DEVELOPING AN IMPROVED PROCESS MODEL FOR FORENSIC ANALYSIS OF CONSTRUCTION PROJECT DELAYS

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Forensic Delay Analysis (FDA) is an activity of specialists in extracting, presenting evidence to contractual claims, disputes that relate to project delays. The most frequently stated problems with FDA are the time-consuming, costly tasks of information retrieval, confusing multiplicity of delay analysis methods, and difficulty of presenting complex evidence. There is a growing body of literature that recognises the importance of Building Information Modelling (BIM) or Artificial Intelligence (AI) in addressing the above problems; however, their integrated approach within FDA has been under-researched. This project has two primary purposes: a) to explore the impact of an integrated approach within FDA, and b) to propose an improved FDA process model. The approach consists of three stages: i. preparing a descriptive model of the current process, ii. designing an improved, prescriptive model under the guidance of the protocols, and iii. transforming it into a working, normative model based on real-world project workflows and emerging advances. The findings show that introducing an improved process model will supplement, inform existing FDA activities, and enhance the current process.

Keywords: artificial intelligence; BIM; dispute resolution; forensic delay analysis

INTRODUCTION

Yaseen *et al.,* (2020) point out that time predictability in construction projects can be impacted by various factors due to their dynamic, complex, and interdependent nature, factors that may be aggravated by others such as inefficient organisation of human resources (Olaniran *et al.,* 2015) and lack of collaboration among project participants in developing the project programmes (Antunes and Poshdar 2018). Adverse deviations in project timelines (referred to as 'delays') may result in disputes over their extent, causation, impact, and, importantly, responsibility. A study by Arcadis

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Boyacioglu, S E, Greenwood, D, Rogage, K, Gledson, B, Parry, A and Hinds, M (2022) Developing an Improved Process Model for Forensic Analysis of Construction Project Delays *In:* Tutesigensi, A and Neilson, C J (Eds) *Proceedings of the 38th Annual ARCOM Conference,* 5-7 September 2022, Glasgow, UK, Association of Researchers in Construction Management, 431-440.

(2021) shows the global average time to solve a construction dispute as 13.4 months and their global average value is US$54.26 million.

These insights show that the analysis of delays is crucial and has created a specialist niche requirement for consultants to undertake what is now commonly termed Forensic Delay Analysis' (FDA). The expert delay analyst might need to deal with many challenging and time-consuming tasks (Brando *et al.,* 2013). The present study is part of an investigation into the impact of new technologies on the existing FDA process, and it aims to reduce the most frequently stated problems with FDA (i.e., the time-consuming and costly tasks of information retrieval, confusing multiplicity of delay analysis methods, and difficulty of presenting complex evidence) by proposing an improved process model. Previous studies with similar interests support the rationale for an improved FDA process are systematically reviewed with the outcome briefly discussed in the following section. The background to the research and the research design are then presented, followed by the findings of the study, which are discussed. Finally, the conclusions and future ambitions of the study are presented.

LITERATURE REVIEW

The existing literature on FDA is extensive and primarily focuses on different techniques to choose the most appropriate analysis method, in addition to the challenges and shortcomings of these methods. Systematically, a review of both theoretical literature and empirical research, which have aimed to give guidance on some of the common delay analysis methods, has revealed that interest in FDA methods is not recent. Early examples include Arditi and Patel's (1989) proposal for using forensic scheduling concepts in developing an expert system that can prevent and resolve time-related construction disputes, and Alkass and Harris's (1991) integrated computerised system that aided the analysis of claims resulting from delays. In more recent studies, researchers such as Braimah (2013), Parry (2015), and Keane and Caletka (2015) have discussed different types of FDA methods, offering a step-by-step explanation of each, and examining their accuracy, reliability, practicality, and popularity.

