrent delay,
231 reliance on imperfect CPM schedules, inability to factor float consumption and allocation, assumption of
232 infinite labour and poor control over the 'logic-mode' applied to calculate the overall delay (Arditi and

Pattanakitchamroon 2006). Sometimes, testifying experts present conflicting interpretations of the same scenario. The authors of one older study (Cunningham & Bubshait 1998) signalled that none of the DATs they investigated was truly fit for purpose. Another paper found that the subjectivity of DATs is high and that their adoption is not determined by the best approach, but an approach that supports a particular position (Harris & Scott 2001). Further discontent is associated with the accuracy of DATs due to reliance on flawed-by-design CPM (Galloway 2006). Hence, occasionally, the 'common sense evaluations' of judges, arbitrators, and adjudicators prevail. This was recently apparent in the Supreme Court of New South Wales in *White Constructions Pty Ltd v PBS Holdings Pty Ltd* [2019] NSWSC 1166.

A proportion of data sources identified by the literature review undermine reliability of DATs (see Table 3), although most fail to provide additional insights into how the identified deficiencies could be resolved. The critique is directed at two aspects – theoretical grounding of FDA and technical flaws of the existing DATs. The dominant view is that FDA is a sphere steered by the legal principles related to specific jurisdictions and an area guided by the protocols developed by professional organisations (Tieder 2009, Nash 2002). This corresponds with the sentiment described in the previous points. Authors highlight that despite the presence of this self-regulation there is no uniformity in the application of different DATs and the FDA process remains discretionary or subservient to distinct principles. Critchlow et al. (2006) evidenced, for example, that even within a simple case study disagreements as to the preferred DAT are a norm and even most notable industry experts may not reach consensus on the optimal approach. These arguments surfaced in another sources. Barry (2009) concluded that within the FDA field "there is a spell for every circumstance".

The strongest emphasis in the literature, however, is concerned with the misapplication of FDA. The core criticism relates to the flaws associated with CPM-schedules and their intrinsic unreliability (Adams 2007) such as a wide disregard of schedules due to insufficient planning competence (Arlington, 2004) or too much complexity for project participants (Adams 2007). Nevertheless, CPM is the predominant scheduling method adopted for FDA and DTA according to judicial precedents and industry guidance (see e.g. SCL, 2002; 2017). A by-product of this discussion was the problem of schedule rectification (Winter 2010). Application of DATs on CPM schedules requires in almost all instances additional effort aimed at correcting the integrity of the schedule to ensure uniformity of the schedule

and its completeness (e.g. so that the entire scope is captured, there are no flaws in the logic and so on). This is also a task through which any ambiguities are removed and consistency of results is increased. This problem, however, was not explored in detail what on its own should mandate further research focus on the problem.

The second identified perspective was confined to applied limitations created by the complexity of DATs. Almost all publications made a comprehensive analysis of technical problems pertinent to the methodologies and approaches discussed within. The leading argument against the present DATs was their undisciplined application of DATs (Bhih and Hagazy 2021; Bektas et al. 2021; Bhih and Hagazy 2020; Winter 2010; Nguyen and Ibbs 2008). The factors that lead to the selection of an appropriate DATs were investigated in the past. The identified texts, however, illuminate that core issues attributable to the mis-selection of analytical tools are linked to unclear protocols and lack of step-by-step guidance (Bhih and Hagazy 2021; Plotnik 2010). A number of texts also indicated that DATs utility is limited due to their fragmentary view on delay drivers (Bhih and Hagazy 2021; Bektas et al. 2021; Bhih and Hagazy 2020; Abotaleb and El-Adaway 2018). Similar notions were made in the past.

Theme: Protocol reference

The problematic of delay measurement is self-regulated through judicial practice and protocols (Lowe et al. 2007). The latter form a set of non-binding guidelines established on the canvas of the former, enriched with technical know-how and industry standards imposed by professional organisations from the field (Chappell 2020). Several of the identified sources do not make any reference to protocols that steer FDA and DATs. Those that do confirm acceptance and dominance of the guidance documents published under the auspices of the SCL, AACEI and ASCE. Other papers within this group merely acknowledge the presence of niche standards - whether issued by professional organisations (Bhih and Hegazy 2021, 2020, 2019; Guida and Saco 2019; D'Onofrio 2017), developed uniquely for some jurisdictions, such as the Indian Standard 15883-2, or contained within standard forms of contract used by the World Bank.

