Forensic Delay Analysis as Evidence of Transaction Costs in Construction Projects

V A Atanasov[1,2], D J Greenwood[3], H Ross[4] and D E Sanchez[5]

[1] International Construction Claims Consulting Ltd, Durham, DH1 5JA, UK
[2] The Law School, Robert Gordon University, Garthdee House, Garthdee Rd, Garthdee, Aberdeen, AB10 7AQ, UK
[3] Department of Mechanical & Construction Engineering, Northumbria University, Newcastle upon Tyne, NE1 8ST, UK
[4] The Law School, Robert Gordon University, Garthdee House, Garthdee Rd, Garthdee, Aberdeen, AB10 7AQ, UK
[5] The School of Computing, Newcastle University, Urban Sciences Building, Science Square, Newcastle upon Tyne, NE4 5TG, UK

E-mail: vasil.angelov.atanasov@mail.com

Abstract. Construction projects are characterised by supply chains with multiple contracts and significant transaction costs. An example of these costs is to be found in the management of project delays. The operationalisation and measurement of transaction costs, especially in the construction context, has hitherto proved difficult. The work reported here is concerned with defining and measuring the resources required for the management of contractual disputes relating to project delays. Its main argument is that concepts from transaction cost economics (TCE) theory (bounded rationality, uncertainty, information asymmetry, and opportunistic behaviour) present serious problems for transaction efficiency. This is exemplified in forensic analysis of construction project delays. Data from twelve case studies are analysed, to reveal that up to 90% of time spent on delay analysis was concerned with searching for and validating information which could, ostensibly, be automatically and reliably captured using digital technologies. This research forms part of a wider study that considers the implications of the identified inefficiencies and makes a case for the exploitation of advances in information technology on the more efficient resolution (or even avoidance) of contractual disputes. It concludes that there is a prima facie case for this, and therefore for the reduction in the transaction costs that relate to the management of construction project delays.

1. Introduction
Construction projects are invariably and manifestly beset by delay [1]. A major consequence of this is costly and time-intensive disputes [5]. This article (or paper) examines disputes arising out of delay in construction projects, with a particular emphasis on viewing such disputes as a significant transaction cost.

In 1937 Coase introduced his theory of Transaction Cost Economics (TCE)[6], which was subsequently taken up and further developed by Williamson [7]. A number of observers have found this theory to be effective in accounting for inefficiencies in the construction sector. However, the practical application of some key aspects of TCE theory has proved contentious.

This article centres around three key hypotheses: (1) that transactional disputes, and the ways in which they are managed, can be seen as an entirely avoidable transaction cost; (2) that – informed by TCE theory – such disputes suffer from informational shortcomings (or asymmetry), including a disequilibrium of information input by project stakeholder and (3) that, in the opinion of the authors of this paper, the drawbacks highlighted in (2) could be addressed by developing customised information tools that, albeit limited by what it is possible by today's technologies, could produce more robust information within the sector.

The empirical findings reported in this article originate from twelve project case studies which address hypothesis (1) (above) by seeking to define and quantify the expenditure of effort which the management of transactional disputes ordinarily necessitates. First, a few background assumptions are outlined, drawing on relevant literature and comprising: (i) a review of distinctive characteristics of construction delay disputes and their typical management, and (ii) a brief summation of key elements of TCE theory. The adopted methodology outlines a case study approach to collection of data. Findings based on an analysis of the collected data include quantifying transaction costs across a range of typical contributors. Finally, having regard to the more encompassing body of work to which this paper contributes, consideration is given to how information technology within the construction sector might be more constructively deployed towards reducing or eradicating some of the transaction costs identified in the study, ultimately with a view to disposing of construction disputes more effectively or efficiently, or eliminating them altogether.

2. Literature Review

This part of the article sets out the findings of a literature review focusing on the two tasks mentioned above, namely: (i) reviewing distinctive characteristics of construction delay disputes and their typical management, and (ii) briefly summarising key elements of TCE theory (extending to discussion of the practical application of those elements to key issues and difficulties prevalent in the construction sector).

2.1. Construction Delay Disputes

A report published in 2021, focusing on construction disputes in the global arena [5], estimates the cost of the average dispute as US$54million, typically playing out over 13 months. The report does not separately itemise cost and duration attributable to delay-based claims, but the National Construction Contracts and Law Report [8], which examines the position in the UK, maintains that disputes centring on project delays were the most prevalent among UK-based construction industry players who had been involved in disputes.

