# Specifying the information requirements for Forensic Delay Analysis

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## Abstract

Delays and late completion are familiar features of construction projects and are commonly accompanied by contractual claims and counter-claims as the parties concerned seek to protect their positions and mitigate their losses. In doing so, the organisations involved will often have recourse to consultants who specialise in the field of Forensic Delay Analysis (FDA). The FDA specialists then perform the analysis, and if required to, act as experts in presenting the results to dispute resolution or judicial hearings. The use of computer scheduling software, has for some time, been integral to the work of FD analysts. Despite this, typical FDA workflows have been heavily reliant upon imperfect, unstructured, manual information that requires a considerable time to collect and validate. This paper reports part of a project to develop a data-driven digital system for optimising the workflows and outputs a company already active in the field of FDA. It explores how FDA practitioners might exploit the growing availability of structured information within building information models to improve the efficiency and effectiveness of their work. The project comprised three stages: (I) to understand the workflows, technologies and operating context of the company; (II) to design a data-driven digital system for optimising workflows; and (III) to validate and refine that tool for market-testing. The results of Stages II and III will be made available in future publications. In Stage I of the study two main phases in the FDA process were identified, each with sub-phases. These begin with the FD analyst first establishing *when* and *where* a delay has occurred and quantifying its impact on completion. Next, the analyst must seek to determine *why* the delay occurred. This involves extensive audits of multiple information sources generated throughout the construction process. These sources typically exist in a variety of formats, included manually-generated material, and can be sparse, irregular, incomplete and sometimes contradictory. As a result, their extraction and validation take up a considerable part of the whole FDA process. The next stage involves the exercise of judgment as to which delay assessment methodology might be applicable to the information available and the current trends in judicial decisions. Finally, there is the production of a detailed report to the client and a presentation of the findings. The development of data-driven digital systems in FDA offers the prospect of enhanced visualization (hence, credibility) of these presentations. It also evokes the possibility of automating some of the time-consuming tasks associated with the process of claims preparation involving both quantitative and qualitative data that can be then subjected to numerical and non-numerical analysis. The requisite technologies are already available and could be integrated into a fully interoperable digitally-driven FDA system. However, the value of such a system would rely upon the collection and retrieval of adequate and credible information in a form that can be processed digitally: a situation that is currently rare. Following guidance such as that provided by the PAS documentation, there is an increased awareness amongst users of digital project models of their information requirements and how to specify them. A similar understanding and specification of the information requirements concerning the project delivery process would provide a basis for a data-driven progress monitoring system which could also, should the need arise, facilitate the extraction of evidence for the FDA process.

**Keywords:** Dispute resolution, forensic delay analysis, information requirements.

# 1. Introduction

Construction projects have been characterised as long-term, dynamic and complex (see, for example: Hillebrandt, 2000; Hughes, et al., 2006; Kärnä, et al, 2009) all of which, according Kraiem and Diekmann (1987) may contribute to their notorious tendency to suffer from delays. The problem of what McKinsey and Company (2017) call the poor 'schedule reliability' of construction projects appears historically ever-present and globally widespread (see, for example, Chan and Kumaraswamy, 1996; National Audit Office, 2001; CIOB, 2008; Gledson and Greenwood, 2017). Furthermore, 'completion on time', alongside 'completion under budget and according to specifications' is part of the so-called 'iron triangle' of project success criteria (Ogunlana, 2010). Over twenty years ago, Alkass *et al.* (1995: 335) declared that "delays are the most common and costly problem encountered on construction projects", while more contemporary authors (Zarei *et al.,* 2018) consider that delay analysis and management remain "critical tasks". This paper concerns the former (i.e. the analysis of delays) rather than the latter (their management). The immediate losses that result from project delays can be considerable and can have an impact upon all parties concerned: for example, the loss of beneficial use by the buyer (normally referred to in the UK as the Employer) and prolongation costs as well as opportunity costs, on the part of the project supply chain. Construction contracts apportion the risks of delay through mechanisms such as liquidated and ascertained damages, extensions of time, and other 'compensation' clauses. Explanations and analyses of these contractual mechanisms are available in the related literature; examples being the advisory protocols issued by professional bodies such as the UK Society of Construction Law (SCL, 2002; 2017) and the American Association of Cost Engineering (AACE, 2011) or in academic publications (for example, Kraiem and Diekmann, 1987; Wickwire, *et al*., 1991; Alkass, *et al.,* 1996; Scott, *et al.,* 2004; Arditi and Pattanakitchamroon, 2006; Braimah, 2013). However, contractual regimes cannot always cope effectively and amicably with the details, complexities and uncertainties of individual cases and there may be recourse to some form of dispute resolution (Clay and Dennys, 2018). A recent report (Arcadis, 2018) has estimated the global average value of construction disputes to be around US$43.4 million. With such sums at stake, the parties seek the services lawyers and consultants: one such service being Forensic Delay Analysis.