The coverage of the three leading protocols in the literature also suggests of preferences, as exemplified in Table 4. The broader scope of application declared by the SCL DDP is reflected in wide references from both, legal and technical papers. The document was intended to provide steer on

289 "common issues that arise on construction contracts" and "means by which parties can resolve" the
290 matters related to extensions of time and delays. The literature confirms that it is used as such reference.
291 The AACEI and ASCE guides, on the other hand, although US-centric, seem to be favoured by authors
292 focused on the mechanics of FDA and DATs. AACEI Recommended Practice 29R-03, proposes "methods
293 of schedule delay analysis, irrespective whether these methods have been deemed acceptable or
294 unacceptable by courts or government boards in various countries around the globe". ASCE's Standard
295 ANSI/ASCE/CI 67-17 - criticised for being not ambitious and 'largely composed of concepts pioneered,
296 proven and standardised by others' (Nagata 2018) - also limits itself to "guiding principles that can be
297 used on construction projects to determine the impact of delays." There are, however, publications that
298 conduct an evaluative assessment from the view point of two or all three guidance documents.

299 In parallel to the above, the review highlights the lack of uniformity within those standards. A
300 common issue highlighted by papers is a lack of definitional coherence between SCL, AACEI and ASCE
301 guides in areas such as concurrency (Axelson 2021, Adams 2007). Bhih and Hagazy (2019) signal
302 conceptual gaps within the protocols. Similarly, pacing delay is covered by AACEI, whereas SCL DDP
303 and ASCE remain silent on this topic. Varying assumptions attached to and steering the guidance
304 documents also create complexities in the sphere of prospective analysis. This has been illuminated by
305 Bhih and Hegazy (2021). Comparable argument was made by Guida and Sacco (2019) who, along the
306 pragmatic presentation of FDA, highlighted a number of internal and external conflicts within different
307 sets of guidelines. Other publications flag reservations about the issue of float ownership (Garner 2007
308 Nguyen 2007), high dependency on CPM schedules (SCL DDP and ASCE) (Hoshino 2003), and
309 complexity (AACEI) (Axelson 2021).

310 Lastly, a few papers criticise the standards for being biased towards specific solutions or being
311 unaligned with the market's expectations (Axelson 2021, Adams 2007). This lack of uniformity in turn
312 is commented in the literature as one of the problems against wider adoption of FDA and DATs, and
313 their acceptance as a fair and equitable methodology to apportion entitlements. Some texts also indirectly
314 suggest that the legalistic nature of the area is unlikely to permit for development of an approach that
315 can be accepted globally noting differences in the local practices and preferences (Cocklin 2013).

316 ## Theme: Schedule determinism

317 A number of authors point that reliance on CPM schedules is insufficient to respond to the
318 uncertainties of major projects and that the in-build determinism can "miss the human dimension of
319 project reality" (Moghayedi 2006). The main scepticism centres around the instability of single-point
320 activity duration estimates when any 'static' schedule is confronted with real-life challenges. Adams
321 (2007) indicates that a schedule that provides the same results in both, forward and backward pass, may,
322 under critical conditions or under resource-constraints, be nullified. Barry (2009) underlines that any
323 prospective analysis, to retain reliability, should correctly simulate the implications of the delay and the
324 future sequences of events. Multiple other authors also raise that determinism violates constraints
325 present in delivery environment, which are unpredictable or uncontrollable, and relies on fallible
326 assumptions – particularly the assumption of unlimited resources – based on imperfect knowledge
327 (Adams 2007).

328 Efforts to mitigate these evident flaws led to development of competitive planning techniques.
329 Programme Evaluation and Review Technique (PERT) was introduced in 1985, a year after CPM was
330 used for the first time, and combated determinism with three-point duration estimated. There are
331 multiple sources commenting on the positives of this approach in the literature. In 1998 the Egan Report
332 endorsed the Last Planner System (LPS) (Adams 2007), which attempted to counter deterministic
333 forecasting with weekly prospective planning reliant on individuals closest to delivery, who were
334 interested in driving 'work rather than production of other plans'. Yet, this proposal, also fails to correctly
335 discount unpredictability. Lastly, Critical Chain Project Management (CCPM) attempted to reduce
336 determinism and contentiousness by way of creating visible 'buffers' available for proactive exploitation
337 use as a contingency in the event of an unexpected (Adams 2007). However, the method has been
338 criticised for driving overestimation, creation of additional time allowances and reliance on resource-
339 levelled schedule, which is rarely optimal (Raz and Dvir 2003, Su et al. 2016). Interestingly, hardly any
340 sources suggest their application in parallel to FDA. Furthermore, none of the papers found propose a
341 DAT based on such planning approaches.