2.2. Construction Project Delays and their Analysis

Pickavance points out that the expression 'delay' lends itself to a variety of interpretations [9]. This difficulty is amplified by the failure of most published standard form contracts to define this important term – and this can itself be a catalyst for disputes. Burr identifies 23 possible meanings, noting that per se the concept lacks 'intrinsic quality'. However, he concludes that delay in completion of the works can be regarded as an 'adverse effect upon completion' by the contractor of the entirety, or a defined section, of the works, as required by the contract [10]. Needless to say, all parties involved in construction projects can suffer delay-related losses. Leading publishers of standard form contracts use contractual devices such as liquidated damages (LDs) and extensions of time (EOTs) as a means of apportioning risk. But those mechanisms are usually of general application and may not assist in averting disputes. The Society of Construction Law [11] has sought to introduce procedures for parties to opt into and follow. However, delay-related disputes are inherently complex, and this can often be compounded by an absence of supporting information [12] and a tendency for differences between parties to escalate [13]. This may precipitate disputes that require to be resolved by formal or informal processes [14].

Kumaraswamy [15] notes that the complexity and often high value of construction disputes have created a need for specialist consultants who practise the techniques of forensic delay analysis (FDA), coming from a background in dispute resolution and claims management. The merits and demerits of FDA techniques are explored in literature where the focus is on distinguishing between methods of the project programme/schedule analysis [11, 16, 17, 18, 19]. The quantification of project delays is usually reliant both on critical path analysis (CPA) and on the availability of validated programmes. In situations where the project records that are required to validate construction programmes are not readily available (as often happens) the CPA may turn out to be both speculative and subjective. FDA techniques may be deployed to facilitate case-building in preparation for dispute resolution processes such as adjudication, arbitration, expert determination or litigation. In that context, FDA consultants may take on the role of independent experts. As Carmichael and Murray put it: the process calls for a 'vast number of documents to be reviewed and people to be interviewed'[20]. Alkass et al. have estimated that the process of gathering and organising information accounts for approximately 70% of the task of building a case and 30% of the time is spent on the analysis of the claim [21]. This claim lacks substantiation, however. In the 2017 SCL Delay and Disruption Protocol [11] there is recognition that any FDA method adopted must be reliant upon the nature, extent and quality of both the programme information and records available. Essentially, what is being suggested here is that the management and resolution of construction disputes, facilitated by FDA, are a clear example of transaction costs. Perhaps inevitably, this engages TCE theory towards the goal of understanding how greater efficiencies can be achieved in construction projects.

In the next part of this paper there is a brief summary of the key literature on TCE theory, with an exploration of its practical application in the construction context.

2.3. Transaction Cost Theory

According to the theory's originator the 'costs of organizing transactions' arise from efforts 'to conduct negotiations leading up to a bargain, to draw up the contract, to undertake the inspection needed to make sure that the terms are being observed, and so on' [22]. Dahlman identified 'search and information costs, bargaining and decision costs, policing and enforcement costs' and added that 'fundamentally [these] reduce to... resource losses due to lack of information'[23]. Williamson recognises two factors that influence these costs as 'the characteristics of the human decision makers ... on the one hand and the objective properties of the market on the other'[24]. Eccles following Williamson, described two influential pairings of these factors as (1) bounded rationality and uncertainty/complexity and (2) opportunism and small numbers [25]. TCE theory has its critics; the most cited being Simon who claimed they have 'no empirical support' [26] and Ghoshal and Moran who regarded TCE as 'not only wrong but also dangerous ...' [27]. These criticisms have themselves been refuted; by Masten in the former case [28], and by Williamson, in the latter [29]. David and Han describe a 'significant variation in support for the theory's predictions'[30]. This debate has continued. Recent examples include Lacity and Khan who conclude that TCE theory only applies 'to specific contexts' [31]; Schermann *et al*. with evidence that both supports and negates TCE theory [32]; and Haaskjold *et al*. who argues a general association between collaboration and reduced transaction costs but support a more restricted context-specific view of TCE applicability [33].