The existing literature on delay analysis methods has highlighted the endeavours of many researchers who focused on reducing the complexity and increasing the efficiency of the existing process. A notable example of these endeavours is the proposal of Birgonul *et al.,* (2015) for an integrated approach to mitigate the shortcomings of FDA by setting sets of rules. There is a consensus among researchers (e.g., Chou and Yang 2017, Gibbs 2017, Chen 2020) that every FDA method requires three main steps: (i) the sourcing of evidence, (ii) its analysis, and (iii) its presentation. At each step there might be challenges and shortcomings. Vidogah and Ndekugri (1997) considered the information retrieval step as the most time-consuming and costly of all aspects of claims preparation. Keane and Caletka (2015) pointed out that the analysis stage was complex and confusing because of lack of guidance on standard methodologies and tools. Despite the recent work of the Society of Construction Law (SCL 2017) and the American Association of Cost Engineering (AACE 2011) to mitigate the confusing multiplicities and variabilities of FDA methods, their proper application is still entirely dependent on adequate supporting project information. In addition, the communication of the findings as evidence has been identified by Gibbs *et al.,* (2017) as another major challenge due to the difficulty of presenting complex information to decision makers who are unfamiliar with it. In addressing the above

problems, recent attention has focused on opportunities presented by emerging technical advances.

Two areas, Building Information Modelling (BIM and, more broadly, digitisation of information) and Artificial Intelligence (AI), are of primary interest. The capabilities of BIM in collection, processing and presentation of data have been recognised by various researchers, and their efficacies (and especially the power of 4D BIM - combining a time dimension with the 3D-model) in the existing FDA process have been assessed in their studies. The important examples of the studies which have explored the potential support of BIM in FDA include the following researchers: Al Shami (2018), Valavanoglou *et al.,* (2018), Ali *et al.,* (2020), Marey *et al.,* (2020). Overall, these cases support the view that BIM offers significant support in the retrieval of information, analysis of programmes, and clear representation of the analysis to overcome the challenges and shortcomings of FDA. This view has been particularly supported by Vacanas *et al.,* (2015) from a more specific perspective of BIM by stating that *"*a BIM model analysed in time (4D) can act like a witness because it is a large and important source of record information*"*.

The construct of 4D BIM in FDA was first articulated by Coyne (2008) who performed schedule delay analysis using 4D BIM and presented the outputs of the analysis. Other researchers have supported this initiative and further examined it with several case studies. The notable and recent examples include Valavanoglou *et al.,* (2018), Ali *et al.,* (2020), and Guévremont and Hammad (2021). Another primary interest area of the study is the adoption of AI algorithms and techniques into the existing FDA process. The first serious discussions of the use of AI in the existing FDA process emerged in a study by Riad *et al.,* (1991) in which an AI-driven knowledge-based expert system for time-based claim management was developed. This attempt has been followed by other researchers who explored adoption of AI to overcome the challenges and shortcomings of existing FDA. These include Barnett and Treleaven (2018), Cheng *et al.,* (2019), Catelain (2019), Gondia *et al.,* (2020), Chen (2020), Bagherian-Marandi *et al.,* (2021), Hassan *et al.,* (2021), and Egwim *et al.,* (2021). Although all these studies might remain narrow in focus dealing only with a particular part of the entire FDA process or attempting to overcome specific challenges, their thorough review lays the groundwork for the present study to introduce an improved FDA process model.

METHOD

The research methodology of the present project is designed in three key stages as shown in Figure 1: (i) preparing a descriptive model of the current FDA process, (ii) designing an improved, prescriptive model relating to the work of the SCL (2017) and the AACE (2011), and (iii) transforming it into a working, normative model based on real-world project workflows and emerging advances.

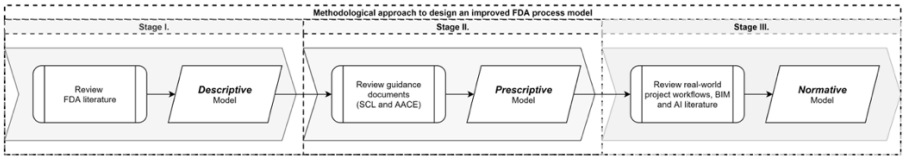

Figure 1: Three-stage methodological approach to design an improved FDA process model