342 Another issue mentioned (but with no reference to CCPM) within the identified literature is the
343 existence of hidden 'time padding' – in various forms – which are applied within CPM schedules to

account for uncertainty or to create buffers that permit to escape blame for late delivery. While these practices are endemic in any major project undertakings and are an industry practice, they often remain undisclosed (Izmailov et al. 2016). They also have a negative impact on health and safety (Moghayedi 2015). This in turn lessens the credibility of schedules in forensic application regardless of whether a prospective or retrospective approach is used. In the prospective analysis, buffers are treated as certain rather than probabilistic elements of the activity duration. In consequence, the actual critical path is distorted. Conversely, when a retrospective view is taken it is assumed that the original duration estimates were accurate and that any alterations within the observed actual duration are the root cause of a delay. Some sources therefore indicate that the industry is going to rely on probabilistic scheduling (Calvey and Winter 2007).

A further problem in this context is limited responsiveness to fluctuating productivity and resources. As for the former, the current approach poorly reflects the likely changes in efficiency of outputs, which are never identical even in a repetitive task (Adams 2007). Despite the fact that this can be partly remedied by 'pessimistic' planning and 'padding', schedules in real environment are subject to unexpected variations. As for the latter, a few sources (Cevikbas and Isik 2021, Adams 2007) note that schedules that are not risk-adjusted cannot be realistic, even when resource-loaded, noting the influence of uncertainty. Table 5 provides a comprehensive overview of the different perspectives on schedule determinism as presented in different literature sources.

Theme: Reported flaws

The flaws of FDA and DATs are factors that raise concerns with regard to their application and existence. Some of these were mentioned in *Theme 3*. While the failures of other solutions may not always render financial losses, improper calculation of delays may lead to significant liabilities. Lastly, the overall purpose of FDA and DATs can always be called into question. If the aim of FDA and DATs is to have evidentiary credibility, flaws of the analyses done for the purpose of calculation of entitlements, make such an effort redundant.

Most papers reported subjectivity as a major flaw of FDA (see Table 6), which seems to have two dimensions. On one hand, some texts indicate that the selection of FDA approach and specific DATs is burdened with discretion and selectivity (an ultimate examples being Axelson 2021 and Critchlow et

al. 2006). Other authors point out that the parties commonly resort to tools, which suit their particular case - either because a given approach allows to exaggerate the entitlement or its implementation, noting for example lack of relevant records to justify calculations or cost to deliver the outputs, is less burdensome (Braimah and Ndekugri 2008, Critchlow et al. 2006). Conversely, it would be irrational to expect a contract administrator or a delay analyst, to apply a sophisticated method ifs a simpler approach is able to satisfy the proof for the intended entitlement.

On the other hand, various authors underline that due to a wide array of available DATs and the multitude of subjective project realities to be analysed via FDA, there isn't a tool that can be unequivocally accepted as correct (Axelson 2021, Marshall 2016, Livengood and Kelly 2014, Yang and Kao 2009, Braimah and Ndekugri 2009). This problem was exemplified by (Critchlow et al. 2006), where one delay case could be convincingly resolved via a series of competitive approaches. Comparable views are contained in multiple other sources, which either depict instances where 'one fits all' approach leads to detestable results or where distinct approaches - supposedly more scientific and directed - fail to add value. There is also considerable case law, which underlines the issues associated with of selection of a particular DAT and that they may create a conflict on its own or lead to further escalation. In *Balfour Beatty Construction Ltd v The Mayor and Burgesses of the London Borough of Lambeth (2002 1 BLR 288)*, for example, an adjudicators decision was challenged on the basis of disagreement as to the relevance and fitness for purpose of the FDA approach employed to establish delay-related entitlements. And *Balfour* is not an isolated incident. The literature further informs that FDA lacks unique answer to the same problem. Furthermore, the outputs of these analyses are driven by other interpretative points, such as the ownership of the float and its apportionment (Keane Caletka 2014, Arditi and Pattanakitchamroon 2006), issues of concurrency (Munvar et al., 2020, Braimah 2013) and pacing delays, and the overall capture of delay drivers.

Further flaws of FDA and DATs are related to reliance on CPM schedules, commonly mandated, contractually or legally. And CPM schedules are known to be imperfect (Galloway 2006). The literature is rich with studies on this problem and conceptual and pragmatic limitations of this scheduling system. It would be thus superficial to list all problems associated with this planning method. From the perspective of FDA and DATs, however, one significant flaw associated with CPM is its significant

400 dependence on the assumption of unlimited resources. The identified sources indicate that this is a
401 fallible presupposition in any practical environment, particularly in any circumstances where deep
402 interdependencies and complexities exist. At the same time, most DATs are executed on schedules which
403 are not resource loaded. The consequence of that is the inability to correctly apportion float in non-
404 critical activities and creation of distorted understanding of the true critical and near-critical paths
405 (Garner 2007, Nguyen 2007). This in turn impacts the accuracy of the analytical outputs of a given DAT
406 since the analysis can be only as valid as the schedule underpinning it.