2.4. Construction Project Delays and their Analysis.

Williamson's refinement and redefinition of the original theories of Coase appeared to spark a keen interest amongst construction management researchers [34]. The authors undertook a systematic literature review of all academic articles and doctoral dissertations that describe or attempt to apply TCE theory related to the Construction Industry. Three academic search tools - Google Scholar, the database of the Association of Researchers in Construction Management (ARCOM), and that of the British Library (EthoS) - were used to determine the body of TCE work that has been published within the Construction Management field. In the 80 years since Coase first introduced the theory, no construction-related reference to TCE was found until Eccles' 1981 paper: suggesting the influence of Williamson's more detailed publications from 1979 onwards. Of the 89 subsequent papers where authors had adopted a 'TCE-lens' to understanding the workings of the construction industry, there were four in the decade between 1981 and 1990; nine between 1991 and 2000; twenty-nine between 2001 and 2010; and between 2011 and 2020, a further forty-eight publications. This indicates a growing interest in the potential application of TCE to the Construction Industry, its organisations, and its projects.

It is instructive at this point to draw attention to Williamson's dichotomy used in reference to TCE approaches, namely: 'a governance branch and a measurement branch'[34]. Authors, including Reve and Levitt [35]; Winch [36] [37]; Walker and Wing [38]; Lai, [39]; Bridge and Tisdell [40]; and Bygballe, *et al.*, [41] have focused attention on the governance branch, following Eccles' initiative to apply TCE theory towards explaining 'boundaries' of construction companies and the organisation of their businesses and projects. Other writers have focused on applying the measurement branch of TCE theory to explain project performance and other phenomena, such as the behaviour of key stakeholders. For instance, Yates and Hardcastle [42] have focused on how bounded rationality and opportunistic behaviour might impact conflict and disputes in construction projects. Greenwood and Yates have adopted the same approach using evidence provided by a partnering case study [43]. Empirical studies by Li *et al*. [44] and You *et al.* [48] identified pre- and post-contract transaction costs, suggesting how these impacted the choice of project delivery systems and type of contract.

The study reported in this paper occupies the measurement branch of TCE theory and the specific approach adopted is described in greater detail in the next part of the article (immediately below).

3. Research Methodology

This study is concerned with (i) identifying the processes and resources currently required for analysing delay disputes; (ii) categorising them using TCE 'language' and aligning them with components of transaction costs (as discussed above); and (iii) operationalising and measuring these costs by examining data collected from twelve project case studies. For ethical reasons cases have been anonymised and described by their function (i.e., Infrastructure Design; Panel Manufacturing Plant; Bridge Construction, etc.). The methodological approach is primarily archival and based upon analysis of the records of twelve case studies chosen from an initial sample of sixty projects. In common with many types of consultants, FDA activity records are kept for payroll, project accounting and client-billing purposes. These provided a rich source of data for identifying, categorising and quantifying the FDA processes and the resources required to sustain them. The selection of cases was based on four criteria. The first was that each involved a delay or delays upon which the parties were unable to reach agreement under the terms of the contract (hence escalated to a dispute). The second criterion was recency: the case studies were selected from the period between January 2015 and January 2021. Projects that started before this timeframe or were incomplete by the end of it were eliminated. The third criterion was representativeness: the case studies must, as far as possible, be reasonably representative of the range of projects dealt with. Finally, the fourth criterion, in order to secure the accessibility and consistency of collected data, was that the entire delay analysis process had been undertaken 'in-house' by a single FDA consultant. This is a significant filter, as projects are often completed by a network of analysts in different international locations. Based on the above criteria twelve projects were identified for further analysis. Daily record-keeping is a fundamental requirement for the FDA, as it is for most consultant organisations. The records from the twelve case-study projects were reviewed to identify: (a) the type of task conducted by each consultant for each working day; (b) the reasons for conducting the tasks; (c) the product that was produced as a consequence of each task; and (d) the time spent on a particular task.

4. Case Studies and Data Analysis

The table below provides a brief description of the case studies including project type, service, type of contract, location, the client, and dispute resolution forum.

IOP Conf. Series: Earth and Environmental Science 1101 (2022) 052009 doi:10.1088/1755-1315/1101/5/052009

Table 1. Case Studies (CS).