# 2. Forensic delay analysis

Forensic Delay Analysis (FDA) is a discipline that specialises in the analysis and presentation of delay claims. Typical FDA procedures are systematically described by such authors as Carmichael and Murray (2006), Braimah (2013) and Parry (2015): later in this article reference will be made to these and how they may change with the increasing digitalisation of the construction industry. The role of the FDA consultant is to produce convincing arguments that support or resist a claim on the grounds of *responsibility, causality*, and *quantum*. The allocation of responsibility may involve differences of opinion over how a particular event can be categorised in terms of contractual obligation. The first point of reference for establishing this will be the contractual agreement between the parties. The basic mechanisms provided by contracts have been mentioned above, as were their shortcomings in coping with the complexities and uncertainties of individual cases. Amongst these are the familiar complications over 'concurrent delays' (see, for example, Kraiem and Diekmann, 1987) and how to treat the 'float' or 'slack' that may be inherent within a contractor's estimated activity durations (see, for example, Householder and Rutland, 1990). Secondly, aside from the burden of responsibility, is the question of whether an alleged delay event has in fact impacted upon the completion of the project (i.e. the question of causality) and if so, how much impact it has had (i.e. the quantum). Establishing these matters will require access to various project records. In analysing these, there may be problems of: (i) selecting an appropriate delay analysis method to demonstrate both causality and impact; and (ii) the availability and accuracy of relevant project data; about the event, the project itself and the supposed impact of one upon the other.

The first of these differences is briefly discussed in the next section. However, it the second that is the main concern of this paper and considered in subsequent sections.

## 2.1 Delay analysis methods

There are several commonly-recognised delay analysis methods. It is outside the scope of this paper to discuss these methods in detail: this is done extensively in the aforementioned SCL Protocols (SCL, 2002; 2017) and AACE International Recommended Practice (AACE, 2011) as well as in academic literature (for example, by Braimah, 2013; Parry, 2015; and Keane and Caletka, 2015). Opinions as to what might be considered an 'appropriate delay analysis method' may differ with individual cases. The criteria may be subjective; for example, based upon familiarity with a particular method, or that the outcome of applying one particular method suits a party's interests more than the other's. External circumstances, such as the preferences expressed by the courts in Common Law jurisdictions, may sway the decision as to which approach is selected. More importantly, each delay analysis method requires specific information, such as reliable programmes (initial and updated) and as-built records, and their availability or non-availability may present a reason for choosing one method over another. The Society of Construction Law (SCL) first issued its Delay and Disruption Protocol in 2002, with a second edition in 2017. This was followed in 2011 by the AACE's International Recommended Practice on 'Forensic Schedule Analysis'. The authors of these documents are careful not to give a blanket endorsement of their recommendations nor do they propose that the documents should be incorporated as contractually binding agreements. Thus, the AACE Recommended Practice "is not intended to override contract provisions regarding schedule analysis methods or other mutual agreement by the parties to a contract regarding the same" (AACE, 2011: 11) whilst the SCL Protocol states that "is not intended that the Protocol should be a contract document" (SCL, 2017:1). In answer to the first of the two questions posed earlier (i.e. regarding the choice of an appropriate delay analysis method) the adoption of documents such as the SCL Protocol or the AACE Recommended Practice (pre-agreed or otherwise) for the management of delay in projects may reduce the likelihood of later arguments. There remains the second question; that of the availability and accuracy of the necessary relevant project data.