407 Furthermore, CPM schedules are prone to manipulation or inaccuracies arising out of non-
408 intentional interference. The manipulation may occur due to the willingness to protect the party's
409 contractual position or due to strategic attempts to camouflage delays to avoid or minimise liabilities.
410 Inaccuracies predominantly result from incompetence or practical difficulties with maintaining a large,
411 frequently updated schedule. Not uncommon, particularly on major undertakings, is that CPM schedules
412 are fragmentary or superficially updated noting the effort and time required to maintain diligence and
413 accuracy of records. Some authors underline that to the same category of issues one can also add lack of
414 experience of the parties in creating and managing CPM schedules, lack of awareness with regard to
415 their importance in delay claims and preferential management based on convenience rather than reality
416 (Galloway 2006). Moreover, with the modern speed of delivery, they become obsolete after a single
417 update period. A minor proportion of sources signal that a contributing factor to this drawback is also
418 added by quandaries generated by software packages used to programme projects (Barry 2009). Some
419 experts note that the functionalities of these can be dissimilar and may condition the ways in which work
420 calendars are assigned, how resources are levelled and how the overall logic of the schedule operates.
421 This in turn exerts influence on the way durations, and consequently delays, are calculated.

422 ## Theme: Reported remedies

423 While most of the papers present extensive critiques of FDA and DATs, only a subset offers
424 pragmatic solutions (Table 7).Commonly authors recommend the amendment of the existing methods
425 either by way of minor modifications in the way FDA and DATs are applied or by perfecting some of
426 their unsettling characteristics. These proposals include recommendations or guidance related to
427 accurate capture and calculation of concurrent delays, more optimal or fair allocation of float and more

428 orderly, mature approach to the overall FDA process. Experts also highlight that several of the
429 shortcomings attributable to DATs are linked to competency of delay analysts and the time and budgets
430 constraints affecting the process. There are also papers which postulate amendments to ancillary issues,
431 which due to their influence on the delay measurement process, should attract increased diligence and
432 systematisation. Hence, some of the texts provide guidance on the routines through which DATs should
433 be selected (Perera et al. 2016; Arditi and Pattanakitchamroon 2006) or, based on surveyed preferences,
434 specify considerations that should drive their choice. Other papers approach weaknesses carried by
435 current DATs quite radically and postulate an overhaul by way of replacement of the current methods
436 with surrogate approaches (Hatipkarasulu 2020, Nguyen and Ibbs 2008).

437 There are also publications, which suggest development of support systems aimed at
438 systematisation and simplification of FDA (Fawzy and El-Hadaway 2013, Ackermann and Eden 2005).
439 Most of these proposals are made in response to the complexity of the protocols in use and to the
440 discretion and flexibility allowed by absence of any regulatory framework, and the bias arising out of
441 familiarity with certain DATs or the ease of their application. The proposed remedies include decision-
442 making tools – such as employment of Analytical Hierarchy Process to the selection of optimal DATs in
443 a given scenario (Perera and Sutrisna 2010) – and automation. To this group one can also allocate
444 solutions based on increased visualisation of delays either through adoption or amalgamation of Building
445 Information Modelling (BIM) with other tools, decision flow charts, which could permit for the selection
446 of most appropriate DAT based on the specificity of the problem and its context and utilisation of
447 common software applications.

448 A handful of sources focuses on the remedies postulated by the industry, which coincide with
449 the suggestions made by in other publications on the area and do not offer any pragmatic or conclusive
450 solutions. Most papers in this group make additional clarifications as to the ways in which DATs should
451 be applied, contain explanatory insights as to how particular problems related to the area should be
452 approached or resolved or how one can remove common misconceptions hindering accurate and
453 repeatable analytical outputs. The panacea to the problems of FDA and DATs proposed by other sources
454 are limited to reminders about the importance of investigating the delay types and additional scrutiny.
455 Typically, these recommendations are developed on the bases of survey outcomes or case studies.

Theme: Innovation

This paper considers innovation as 'the generalisation, acceptance and implementation of new ideas, processes, products or services' (West and Anderson 1969). The substantial part of the gathered literature does not offer innovation in the above meaning and does not propose meaningful advancements within FDA and DATs. Papers are summative or descriptive. Only selected papers offer additional value to the problems or constraints, or the discrete aspects of the field itself.