CS	Project Type	Service	Location	Client	Contract	Forum
1	Mixed use development	Independent delay report	Asia	Contr.	FIDIC	Arb.
2	Shopping centre	Independent delay report	UK	Eng.	JCT	Adj.
3	Infrastructure (tunnelling)	Independent delay report	UK	Contr.	NEC	Adj.
4	Railway services	Independent delay report	UK	Eng.	NEC	CAP
5	Bridge construction	Independent delay report	Africa	Con.	FIDIC	DAB
6	Panel manufacturing plant	Delay analysis report	UK	Suppl.	NEC	Neg.
7	Infrastructure design	Delay analysis report	UK	Design.	NEC	Neg.
8	Infrastructure construction	Independent delay report	UK	Contr.	Bespoke	Adj.
9	Infrastructure design	Delay analysis report	UK	Design.	NEC	Neg.
10	Data centre	Independent delay report	UK	Contr.	JCT	Adj.
11	Food packaging plant	Independent delay report	UK	Contr.	JCT	Adj.
12	Office building	Independent delay report	UK	Contr.	JCT	Adj.

Earlier work by the authors Atanasov *et al*. revealed that the FDA process can be divided into four broad categories (Cat) of activities (or tasks) [49]. Preliminary tasks (Cat. 1) including a review of available records, meetings or correspondence with clients to establish the aims, objectives of the FDA and a basis for further records requests. Delay analysis (Cat. 2) involving a review of available programmes to establish the accepted 'baseline' (as-planned) and as-built programmes, their validation, and the creation of tables, schematics, and other charts to illustrate high level, mid-level, and detailed comparisons, and drafting the methodology and findings. It is a process where the start and completion dates of the programme activities are compared to the available as-built records which could be in the form of daily, weekly, fortnightly, or monthly reports. Causation analysis (Cat. 3) including a review of contemporaneous records to identify relevant issues, create chronologies to describe identified issues, creation of tables, schematics, and other charts to illustrate findings and draft and edit relevant sections of report. Undifferentiated activities (or 'Others') where in a record it was difficult to allocate time to a single category, e.g., where records related to time spent overall on all of them, it was assumed that the relative proportion of time could be allocated to Categories 1-3 pro-rata to the predominant patterns from data that could be differentiated. Analysis of the records from each of the twelve case studies produced the following results.

Table 2. Summary of Production Hours.

Categories	Preliminary Tasks	Delay	Causation	Others	Total	Total less Others
Production hours Case 1	84	725	561	418	1788	1370
Production hours Case 2	24	231	39	252	546	294
Production hours Case 3	44	179	238	20	481	461
Production hours Case 4	101	1975	37	571	2684	2113
Production hours Case 5	58	374	175	381	988	607
Production hours Case 6	52	374	35	17	378	461
Production hours Case 7	27	1518	823	1588	3956	2368
Production hours Case 8	211	144	6	623	984	361
Production hours Case 9	74	641	730	624	2069	1445
Production hours Case 10	58	594	47	70	769	699
Production hours Case 11	15	773	44	1101	1933	832
Production hours Case 12	16	413	30	319	778	459
Production hours (all cases)	764	7941	2765	5984	17354	11470

This shows that the highest number of classifiable FDA hours (7941) were spent on quantification and analysis of the project Delay (69%) and Causation Analysis (24%). The quantification of delay consistently accounted for a significant percentage of the hours spent by the FD analysts. By contrast, in seven of the twelve case studies, the classifiable hours spent by the FD analysts on Causation Analysis were relatively insignificant (i.e., less than 10% of the classified hours). This indicates that the main aspect of the FDA's consultancy service is the quantification of delay, including identification, validation and analysis of delays. In nine of the case studies a significant portion of the total hours (5984 hours) were difficult to classify with accuracy, though informal records suggest that these may be consistently attributable to the former two categories (generally, the description of the FDA activity only refers to Delay quantification and analysis and Causation analysis), it should be highlighted that this is an assumption made for the purpose of this research. However, the Delay category accounted for the highest total of hours.

In term of the individual cases the information provided can be used to analyse the production hours. For example, in Case 1 the quantification and analysis of Delay accounted for around 53% of the classifiable hours (40% of the total). Although this activity accounted for around 40% of the total, it was not possible to identify the 'other' activities, due to the level of accuracy in the description provided in the time sheets. It may be that a significant part of the 418 'Others' hours was also spent on the quantification and analysis of Delay. The time spent on Causation Analysis (41%, or 31% of the total) was less than the time spent on identification, validation, and analysis of the accepted as-planned and as-built programmes.