The process symbols at each stage in the methodological approach indicate how the existing FDA process transforms into a normative model through potential

improvements and overlay of potential technologies across the process. As a first step toward achieving this aim, the literature in areas of FDA, BIM, AI (relating to construction) and their contributions was evaluated and taken into consideration at each stage of the methodological approach. In stage I, to identify the existing FDA process and generate a descriptive model, relevant FDA literature was reviewed. This stage primarily benefitted from studies of different delay analysis methods and factors affecting the selection of these methods. In stage II, the guidance documents of the SCL (2017) and the AACE (2011), are used to capture the complexities of the FDA methodologies and to reduce the subjectivity involved in the entire process, consequently, to generate a prescriptive model. In stage III, the process is transformed into a normative model through review of two different sources: a. case-studies from the industry, such as subject expert reports from construction law specific journals, etc., and b. all the relevant BIM and AI literature.

FINDINGS

Using the output of the three-stage process described in the previous section the FDA process model is generated. A simplified version, showing only the main steps of the process, is shown in Figure 2.

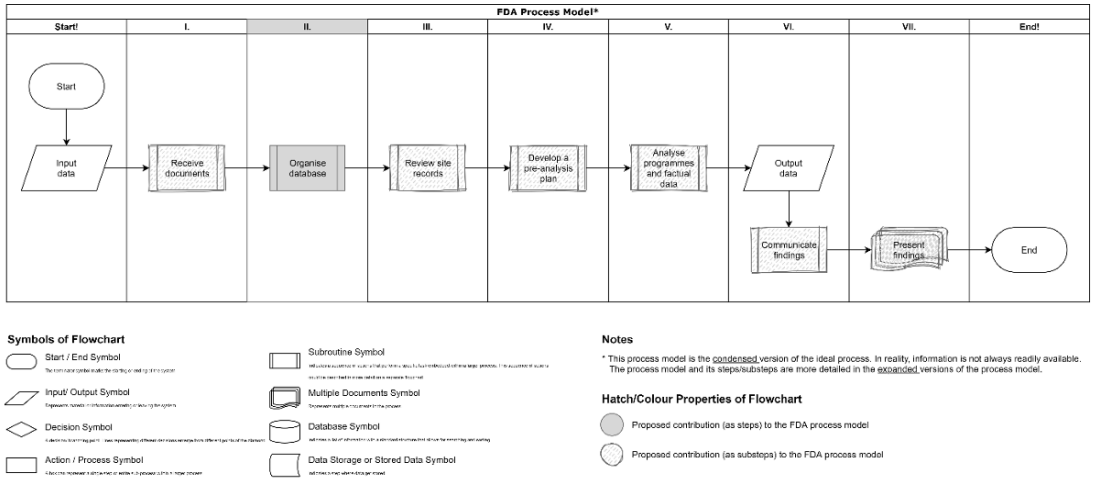

Figure 2: Simplified version of the FDA process model

An expanded version is shown in Figure 3. The sub steps and sub-sub steps are discussed in detail in the following paragraphs.