The collated sources (Table 8) propound that innovation in the sphere of FDA takes place at two levels. On the first level, technology-driven approaches are being implemented to both, assist in understanding and quantifying delays, and increase the efficiency of the FDA process. Improvements are predominantly sought in tasks affected by effort pressures, where rapid completion of analytically-demanding or resource-intensive tasks is required to formulate and support claims (Bhih and Hegazy 2021). DATs are demanding tools, which aside from technical know-how rely also on detailed data harvesting and interpretation. The latter is additionally affected by the ever-changing project schedules and travails to obtain, secure and present evidence. Evidential matters in fact can constitute a difficulty on their own due to either fragmentary records or their extensiveness and dispersion, which may demand significant time commitment to build and support a case (Bhih and Hegazy 2020). Furthermore, FDA, is often reliant on CPM-scheduling methods, which themselves are subjected to progressive changes. The outputs of the search, however, did not reveal any specific mentions of innovations that gain an increasing popularity within the project programming sphere. The only two exceptions were the use of 4D-BIM planning, which is seen by many authors as a remedy to the typical shortcoming associated with DATs and FDA (Guévremont and Hammad 2020), and software systems, or their unique applications, enabling more efficient presentation of delay-scenarios and their causes (Fagiar et al. 2019). The gathered literature did not contain any mentions of smart contracts, virtualisation, application of Artificial Intelligence and other novel approaches rapidly making presence in the project management domain.

On the second level, several authors report that FDA and DATs progress somewhat involuntarily due to the dynamism of changes within the environment in which these methodologies operate. Novel systems, streamlined delivery models and increased use of data are now a common sight on projects. Acknowledging the above many sources list innovation as enhancements permitting FDA and DATs to

484 remain aligned or compliant with other recent advancements such as BIM, big data, machine learning
485 algorithms to name a few. Another strong stimulus for advancement is the limited accuracy and
486 credibility of the existing methodologies. Accordingly, a number of papers is focused on studies
487 attempting to increase reliability in which delays are quantified and apportioned by forwarding non-
488 conventional processes or tools. Winter (2010), for example, shown a novel method of correcting the
489 flaws in project schedules prior to application of DATs. Several texts illustrated innovative approaches
490 to quantification of concurrent delays (Bhih and Hegazy 2020), elimination and simplification of
491 schedule interdependencies (Abotaleb and El-Adaway 2018) and enhancement of the conventional FDA
492 with simulative modelling approaches (Fagiar et al. 2019; Avalon and Rider 2009; Eden et al. 2005). The
493 search outputs also led to a number of publications proposing completely novel DATs and FDA processes.
494 Nguyen and Ibbs (2008), for example, proposed an extended method of analysing delays, which in
495 contrast to the standard DATs, captures also the secondary variables such as schedule dynamics, float
496 and resource allocation. Guida and Sacco (2020) introduced an algorithmic method of delay evaluation
497 and allocation. Winter (2013) proposed a 'zero-step schedule', which is a new DAT based on logic
498 changes implemented directly onto the target schedule. Livengood and Kelly (2013) proposed a novel
499 perspective on duration risk and delay measurement.

500 ## Other general observations

501 The data collection and analysis conducted for the review permits also for additional subjective
502 observations, which should constitute areas for further research. These are authors' impressions of the
503 overall area, some of which have additional support in rejected materials as being not directly relevant
504 to the study, but with relevant to the area, or shorter publications, which although valuable did not meet
505 some of the criteria for inclusion. Additional stimulus was also the background undertone of some
506 publications, expressed outside their core substance.

507 The authors note that a substantial part of studies on FDA and DATs, and the related area of
508 project disputes, is general in nature. The remarks and recommendations made within a number of
509 studies are commonly known or replicate study designs of several past studies. This is particularly visible
510 through repetitive papers on project delays or issues encountered during execution. However, only a few
511 of these texts seek to identify true root causes of problems affecting delivery. In the authors' view, further

512 research efforts should be aimed at deeper analysis of the underlying factors driving delays or impeding
513 their measurement. A positive contribution to the current state of knowledge would be gained by
514 developing an interdisciplinary or alternative approaches to the area going beyond current ramifications
515 of the area. At present, FDA and DATs are treated conservatively and any bold and non-standard
516 proposals are rare.

517 Furthermore, there is abundance of descriptive papers, which do not contribute to FDA in ways
518 other than providing a summary of the status quo. Such an approach is unlikely to fuel progress in a
519 domain that is pragmatic, niche and solution-oriented. Moreover, it is not capable of initiating a further
520 discourse, which is not only critical to inject new conceptualisations into the area, fundamentally
521 unchanged since their inception, but also to provide new theoretical perspectives that could lead the
522 practice. Accordingly, in the authors' opinion there is a need for more action and constructive research.
523 Both are not new to project management discipline and both have the potential to lead to findings leading
524 to genuine problem-solving and usable propositions, while appreciating theoretical contributions and
525 their empirical grounding. These were the approaches that manifested during the core industry-led
526 research undertakings such as Latham and Egan Reports.