5. Findings and Discussion

Based on twelve cases, the resources required for managing time-related contractual disputes over project delays were measured. The findings indicate that up to 90% of FDA costs were expended in retrieving, validating, and processing project records for analysis where most of those hours are spent on validation of as built data. This figure is particularly high compared to less than 25% spent on the more contentious aspect, i.e. making an argument for causation. Where such records are incomplete, inferences are needed that themselves require further efforts to justify, including the use of processes such as reconstruction of the data which are prone to errors and biases. Although the study was limited in terms of sample size, it is based on the kind of evidence that has hitherto been rare or non-existent. Not only does this provide empirical evidence to support the estimates but provides a relatively detailed indication of the categories of activities performed by FD analysts and quantifies the time spent on those tasks which can be used as an indicator of the cost of the service. Perhaps most importantly, the evidence indicates that there is a duplication of costs where the delay analysis is conducted originally by the commercial teams of the parties and again by independent consultants. It could be argued that the efforts of both teams are examples of construction project transaction costs and that these costs increase when the commercial team is unable to complete the task effectively and external FD analysts are contracted to complete the claims.

Recognising the conclusion of Haaskjold et al. that ‘conflicts can lead to significant transaction costs’, the study was set within the lens of TCE theory [33]. This approach was supported by the findings, in that (1) contractual disputes offer a striking example of unnecessary transaction costs; and (2) that, reflecting TCE theory, these costs are fuelled by the phenomenon of bounded information, requiring what Dahlman (1979: 148) identifies as ‘search and information costs’ and ‘resource losses due to lack of information’. Furthermore, such situations provide scope for opportunistic behaviour and exploitation by individual agents in their unwillingness to share any information that does exist. From an academic perspective, this is a rare example of the operationalisation and measurement of transaction costs.

More important is the practical relevance of the work. Despite the current deficiencies, the information required for FDA could potentially be made available in accurate and verifiable formats. For example, there is a range of software products to support the management of time on projects and versions of these were available to all the key participants in the cases in question. All such products have a facility for the capture and archiving of evolving versions of the schedules they are used to produce. A more recent technological advance is that of Building Information Modelling (BIM). Authors from Gibbs *et al*. to Sanchez *et al*. have explored how BIM and related digital technologies could assist with FDA [50][51]. Advances such as the introduction of 3D scanners [52], drones [53], sensors [54] present an opportunity for accurate contemporaneous collection and processing of construction project information. Furthermore, the application of emerging blockchain technology to the capture of progress information could eliminate the requirement for human agency [55]. Properly managed, this could remove the possibility of information asymmetry and its opportunistic exploitation by one agent or another. In this way, the utilisation of information technology is likely to improve the current efficiency of resolution (or avoidance) of contractual disputes by reducing (or even eliminating) the factual arguments relating to the actual progress of the construction works. In summary, transaction efficiency could be improved by automating the capture and management of the required information by minimising arguments over the sufficiency or accuracy of the records and, as a consequence, potential disputes regarding the parties’ liability for critical project delays.

6. Conclusions and Further Research

Despite these opportunities, the proportion of time the FD analysts spend on delay analysis indicates serious current deficiencies in the capture, storage, retrieval, and processing of information by the representatives of the organisations in question. The findings indicate that reconstruction and validation of data is time-consuming and resource-intensive process. This lack of adequate and credible information is a clear example of the bounded rationality, which, as discussed earlier, is one of the main factors in the escalation of transaction costs. Bounded rationality provides scope for opportunistic behaviour and this is exploited by individual agents in their unwillingness to share such information that does exist. Together these factors add further to the conflict and disputes in construction projects, and ultimately to their cost. The adoption of available technical solutions would, in the language of TCE, reduce bounded rationality and information asymmetry, by making relevant information reliable, accessible and transparent and thereby reducing uncertainty and opportunistic behaviour. Exploration of the previously noted issue of the potential duplication of project costs related to quantification and substantiation of project delays (i.e., by both the project commercial team and later by FDA consultants) and an investigation of effective solutions (technical and contractual) to reduce transaction costs would also be a valuable line of enquiry.