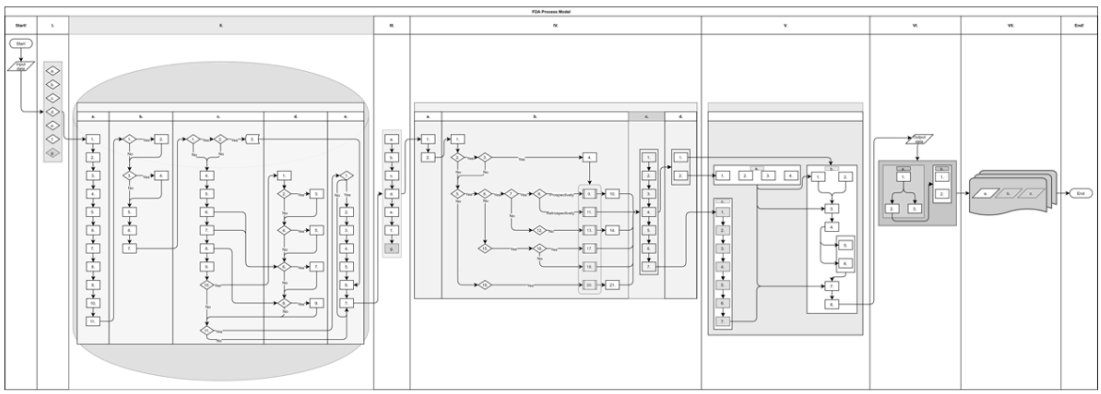

Figure 3: Detailed version of the FDA process model

Receive documents (I.)
The purpose of this step, which largely follows existing practice, is to source information required for the analysis. Its sub steps (a-f) are existing activities: a. contract documents, b. progress records, c. resource records, d. cost records, e. correspondence and administration records, and f. key programmes. The availability of these documents has an impact on the selection of the delay analysis method. In addition to these current activities, a new sub-step, checking the availability of *g.* BIM data is proposed. Despite the recognition, in SCL (2017), of the growing use of BIM and its acceptance as evidence, there is no guidance on how to utilise it and integrate it into the FDA process. This will be covered in the proposed process model.

Organise database (II.)
In this completely new main step, the previously received documents are split into five sub steps (a-e) requiring the entry of: a. 'general' project information, b. 'Delay-specific' project information, c. electronic document management system (EDMS) information and project records, d. programme information, and e. 'other' project information. Each sub step is further broken down to include different types of questions. For example, a. Enter 'general' project information contains eleven questions as sub-sub steps (1-11): 1. What is the project description?, 2. What is the original contract value of the project?, 3. What is the date of instruction to proceed with early work?, 4. What is the date of contract award/ letter of appointment?, 5. What is the date of access to site?, 6. What is the original completion date of the project?, 7. What is the expected date for completion of the project?, 8. What is the project type?, 9. What is the role of the client in the project?, 10. What is the legal role in the tribunal?, and 11. What is the form of contract used for the project and which version?. In sub step b. (Enter 'delay-specific' project information) seven delay-specific questions are introduced as sub-sub steps (1-7): 1. Does the contract specify/mandate a specific delay analysis method?, 2. What is the delay analysis method?, 3. Does the contract language constrain the selection of delay analysis method?, 4. What is the relevant provision in the conditions of contract?, 5. What is the size of the dispute?, 6. What is the budget for the FDA?, and 7. What is the time for the FDA? In sub step c (Enter EDMS information and project records) the aim is to check the availability of an EDMS in the project to expedite the factual data linking process of project records or to do it through categorising questions. Eleven sub-sub steps are introduced (1-11): 1. Does the project have an EDMS?, 2. Does the client share EDMS?, 3. Data stored in EDMS are linked to the database, 4. Which of the resource records are available?, 5. Which of the cost records are available?, 6. Which of the minutes of meetings are available?, 7. Which of the progress reports are available?, 8. Which of the technical records are available?, 9. Which of the other correspondence and administration records are available?, 10. Are the programmes available?, and 11. Does the project have BIM scope? One of the key factors which affects the selection of FDA method is the availability and quality of project programmes. In sub step d (Enter programme information) nine sub-sub steps aim to question these key factors (1-9): 1. What is the scheduling software used in the project?, 2. Is the baseline programme available?, 3. What is the nature of baseline programme?, 4. Is/are the updated programme/s available?, 5. What is the nature of updated programme?, 6. Are the site records available?, 7. What are the types of site records?, 8. Are the as-built data available?, and 9. What are the types of records? In sub step e (Enter 'other' project information) the intention is to collect the BIM

information of the project to link it with the data collected in the previous sub steps. Seven sub-sub steps are introduced (1-7): 1. Are there any BIM models available? 2. For what purposes are these models produced? 3. What are the file formats of BIM models? 4. What is the BIM authoring software of the project? 5. How many people have read/write permissions on BIM models? 6. Link all collected and organised project data with BIM models (if any) to start preparing of Forensic Information Model (FIM). If not, move to the next step, and 7. Database is organised, move to the next step 'review'.