527 Lastly, more research input is needed on the ways in which the use of FDA and DATs can be
528 made less frequent in supporting disputes. The available literature is predominantly focused on the
529 contentious surrounding in which the delay analysis process is employed. However, still too little is
530 known about pragmatic solutions concentrated on dispute avoidance - in whatever synonymic form it is
531 described – and how delay claims can be mitigated or avoided (Aibinu 2008, Yates and Epstein 2006).
532 The authors note that, by adhering to its operating principles, the DAT can assist in the early
533 identification of drivers of delay, enabling parties to proactively implement mitigation measures and
534 minimise the risk of dispute. Furthermore, a standardised process applied before a dispute crystallises
535 can foster trust and cooperation between project stakeholders, as a reliable DAT output, together with
536 well-documented, evidence-based conclusions, enables parties to negotiate from an informed position.
537 This fosters a collaborative environment where parties are more likely to address issues amicably, leading
538 to fair resolutions and a reduced likelihood of escalation.

539 The prospective literature should therefore start seeking answers not to questions as to what
540 drives the disputes, what are the outcomes of delays or which factors are the core delays drivers. Instead,
541 more work should be done as how to stop delays and contentious dealings from occurring or at least
542 realistically minimise their impacts on projects. While the authors understand that conflicts cannot be
543 completely eradicated, some of the recent major projects delivered globally were delayed and riddled
544 with disputes, despite employing or having internal knowledge that is reflected in the literature. In the
545 current body of knowledge there is only a few papers, which touch upon this topic (Yates and Epstein
546 2006).

547 Conclusions

548 Based on the analysis of the identified sources FDA and DATs are acknowledged in the literature
549 and continue to pose research interest. In parallel, one can observe the growing theoretical and pragmatic
550 importance of the topic, particularly noting the magnitude of EOTs and the increasing application of
551 FDA and DATs in project environment. Almost all papers underline that such scenarios are now a
552 'universal issue' likely to be present within any undertaking in any location. Hence moving towards a
553 deeper understanding of the area and more vibrant research activity in this domain would benefit project
554 practitioners, from both, the legal and engineering angle. Knowing the issues burdening the technicalities
555 of the process may prove useful in constructing and defending claims or contesting the validity of its
556 findings. Conversely, adopting correct delay measurement methodology and cognisance of its limitation
557 may assist in building a strong case or providing less-contestable evidence.

558 On the other hand, the review confirms that the problematic of FDA and DATs is still not
559 exhaustively investigated, leads to ambiguities, and remains reliance on methodologies developed
560 decades ago. The sources identified during this study in significant proportion cover the same approaches
561 and are predominantly descriptive or explanatory. Aside from a few publications, mainly of technical
562 nature, that attempt to propose new perspectives on the problem or new tools, there is no visible impetus
563 to make any forward leaps in the area. Any new proposals are either cautiously voiced or presented as
564 suggestions without the necessary evidential support. What can be noticed in addition to the little
565 effusiveness on such proposals is also their limited frequency. Therefore, to increase the credibility and
566 reliability of FDA and DATs innovative and alternative insights should be encouraged and adopted. To

put it in the words of the Construction Industry Review Committee (Hong Kong) many of the problems faced by in the thematic area of this study "stem from long established processes and practices" and to initiate a progress "a change of culture and mindset" are a must.

The review also unfolded the imbalances between the research outputs on the topic between different jurisdictions, specific delay protocols and project settings. Focusing first on the jurisdictional aspect, the dominance of common law approaches to FDA and DATs in the literature cannot be overlooked. Conversely, there is notable lack of papers outlining the applications of FDA and DATs in jurisdictions without developed jurisprudence on the topic or jurisdictions with specific local project delivery practices. Noting the progressing globalisation of major projects and their likely global impact, this is a gap, which should be addressed. Furthermore, as exemplified in detail above, the application and interpretation of guidance provided by the protocols or practice recommendations is continually uneasy and prone to interpretative perplexities. Diversity of methodological preferences endorsed by independent professional bodies may be excusable. However, the extent of discretion as to the application of core principles noting that FDA and DATs are commonly exploited internationally is not. The absence of comparative application of FDA and DATs across different project categories is unsettling. The review shows that these methodologies remain almost reserved to large construction or engineering projects. However, it is commonly known that delays are not unique phenomena and are likely to affect a project of different sizes and types. Accordingly, applications of delay analysis and its theoretical ramifications should be extended and investigated further in different project environments.

Data Availability Statement

No data, models, or code were generated or used during the study.