Acknowledgement
The authors would like to acknowledge the assistance of the Major Projects Association, UK for its continuing support throughout the study.

References
[1] Adam A, Josephson P E and Lindahl G 2017 Aggregation of factors causing cost overruns and time delays in large public construction projects: Trends and implications *Engineering, Construction and Architectural Management* **24** 393-406
[2] Ansah R H, Sorooshian S and Mustafa S B 2018 The 4Ps: A framework for evaluating construction projects delays *Journal of Engineering and Applied Sciences* **13** 1222
[3] Durdyev S and Hosseini M R 2019 Causes of delays on construction projects: a comprehensive list *International Journal of Managing Projects in Business*
[4] Larsen J K, Shen G Q, Lindhard S M and Brunoe T D 2016 Factors affecting schedule delay, cost overrun, and quality level in public construction projects *Journal of Management in Engineering* **32** 04015032
[5] Arcadis 2021 *Global Construction Disputes* (Arcadis)
[6] Coase R H 1937 The nature of the firm *Economica* **4** 386-405
[7] Williamson O E 2018 Transaction-cost economics: the governance of contractual relations *The Journal of Law and Economics* **22** 233-61
[8] National Building Specification 2018 National Construction Contracts and Law Report (National Building Specification)
[9] Pickavance K 2010 *Delay and Disruption in Construction Contracts* (London: Sweet and Maxwell)
[10] Burr and Castro A M 2016 *Delay and Disruption in Construction Contracts* (CRC Press)
[11] Society of Construction Law 2017 *Society of Construction Law Delay and Disruption Protocol* (Society of Construction Law)
[12] Love P, Davis P, London K and Jasper T 2008 Causal modelling of construction disputes *In Proc. of the 24th Annual Conf. of ARCOM* (Cardiff: ARCOM) pp 869-78
[13] Loosemore M 1999 Bargaining tactics in construction disputes *Construction Management & Economics* **17** 77-88
[14] Clay R, Dennys N and Hudson A A 2016 *Hudson's Building and Engineering Contracts: First Supplement to the 13th Edition* (London: Sweet & Maxwell)
[15] Kumaraswamy M M 1997 Conflicts, claims and disputes in construction *Engineering Construction and Architectural Management* **4** 95-111
[16] Kraiem Z M and Diekmann J E 1987 Concurrent delays in construction projects *Journal of Construction Engineering and Management* **113** 591-602
[17] Braimah N 2014 Understanding construction delay analysis and the role of preconstruction programming *Journal of Management in Engineering* **30** 04014023
[18] Scott S, Harris R A and Greenwood D 2004 Assessing the new United Kingdom protocol for dealing with delay and disruption *Journal of Professional Issues in Engineering Education and Practice* 1**3** 50-9
[19] American Association of Cost Engineers 2011 *RP 29R-03 Forensic Schedule Analysis no 29* (American Association of Cost Engineers)
[20] Carmichael S and Murray M 2006 Record keeping for contemporaneous delay analysis: A model