## 2.2 The availability and quality of relevant project data

Previous studies of the FDA process have revealed that it typically involves two phases: analysis and presentation. The analysis phase requires both quantitative and qualitative data. Carmichael and Murray (2006: 1008) refer to the "vast number of documents to be reviewed and people to be interviewed" and Alkass et al. (1995) estimated that this searching and organizing of information accounts for around 70 per cent of the effort in preparing a case. It appears that much of this effort is due to the inadequacy of available information. An observation by Major and Ranson (1980) was that incomplete and inadequate information represented "a common and substantial area of failure in site and head office management". This is a situation that was found to persist in more recent times, according to Carmichael and Murray (2006) and Craig and Sommerville (2007). Improved record collection and management systems have been proposed by Scott (1990) and by Carmichael and Murray (2006). This information is the essential data for comparisons to be made between how and when work what was planned and how and when it was ultimately carried out. Any of the aforementioned FDA methodologies could be rejected if its input data are flawed. In fact, it was the recognition of this that accounts for a major difference between the 2002 and 2017 editions of the SCL Protocol in determining a 'preferred method' as in the latter there is discussion of the advantages and disadvantages of analysis methods in relation to their data requirements and the quality and availability of those data.

## 2.3 The adoption of information technology for FDA

Parts of the FDA process are already heavily reliant upon computer software. The critical path method (CPM) and related techniques have some time ago become the norm for planning and scheduling construction activities (Wickwire *et al*., 1991). Presentations using CPM software have appeared in dispute resolution forums from the early 1970s and are now a widely accepted method for illustrating delay claims. Over the past twenty years there have been proposals for 'expert systems' that

link 'project management' (i.e. scheduling) software to external databases for manipulating project data for the purposes of delay analysis and assessment (for an early example, see Alkass *et al*., 1995). However, there is still little, or no evidence of such systems being successfully adopted for the crucial tasks of information collection, retrieval and analysis., in fact, the FDA specialism is described by Gibbs *et al.* (2013: 49) as having "benefited the least from … developments in information technology". The increasing adoption of Building Information Modelling (BIM) presents a further opportunity to enhance the FDA process by enabling the capture of relevant data and its later retrieval for analysis. Compared to that traditionally obtainable, the information within a digital model is potentially, according to Crotty (2011), not only more extensive, but of higher quality. It also creates the possibility of interfaces with other digital systems such as the real-time capture of field operations data for schedule monitoring (see, e.g. Taneja et al., 2011 and Zaher et al., 2018) thereby facilitating better record keeping practices and on-going contract administration. Furthermore, the combination of 3D models with a visualised and synchronised schedule, known colloquially as '4D', has become a widely available technology for planning and construction (see, e.g. Gledson and Greenwood, 2017). This digital enhancement of construction scheduling presents great opportunities to improve, and even resolve, some of the issues surrounding the availability and quality of information for FDA. Thus, in the case of FDA the effective deployment of such digital technology could not only improve the visualisation, understanding and credibility of the arguments presented in support of a case, but could also potentially facilitate the retrieval of information required by FDA analysts at any point throughout the project. This last advantage is now examined further.