This manuscript contains a literature review and the main source of information are secondary documents, which are cited in the References section.

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Endnotes

1. Some examples of notable cases include: (for Australia) Built Qld Pty Ltd v Pro-Invest Hospitality Opportunity (ST) Pty Ltd [2021] QSC 224, White Constructions Pty Ltd v PBS Holdings Pty Ltd [2019] NSWSC 1166, Santos Ltd v Fluor Australia Pty Ltd [2017] QS 153, (for the United Kingdom) Fluor Ltd v Shanghai Zhenhua Heavy Industry Co, Ltd [2018] EWHC 1 (TCC), Walter Lilly & Company Ltd v Mackay and another [2012] EWHC 1773, (for US) Mactec Inc v Bechtel Jacobs Co LLC, 346 F. App'x 59, 78 (6th Cir. 2009), Weaver-Bailey Contractors Inc v United States, 19 C1. Ct. 474 (1990).
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974 Figure Captions

975 • Figure 1. The applied literature review process

976 • Figure 1. Theme extraction and synthesis

977 Table Captions

978 • Table 1. Theme: Project characteristics

979 • Table 2. Theme: Contractual or legal references

980 • Table 3. Theme: Reliability

981 • Table 4. Theme: Protocol reference

982 • Table 5. Theme: Schedule determinism

983 • Table 6. Theme: Reported flaws

984 • Table 7. Theme: Reported remedies

985 • Table 8. Theme: Innovation

Tables

Sources	Project characteristics
Mohammady and Gibson (2020); Abdelhadi (2016); Muhamad et al. (2015); Parry (2015); Hess and Bailey (2015); Abdelhadi (2015); Cocklin (2013); Fenwick Elliot (2012); Pathiranage and Halwatura (2010); Tieder (2009); Abd El-Razek et al. (2008); Lowe et al. (2007); Garner (2007); Abdul-Rahman et al. (2006); Lo et al. (2006);	Projects in a specific geography
Forbes (2016); Fawzy and El-Adaway (2013, 2012); Lo et al. (2006);	Projects in a specific delivery environment
Mehany and Grigg (2016); Larsen et al. (2016)	Public projects
Mohammady and Gibson (2020); Guida and Sacco (2019); Mehany and Grigg (2016); Muhammad (2015); Fawzy and El-Adaway (2013, 2012); Abd El-Razek et al. (2008)	Major projects

Table 1. Theme: Project characteristics

Sources	Contractual or legal references
Lee (2020); Munvar et al. (2020); Coulson (2019); Hess and Bailey (2015); Cocklin (2013); Marrin (2013); Oram (2012); Fenwick Elliot (2012); Tieder (2009); Winter (2009); Garner (2007); Adams (2007); Lowe et al. (2007); Nash (2002)	Focus on specific jurisdiction(s)
Bektas et al. (2021); Axelson (2021); Lee (2020); Coulson (2019); Hess and Bailey (2015); Cocklin (2013); Marrin (2013); Oram (2012); Fenwick Elliot (2012); Winter (2009); Garner (2007); Adams (2007); Lowe et al. (2007); Nash (2002)	Reference to case law
Fawzy et al. (2018); Marshall (2016); Bailey (2014); Winter (2009); Critchlow et al. (2006); Nash (2002)	Reference to contract
Munvar et al. 2020; Ibbs et al. 2011; Fawzy et al. 2008; Garner 2007	Mixed papers (focus on both, legal and technical aspects)

Table 2. Theme: Contractual or legal references

991

Sources	Reliability
Bhih and Hagazy (2021, 2020); Axelson (2021); Bektas et al. (2021); Munvar et al. (2020); Winter (2010); Albinu (2009); Barry (2009); Nguyen and Ibbs (2008)	Undisciplined application
Bhih and Hagazy (2021); Avalon (2016); Livengood and Kelly (2014); Perera and Sudeha (2016); Plotnik (2010); Said (2009); Yang and Kao (2009);	Lack of guidance or use of incorrect approach
Bhih and Hagazy (2021, 2020); Bektas et al. (2021); Abotaleb and El-Adaway (2018); Nagata (2018); Livengood and Ottesen (2010); Pickavance (2008)	Limited applicability
Sanchez et al. (2019); Abdelhadi (2015); Braimah (2013);	Limited data