for effective event management *Construction Management and Economics* **24** 1007-18
[21] Alkass S, Mazerolle M, Tribaldos E and Harris F 1995 Computer aided construction delay analysis and claims preparation *Construction Management and Economics* **13** 335-52
[22] Coase R H 1960 The problem of social cost *Classic Papers in Natural Resource Economics* (London: Palgrave Macmillan)
[23] Dahlman C J 1979 The problem of externality *The Journal of Law and Economics* **22** 141-62
[24] Williamson O E 1975 Markets and hierarchies: analysis and antitrust implications: a study in the economics of internal organization *University of Illinois at Urbana-Champaign's Academy for Entrepreneurial Leadership Historical Research Reference in Entrepreneurship* p 286
[25] Eccles R G 1981The quasifirm in the construction industry *Journal of Economic Behavior & Organization* **2** 335-57
[26] Simon H A 1991Organizations and markets *Journal of Economic Perspectives* **5** 25-44
[27] Ghoshal S and Moran P 1996 Bad for practice: A critique of the transaction cost theory *Academy of Management Review* **21** pp 13-47
[28] Masten S E 1996 Empirical research in transaction cost economics: challenges, progress, directions *Transaction Cost Economics and Beyond* 43-64
[29] Williamson O E 1996 *The Mechanisms of Governance* (Oxford: Oxford University Press)
[30] David R J and Han S K 2004 A systematic assessment of the empirical support for transaction cost economics *Strategic Management Journal* **25** 39-58
[31] Lacity M C and Khan S A 2016 Transaction cost economics on trial again *The Journal of Strategic Information Systems* **25** 49-56
[32] Schermann M, Dongus K, Yetton P and Krcmar H 2016 The role of Transaction Cost Economics in Information Technology Outsourcing research: A meta-analysis of the choice of contract type *The Journal of Strategic Information Systems* **25** 32-48
[33] Haaskjold H, Andersen B, Lædre O and Aarseth W 2019 Factors affecting transaction costs and collaboration in projects *International Journal of Managing Projects in Business*
[34] Williamson O E 1989 *Handbook of Industrial Organization* Transaction cost economics **1** 135-82
[35] Reve T and Levitt R E 1989 Organization and governance in construction *International Journal of Project Management* **2** 17-25
[36] Winch G 1989 The construction firm and the construction project: a transaction cost approach *Construction Management and Economics* **7** 331-45
[37] Winch G M 2015 Project organizing as a problem in information *Construction Management and Economics* **33** 106-16
[38] Walker A and Wing K C 2001 The relationship between construction project management theory and transaction cost economics *Engineering Construction and Architectural Management* **6** 166-76
[39] Lai L W 2000 The Coasian market-firm dichotomy and subcontracting in the construction industry *Construction Management and Economics* **18** 355-62
[40] Bridge A J and Tisdell C 2004 The determinants of the vertical boundaries of the construction firm *Construction Management and Economics* **22** 807-25
[41] Bygballe L E, Håkansson H and Jahre M 2013 A critical discussion of models for conceptualizing the economic logic of construction *Construction Management and Economics* **31** 104-18
[42] Yates D J and Hardcastle C 2003 *The Causes of Conflict and Disputes in the Hong Kong Construction Industry: A Transaction Cost Economics Perspective* RICS Foundation
[43] Greenwood D and Yates D J 2006 The determinants of successful partnering: a transaction cost perspective *Journal of Construction Procurement* **12** 4-22
[44] Li H, Arditi D and Wang Z 2012 Transaction-related issues and construction project performance *Construction Management and Economics* **30** 151-64
[45] Li H, Arditi D and Wang Z 2013 Factors that affect transaction costs in construction projects *Journal of Construction Engineering and Management* **13** 60-68

[46] Li H, Arditi D and Wang Z 2014 Transaction costs incurred by construction owners *Engineering, Construction and Architectural Management* Jul **21** 444-58
[47] Li H, Arditi D and Wang Z 2015 Determinants of transaction costs in construction projects *Journal of Civil Engineering and Management* **21** 548-58
[48] You J, Chen Y, Wang W and Shi C 2018 Uncertainty, opportunistic behavior, and governance in construction projects: The efficacy of contracts *International Journal of Project Management* **36** 795-807
[49] Atanasov V, Greenwood D and Robson S 2020 The Management of Disputes as an Element of Construction Transaction Costs: An Empirical Study *In Proc. of the 36th Annual ARCOM Conf.* (Glasgow: ARCOM) pp 235-45
[50] Gibbs DJ, Emmitt S, Ruikar K and Lord W 2013 An investigation into whether building information modelling (BIM) can assist with construction delay claims *I .J. 3D. I. M.* **2** 45-52
[51] Sanchez D, Greenwood D J, Benghi C, Atanasov V A and Parry A 2019 Specifying the information requirements for Forensic Delay Analysis *In Proc. of the CIB W78* (Newcastle upon Tyne: CIB W78) pp 679 - 88
[52] El-Omari S and Moselhi O 2008 Integrating 3D laser scanning and photogrammetry for progress measurement of construction work *Automation in Construction* **18** 1-9
[53] Li Y and Liu C 2019 Applications of multirotor drone technologies in construction management *International Journal of Construction Management* **19** 401-12
[54] Akinci B and Anumba C 2008 Sensors in construction and infrastructure management *Journal of Information Technology in Construction* **13** 69-70
[55] Li J, Greenwood D and Kassem M 2019 Blockchain in the built environment and construction industry: A systematic review, conceptual models and practical use cases *Automation in Construction* **102** 288-307