### 2.4 Information in BIM-based projects: problems revealed

Despite Crotty's optimistic forecast of more extensive and higher quality interoperable information within a digital model, there remain inherent problems. The first concerns the availability of suitable data with which to populate the model. This may relate to uncertainty as to what information to specify, what to capture, or how to manage or structure it; or there may be a proprietorial reluctance to provide the information. The opposite scenario is one of information overload and chaos (see, for example, Gangatheepan, *et al.,* 2018: 260) as without its proper management the high volume of information possible could be counterproductive. Since 2011, when the use of BIM was mandated in the UK, publications such as PAS 1192-2:2013 (BSI, 2013) ('internationalised' and replaced by IS 19650) have advised on how to specify the information requirements for a digital model. In particular, the 'Employers Information Requirements' are defined as "the documented expectations of facility owners/commissioners for sharable structured information" (BSI, 2013: 51). Thus, with an increased understanding and uptake of these documents, owners and/or commissioners of built assets should be able to specify clearly the information needed at any time within a digital model. The question is whether any increased understanding of information requirements will assist the FDA process.

## 3. Methodology: an empirical study of FDA information needs

The study upon which this paper is based was a project to examine the prospect of exploiting digital technology to develop a data-driven digital system for improving the workflows of an organisation already active in FDA. This required a deep understanding of those workflows before attempting to design automated (or semi-automated) solution with more efficient functionalities that could be prototype-tested, validated and eventually commercialised. The project involved three research stages, namely:

Stage I: Situational Awareness: understanding the context of the company and its current workflows, its current technologies, as well as its outputs, services, and customers;

Stage II: Discovery and Decisions: the integration of digital tools and techniques and production of an initial capability model with performance criteria;

Stage III: Implementation and Validation of new technology-enhanced workflows leading to new business capability that can be market-tested and validated with appropriate refinements.

Different research and data collection methods were required for each of the stages. For Stage I (Situational Awareness) the research method was a combination of (a) desk study and (b) ethnography. The data collection method was, for (a) subject literature and IT product reviews, and for (b) by observation, unstructured interviews of FD analysts working within the host organisation, as well as access to archival material in order to develop an understanding of FDA workflows and outputs. Stage II required iterative technical development, including the identification (or in some cases, creation), testing, adaptation and modification of candidate software solutions and evaluation of their required functionalities. This required the creation of computer code, primarily to create interoperability between the various digital workflow solutions. Stage III, which concerned testing and refining the prototype, required focus-group evaluation and further development activities, respectively.

# 4. Findings: FDA information needs

The research problem addressed in this paper concerns the adequacy of available information for the envisaged data-driven digital system for supporting FDA. The prospects of obtaining such information, as already argued, may well be enhanced in a future digitalized project environment, but a prerequisite is the understanding of the information needs and how they can be met. In order to examine this further, an investigation was made of the current workflows within the host organisation, its use of software to support these, and its information flows and requirements. The section concludes with the potential for, and challenges to the introduction of a more automated data-driven system of FDA within the organisation.

## 4.1 Current FDA workflows

Based on the observations from Stage I of the project, Figure 1 shows a simplified FDA work-flow involving two phases. The first phase, *Analysis*, is to determine when and why delays happened and what were the effects. The second, *Presentation*, deals with how findings are to be demonstrated.

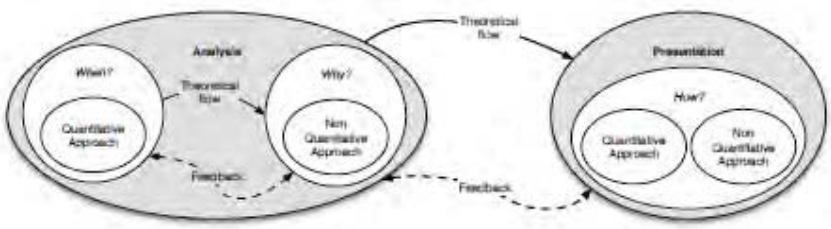


*Figure 1: Forensic Delay Analysis simplified work-flow*

The *Analysis Phase*, in turn comprises two interdependent and often simultaneous process: *Extraction* and *Examination* (*sc.* of information).