Review site records (III)

The data collected and organised in the previous steps are ready to be reviewed. This step examines these collected data. There are seven sub steps (a-g): a. Review delay-relevant conditions of contract, b. Review progress records, c. Review resource records, d. Review cost records, e. Review correspondence and administration records, f. Review key programmes, and g. Review BIM models. With the greater availability of appropriate digital information collected so far, the learning, inference, and predictive powerful capabilities of AI (such as analysing voluminous, complex, and interdependent data sets of varying structure for deriving useful insights) can be applied to this step to enhance the efficiency of the resulting FDA process.

Develop a pre-analysis plan (IV.)

Both AACE (2011) and SCL (2017) consider the factors which affect the selection of the most appropriate delay analysis method, the main factor being the availability and quality of project information. This main step consists of four sub steps (a-d): a. Identify key issues, b. Select a suitable delay analysis method, c. Prepare BIM models to link with programmes and factual data, and d. Prepare a suitable work plan for analysis.

a. Identify key issues: Different types of sources and factors of delay which are found as outcomes of the literature review studies are split into two sub-sub steps (1-2): 1. Who/ what are the sources of delay? and 2. What are the factors of delays?

b. Select a suitable delay analysis method: All the data which are collected, organised, and reviewed in the previous steps/sub steps compose technical, legal and practical considerations which affect the selection of delay analysis method. Following these considerations, analysts can identify the most appropriate method and justify their decisions by solid reasons. The decision points and actions in this sub step are represented with twenty-one sub-sub steps (1-21): 1. Check the conditions for selection of delay analysis method, 2. Does the reviewed database suggest/ mandate a delay analysis method? (e.g., contractual requirement, etc.), 3. Can the selection of delay analysis method be proved by these constraints?, 4. Choose the identified delay analysis method, 5. Baseline programme available?, 6. Logic-linked baseline programme available?, 7. Updated programmes or progress information with which to update the baseline programme available?, 8. Delay impact is determined?, 9. Select "Time Impact" Analysis, 10. Model a selection of delay events, 11. Select "Time Slice Windows" Analysis, 12. As-built data available?, 13. Select "Impacted As-Planned" Analysis, 14. Model a selection of delay events, 15. As-built data available?, 16. As-built programme available?, 17. Select "Retrospective Longest Path" Analysis, 18. Select "As-Planned vs As-Built" Windows Analysis, 19. Logic-linked as-built programme available?, 20. Select "Collapsed As-Built" Analysis, and 21. Model a selection of delay events.

c. Prepare BIM models to link with programmes and factual data: Following the selection of suitable delay analysis method, to prepare the forensic information model (FIM, i.e., a forensic visual database), previously reviewed BIM models are linked with relevant programmes and factual data in seven sub-sub steps (1-7): 1. Identify required BIM files, 2. Check the file formats and compatibility of the BIM files, 3. Import BIM models into 4D simulation software, 4. Import key programmes into 4D simulation software, 5. Link 4D models with programmes and key issues, 6. Check whether there is work breakdown discrepancy between models and programmes, and 7. Modify models in the authoring software and re-import into 4D simulation software if necessary.

d. Prepare a suitable work plan for analysis: The sub step consists of two sub-sub steps (1-2): 1. Quantitative process (WHEN and WHERE a delay occurred), 2. Qualitative process (WHY the delay occurred).

Analyse programmes and factual data (V.)
The existing analysis process consists of two sub steps (a-b): a. Analyse factual data (qualitatively), b. Analyse programmes (quantitatively). Additionally, the support of FIM is proposed as a new sub step: *c.* Support analysis using Forensic Information Model (FIM). a. Analyse factual data (qualitatively): The qualitative process of factual data analysis includes four sub-sub steps (1-4): 1. Design analysis, 2. Procurement analysis, 3. Construction analysis, and 4. Commissioning analysis. b. Analyse programmes (quantitatively): The quantitative process of programme analysis includes eight sub-sub steps (1-8): 1. As-Built Progress Data, 2. Contemporaneous Programmes, 3. Validate inputs, 4. Construct set of programmes for the delay analysis, 5. Identify and quantify critical delays by period and milestone, 6. Identify the origin of critical delays by period and milestone, 7. Causation Analysis, 8. Conclusions and Opinion. c. Support analysis using FIM: The previously created FIM supports analysis with seven sub-sub steps (1-7): 1. Generate storyboards based on delay-specific scenarios, 2. Create simulations for what-if scenarios, 3. Convert animated model into .fbx file format, 4. Verify the correctness of geometric and non-geometric data in the game engine, 5. Return 4D simulation software, modify data and re-export if necessary, 6. Integrate with 3D mapping APIs to visualise the environment of the project (to observe/ highlight potential effects), and 7. Analyse what-if scenarios visually.