992 Table 3. Theme: Reliability

993

Sources	Protocol reference
Bhih and Hegazy (2021, 2020, 2019); Axelson (2021); Absul-Malak and Mehdi (2020); Hatipkarasulu (2020); Guida and Sacco (2019); Abotaled and El-Aldaway (2018); Livengood and Kelly (2013), Livengood (2012); Sanders et al. (2012); Sanders (2011); Lowe et al. (2007);	AACEI
Bhih and Hegazy (2021, 2020, 2019); Guida and Sacco (2019)	ASCE
Bhih and Hegazy (2021, 2020, 2019); Axelson (2021); Lee (2020) Coulson (2019); Guida and Sacco (2019); Hess and Bailey (2015); Cocklin (2013); Marrin (2013); Oram (2012); Adams (2007); Lowe et al. (2007); Critchlow et al. (2006); Pickavance (2004); Marrin (2002); Nash (2002)	SCL

994 Table 4. Theme: Protocol reference

995

Sources	Problems related to schedule determinism
Axelson (2021); Cevikbas and Isik (2021); Anthony (2016); Albogamy et al. (2014); Kelly (2010); Adams (2007)	Acknowledgement of duration uncertainty
Bektas et al. (2021); Cevikbas and Isik (2021); Livengood and Kelly (2013); Adams (2007)	Need to apply risk-based scheduling

996 Table 5. Theme: Schedule determinism

997

Sources	Reported flaws
Bhih and Hegazy (2021, 2019); Bektas et al. (2021); Livengood and Kelly (2013); Winter (2010); Nguyen and Ibbs (2008)	Poor accuracy
Bhih and Hegazy (2021); Axelson (2021); Plotnik (2010); Barry (2009); Garner (2007); Nguyen (2007)	Reliance on CPM scheduling
Bhih and Hegazy (2021); Bektas et al. (2021); Abotaleb and El-Adaway (2018); Livengood and Kelly (2013); Braimah (2013); Critchlow et al. (2006);	Low credibility
Adams (2007); Critchlow et al. (2006)	Subjectivity

998 Table 6. Theme: Reported flaws

999

Sources	Reported remedies
Bhih and Hegazy (2021, 2020); Abdul-Malak and Mehdi (2020); Bektas et al. (2021); Hatipkarasulu (2020) Guévremont and Hammad (2020), Said (2009)	Enhancement
Guevremont and Hammad (2020); Bektas and Dickmen (2020) Fagiar et al. (2019); Sanchez et al. (2019), Guida and Sacco (2019); Abotaleb and El-Adaway (2018); Yang and Tsai (2011); Kelly and Carson (2010); Pickavance (2008)	Integration with other method/technique
Fagiar et al. (2019); Mehany and Grigg (2016); Bailey (2014); Fawzy and El-Hadaway (2013), Sanders (2011); Sanders et al. (2011); Ackerman and Eden (2005)	Guidance
Hatipkarasulu (2020); Nguyen and Ibbs (2016)	Alternative methods

1000 Table 7. Theme: Reported remedies

Sources	Innovation
Bhih and Hegazy (2021, 2020); Guida and Sacco (2020); Hatipkarasulu (2020); Livengood (2012); Kelly (2012); Avalon and Rider (2009); Nguyen and Ibbs (2008); Eden et al. (2005)	Process improvement leading to efficiencies
Guevremont and Hamad (2020); Hatipkarasulu (2020); Pickavance 2008)	Technological enhancement
Bektas et al. (2021); Mohammady and Gibson (2020); Fagiar et al. (2019); Winter (2013); Livengood and Kelly (2013); Scott (2009); Nguyen and Ibbs (2008);	Novel method or approach
Abotaleb and El-Adaway (2018); Kelly (2012); Sanders (2011); Plotnik (2010); Pickavance (2008)	Simplification or resolution of a problem

Table 8. Theme: Innovation

1 Some examples of notable cases include: (for Australia) Built Qld Pty Ltd v Pro-Invest Hospitality Opportunity (ST) Pty Ltd [2021] QSC 224, White Constructions Pty Ltd v PBS Holdings Pty Ltd [2019] NSWSC 1166, Santos Ltd v Fluor Australia Pty Ltd [2017] QS 153, (for the United Kingdom) Fluor Ltd v Shanghai Zhenhua Heavy Industry Co, Ltd [2018] EWHC 1 (TCC), Walter Lilly & Company Ltd v Mackay and another [2012] EWHC 1773, (for US) Mactec Inc v Bechtel Jacobs Co LLC, 346 F. App'x 59, 78 (6th Cir. 2009), Weaver-Bailey Contractors Inc v United States, 19 C1. Ct. 474 (1990).

2 The Society of Construction Law

3 The American Society of Civil Engineers

4 Association for the Advancement of Cost Engineering

5 The Royal Institution of Chartered Surveyors

6 The Chartered Institute of Building

7 The Chartered Institution of Civil Engineering Surveyors

8 The Institution of Civil Engineers

9 The Project Management Institute

10 The Association for Project Management