The *Extraction* process deals with ordering, tabulation and systematically cataloguing data that has been made available. During this process various validations are performed on the data, which may require significant clarification, rectification, or reconstruction.

The *Examination* process involves the analysis of extracted (validated) data, some of which can be accomplished using a quantitative approach (e.g. the numerical analysis of base-line *versus* actual schedules). The output of this phase is usually a detailed report (comprising narrative, graphs and numbers) and presentation slides. The situation is much as that described by earlier studies (e.g. Alkass *et al.*, 1995; Carmichael and Murray, 2006) save for the now-extensive use of computer software throughout the process. This includes common office software (Microsoft Office, Libre Office, iWork,

Google Docs, etc.), computer spreadsheets (Excel, Calc, Numbers, Google Sheets etc.). However, these software applications are invariably used to gather data rather than to perform meaningful analysis. For example, spreadsheets are used to store and retrieve data (including graphical export mode) rather than for calculation or statistical purposes; extensive human intervention is still required for purposes of inspection, comparison and pattern recognition.

The *Presentation Phase* is supported by the use of presentation software (PowerPoint, Impress, Pages, Google Slides, etc.) and the Project Management software programs that have the strongest user base in the construction industry (i.e. Oracle Primavera P6, Asta Powerproject and Microsoft Project) thus allowing for the FD analyst to work in the same schedule presentation format as the data received.

## 4.2 Information flows and requirements

The flow diagram shown in Figure 2 is an overview on how data are exchanged between an FD analyst, the client (i.e. that has commissioned the FDA) and ultimately, the tribunal (or equivalent third-party adjudicator). The current extraction process relies heavily on the dissection of (mostly) unstructured electronic data and paper-based files, augmented by oral explanations obtained from interviewing key participants. The data involved in the *extraction* process can be both qualitative and quantitative, and although the *examination* process may at first appear to rely upon predominantly numerical data (e.g. to enable the comparison of base-line *versus* actual schedules) in reality the questions of *why* a delay happened and *what* were its effects are primarily answered by a more non-quantitative approach in which analysts try to create a logical network of causes and effect usually by performing examination, observation and deduction.