Communicate findings (VI.)
The analysis output is communicated through two sub steps (a-b): a. Generate preparatory files, and b. Generate expert reports. The former is proposed as a new sub step and consists of three sub-sub steps (1-3): 1. Design user interface (UI) of the final output (for media files or interactive application), 2. Export as a media file (e.g., image, video), 3. Export as an interactive application. The latter is an existing substep and it consists of two sub-sub steps (1-2): 1. Prepare presentations, 2. Prepare expert reports.

Present Findings (VII.)
In the existing process the findings are mostly presented as a. Presentations. As addition to this traditional sub step, b. Simulations (e.g., videos, images, etc.) and c. Interactive applications (e.g., smart applications) are proposed as potential presentation methods.

The work presented here involved three stages. In the first, a descriptive ('as-is') model of the FDA process was created based upon current literature and observation

of existing practice. Stage II sought to incorporate the guidance from the SCL (2017) and AACE (2011) documents and offer a systematic decision model for selection between the different delay analysis methods contained in these documents. In the final stage, a normative model was produced that combined the necessary elements of the FDA process, with systematic FDA method selection and opportunities for greater effectiveness and efficiency offered by BIM and AI technologies. The proposed process model can assist FDA in the detection of causes of delays, the retrieval of evidence, and the better presentation of that evidence to support or reject FDA claims. It is suggested that the new process model can reduce time-consuming and costly information retrieval tasks through the implementation of BIM (and more broadly, digitisation of information) and AI.

Furthermore, the systematic approach proposed within the model can reduce confusing multiplicity of delay analysis methods. Finally, the presentational benefits of BIM can assist in presenting complex evidence. It is recommended that those professionals undertaking FDA should use the process model to achieve a better understanding of their workflow and provide a more systematic rationale for presenting their arguments. The implications of the normative model are significant in at least two major respects: (a) in terms of the potential for enhanced analytical capability, and (b) its presentational benefits in support of the existing FDA process. The resulting model can contribute to generating a more systematic approach for FDA methodologies and reducing the subjectivity of analysts: thereby increasing confidence in their arguments.

CONCLUSIONS

The present study describes part of a wider research project which explores the impact of an integrated approach of advances (such as BIM and AI) within FDA and proposes an improved FDA process model by incorporating these advances to minimize the challenges of the existing process. In line with this purpose, previous studies (including relevant publications in the literature, protocols and recommended practices from the international associations, case studies from construction law specific journals, etc.) in the subject areas of FDA, BIM, and AI (relating to construction) were thoroughly reviewed.

The review has identified that the existing methodologies lack a complete process model (integrated with the emerging advances) which aims to guide subject experts (e.g., delay analysts, etc.); therefore, the subjective approach analysis currently applied to the FDA process remains a problem. To address the issue regarding an incomplete process model, using a three-stage methodological approach, a descriptive model was generated, then, it was transformed into initially a prescriptive, eventually a normative model. As an output of the effort, an improved FDA process model, which can assist in the detection of causes of delays, finding and presenting evidence to support claims is proposed. It is proposed that the new process model can further support the idea of generating a systematic approach for FDA methodologies and reduce the subjectivity of the analysis process by underpinning the reasons of the selection of the methodologies.

The previous literature review study from an earlier stage in this project and the present study lay the groundwork for future stages of the research to explore and experiment with the integration of the advances in the FDA process to enhance its efficiency and effectiveness of its outputs and reduce its subjectivity. The initial findings show encouraging prospects for the improved FDA process model by

incorporating the advances. Further work is needed to establish the viability of the improvements on real-world project workflows and to collect expert feedback to assess their effectiveness in presenting evidence in claims and disputes.

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