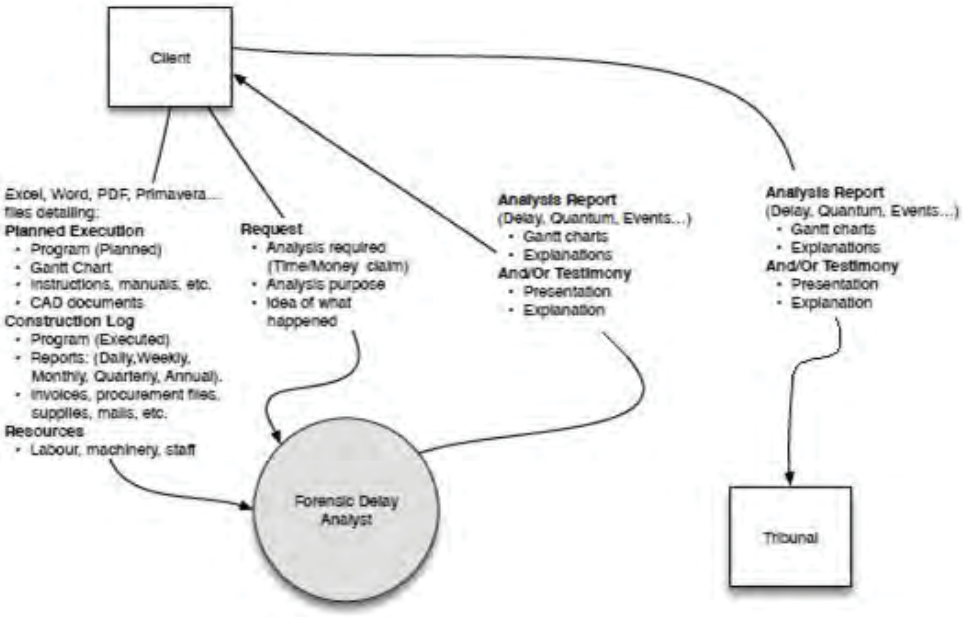


*Figure 2: the flow of information in the FDA process*

The *Examination* process then involves the analysis of extracted (validated) data, which, as already noted can be both quantitative and qualitative in nature. The output of this phase is usually a detailed report (comprising narrative, graphs and numbers) and presentation slides. There was an apparent anomaly in the non- use of available special software products that are targeted towards FDA. These include products that can automatically investigate variances between two or more schedules, (including those on different native platforms) such as Acumen Fuse, Change Inspector, Steelray Project Analyzer, and Schedule Analyzer. The creator of one of the aforementioned products claims that a variance analysis of schedules that would conventionally take 2-4 hours can be completed in under one minute (Deltek, 2017). However, the reluctance to use such specialist applications is likely to be because their

utility is reduced or nullified if, as noted earlier, appropriate data are unavailable, or they are incomplete, unstructured, and unreadable. The opportunities to use analysis software is not limited to purely quantitative data. Stage I investigations revealed that much of the current information gathering for FDA was essentially qualitative, with data comprising unstructured, manually-generated information requiring a considerable amount of time to collect and validate. However, if such information could be digitally captured, ideally at source, then it can be more efficiently extracted. It should be noted that other disciplines, including social sciences (Fielding and Raymond, 1998), crime-scene investigation (Levy, 2015) or marketing (Rettie *et al.,* 2008) have information extraction procedures that are in essence similar to those performed by FDA and have developed Computer Assisted Qualitative Data Analysis Software (CAQDAS) to analyse large quantities of data contained in speeches, police declarations, interviews, and surveys. It is evident from Figure 2 (above) that the typical information interchanges in FDA could be readily accommodated by a BIM Common Data Environment (CDE). Field progress data could be added to the project model, including qualitative data that were digitally captured by use of a CAQDAS system. The capture of the relevant information within a project model could thus represent a dramatic improvement on the efficiency of the FDA *extraction* process. And finally, the digital nature of extracted information would permit the use of specialist software which could be integrated into a system for analysing both quantitative and qualitative data during the FDA *examination* process.

# 5. Conclusions

The increased availability of structured, machine-readable project data prompted by the growing adoption of BIM could have a constructive effect on the resolution of construction claims and disputes. Uncertainty about design and construction information is a frequent component in claims causation: this could be significantly reduced when supply chain organisations have access to the digital project model. One of the main problems for the FD analyst, indeed for all parties involved in claims and dispute resolution, is the availability and authenticity of records. Digitalisation of the contract administration process could enable automated or semi-automated digital record-keeping which in turn would provide structured, verifiable data upon which to base the resolution of claims and disputes. In terms of data analysis, a hybrid approach could accommodate both quantitative and qualitative data extraction and examination. These findings suggest that, subject to the availability of the requisite data in structured, digital form, it is indeed feasible for FDA workflows to be more efficiently and effectively performed. There is, however, a major challenge. The prospect of a data-driven digital process depends upon a quality and rigour of record-keeping which, by current evidence, cannot be relied upon. A possible solution lies in the PAS-1192 documentation described earlier and thanks to which, owners, designers and constructors are becoming more familiar with what information may be required in their digital project models in order to best exploit the capabilities of BIM. Thus, a set of 'progress information requirements', agreed at the contract stage could stipulate what data was to be captured, when, by whom, and in what format. It may be imagined that optimism bias (i.e. the fact that, despite evidence to the contrary, project participants would not admit to the likelihood of a dispute at the outset) would deter the use of such an agreement. However, there are other, more immediate benefits. Ready access to verifiable data should enable claims to be minimized; or when they arose, to be settled commercially (and even settled automatically using distributed ledger technology) rather than progressing to formal third-party proceedings, such as arbitration. Where disputes did occur, the availability to the FD analyst of structured digital data would greatly reduce the time and resource required for its analysis, and the presentation of the complex issues that are involved in a claim could be facilitated by the appropriate and agreed management and analysis of the digital records. The digitalisation of the dispute resolution process with appropriate feedback supported by artificial intelligence and machine learning would perhaps ultimately change the role of the FD analyst, from that of a contentious retrospective claims consultant, to pre-contract delay risk analyst.

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# References


Alkass, S., Mazerolle, M., Tribaldos, E. & Harris, F. (1995). Computer aided construction delay analysis and claims preparation. Construction Management and Economics, 13: 335–52.

Alkass, S., Mazerolle, M., & Harris, F. (1996). Construction delay analysis techniques. Construction Management & Economics. 14(5), 375-394.

AACE (American Association of Cost Engineering) (2011). International Recommended Practice no. 29r-03, 'Forensic Schedule Analysis'. April 2011. [Online]. Available at: https://web.aacei.org/docs/default-source/toc/toc_29r-03.pdf?sfvrsn=4 .[Accessed 26-04-2109].

Arcadis Contract Solutions (2018) Global Construction Disputes Report. Available at: file:///D:/00%20PUBLICATIONS%20IN%20PREPARATION/CIB%20World%20HK/Arcadis%20Global%20Construction%20Disputes%202018.pdf . [Accessed 04-02-2019]

Arditi, D., & Pattanakitchamroon, T. (2006). Selecting a delay analysis method in resolving construction claims. International Journal of project management, 24(2), 145-155.

Braimah, N. (2013). Understanding construction delay analysis and the role of preconstruction programming. Journal of Management in Engineering, 30(5), 04014023.

Broome, J.C. & Hayes, R.W. (1997). A comparison of the clarity of traditional construction contracts and of the New Engineering Contract. International Journal of Project Management Vol. 15, No. 4, pp. 255-261.

BSI (2013) PAS 1192-2:2013 Specification for information management for the capital/delivery phase of construction projects using building information modelling. British Standards Institute, London.

Carmichael, S., & Murray, M. (2006). Record keeping for contemporaneous delay analysis: A model for effective event management. Construction Management and Economics, 24(10), 1007-1018.

Chan, D. W., & Kumaraswamy, M. M. (1996). An evaluation of construction time performance in the building industry. Building and Environment, 31(6), 569-578.

CIOB (2008) Managing the Risk of Delayed Completion in the 21st Century, Chartered Institute of Building, Ascot, UK.

Clay, R., & Dennys, N. (2018) Hudson's Building and Engineering Contracts (13th ed.). London: Sweet & Maxwell (U.K.).

Craig, N. & Sommerville, J. (2007) Records management and information processing on construction sites using digital, pen and paper. Records Management Journal, vol. 17, no. 3, pp. 201–215.

Crotty, R. (2011) The Impact of Building Information Modelling: Transforming Construction. New York, Routledge.

Deltek (2017) Deltek Acumen Fuse product sheet. Online PDF. Available at: https://www.deltek.com/en/products/project-and-portfolio-

management/acumen/modules/acumen-fuse 5 [Accessed 07-05-2019].

Fielding, N. & Raymond, L. (1998) Computer Analysis and Qualitative Research. Sage Publications,

Gangatheepan, S., Thurairajah, N., & Lees, M. (2018). From information transmission to engagement in practice: A study on BIM enabled construction projects. In: ARCOM 2018: 34th Annual Conference - A Productive Relationship: Balancing Fragmentation and Integration, 3rd - 5th September 2018, Belfast, UK.

Gledson, B.J., and Greenwood, D.J. (2017) The adoption of 4D BIM in the UK construction industry: an innovation diffusion approach. Engineering, Construction and Architectural Management, 24 (6), 950-967.

Gibbs, D.J., Emmitt, S., Ruikar, K., and Lord, W. (2013). An investigation into whether building information modelling (BIM) can assist with construction delay claims. International Journal of 3-D Information Modeling (IJ3DIM), 2(1), 45-52.

Hillebrandt, P. M. (2000). Economic theory and the construction industry. London: Macmillan.

Householder, J. L., & Rutland, H. E. (1990). Who owns float? Journal of Construction Engineering and Management, 116(1), 130-133.

Hughes, W., Hillebrandt, P. M., Greenwood, D., & Kwawu, W. (2006). Procurement in the construction industry: the impact and cost of alternative market and supply processes. Routledge.

Keane, P.J. and Caletka, A.F. (2015) Delay analysis in construction contracts. John Wiley & Sons.

Kärnä, S., Sorvala, V. M., & Junnonen, J. M. (2009). Classifying and clustering construction projects by customer satisfaction. Facilities, 27(9/10), 387-398.

Kraiem, Z.M., & Diekmann, J.E. (1987) Concurrent delays in construction projects. Journal of Construction Engineering and Management 113 (4): 591-602.

Levy, B. (2015) The need for informatics to support forensic pathology and death investigation. Journal of Pathology Informatics, 6.

McKinsey & Company (2017) reinventing Construction: a route to higher productivity. Available at: https://www.mckinsey.com/~/media/mckinsey/industries/capital%20projects%20and%20infrastructure/our%20insights/reinventing%20construction%20through%20a%20productivity%20revolution/mgi-reinventing-construction-executive-summary.ashx.[Accessed 03-02-2019]

NAO (National Audit Office) (2001) Modernising Construction. Available at: https://www.nao.org.uk/wp-content/uploads/2001/01/000187.pdf. [Accessed 03-02-2019].

NBS (National Building Specification) (2016) 'What is Building Information Modelling?' Available at: www.thenbs.com/knowledge/what-is-building-information-modelling-bim.[Accessed 07-02-2019].

Ogunlana, S. O. (2010). Beyond the 'iron triangle': Stakeholder perception of key performance indicators (KPIs) for large-scale public sector development projects. International journal of project management, 28(3), 228-236.

Parry, A. (2015) The improvement of delay analysis in the UK construction industry. Unpublished PhD thesis. Available at: http://nrl.northumbria.ac.uk/27294/ 2. [Accessed: 06-02-2019].

Rettie, R., Robinson, H., Radke, A. and Ye, X. (2008). Caqdas: a supplementary tool for qualitative market research. Qualitative Market Research: An International Journal, 11 (1): 76–88.

SCL (Society of Construction Law) (2002) Delay and Disruption Protocol, 1st Edition. Society of Construction Law. Hinckley, Leicestershire, UK.

SCL (Society of Construction Law) (2017) Delay and Disruption Protocol, 2nd Edition. Society of Construction Law. Hinckley, Leicestershire, UK.

Scott, S; Harris, R; and Greenwood, D.J. (2004). Assessing the New United Kingdom Protocol for Dealing with Delay and Disruption. American Society of Civil Engineers, Journal of Professional Issues in Engineering Education and Practice, 130 (1) 50-59.

Taneja, S., Akinci, B., Garrett, J.H., P.E., Soibelman, L., Ergen, E., Pradhan, A., Tang, P., Berges, M., Atasoy, G., Liu, X., Shahandashti, M.S., & Anil, E.B. (2011). Sensing and Field Data Capture for Construction and Facility Operations. ASCE Journal of Construction Engineering and Management, 870–881.

Wickwire, J. M., Driscoll, T. J., Hurlbut, S. B., & Groff, M. J. (1991). Construction scheduling: Preparation, liability, and claims (p. 158). Wiley Law Publications.

Zaher, M., Greenwood, D.J., & Marzouk, M. (2018). Mobile augmented reality applications for construction projects. Construction Innovation, 18(2), 152-166.

Zarei, B., Sharifi, H., & Chaghouee, Y. (2018). Delay causes analysis in complex construction projects: a Semantic Network Analysis approach. Production Planning & Control, 29 (1), 29-40.