# DIGITALISATION AND TRANSACTION COSTS: AN EXPLORATION OF BIM-ENABLED DESIGN COLLABORATION

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Despite arguments pointing to the major potential of digital technologies and processes to improve coordination and transform construction, in practice digitalisation has led to limited improvements and transformation. Previous research suggested that this is mainly due to the misalignment between the digital technologies and processes on the one hand, and the established organizational and business practices in construction on the other. This paper uses Transaction Cost Theory to create further insights into this misalignment. The empirical study focuses on design collaboration activities in a design-and-build project in the UK. Based on the observational and interview data collected from design meetings and their participants, the paper reveals the impact of BIM on the transaction costs of design collaboration. While BIM is supposed to reduce transaction costs by providing a shared medium that facilitates the search, negotiation and implementation of design decisions, there are additional transaction costs that arise to make such a shared digital medium functional under the existing professional and organizational arrangements. It is concluded that Transaction Cost Theory is a useful theoretical tool to help align the digital tools/processes and the wider organisational and business considerations in construction.

Keywords: design collaboration; digital transformation; transaction cost theory; BIM

## INTRODUCTION

Digital construction technologies and processes have attracted ongoing academic and practical interest due to their potential for improving coordination, and thus, revolutionising how built assets are delivered and operated. However, although such digital technologies and processes are increasingly adopted globally, there have been mixed findings about their impact on the efficiency of coordination, which raised questions about the transformative power of digitalisation (Çıdık and Boyd 2022). Meanwhile, there is a growing body of research which suggests that the organisation and business models of construction firms and projects are misaligned with digital technologies and processes, thus limiting the benefits and transformative power of digitalisation (Dossick and Neff 2010, Çıdık *et al.,* 2017, Aksenova *et al.,* 2018, Woodhead *et al.,* 2018).

Although previous research provided some important insights regarding the misalignment between the requirements of digitalisation, and the established organisational and business practices in construction, this debate is far from settled

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with limited empirical evidence and theory. To further this ongoing debate, this paper proposes the use of Transaction Cost Theory (Williamson 1979, 1981). According to Williamson (1981), "[t]he transaction cost approach to the study of economic organization regards the transaction as the basic unit of analysis and holds that an understanding of transaction cost economizing is central to the study of organizations" (p. 548). Thus, this paper will use Transaction Cost Theory to explore the misalignment between the modes of organizing transactions as required by digital technologies and processes, and by the established organisational and business practices in construction. This will reveal new insights about the reasons underpinning the limited improvements in coordination and limited transformation in construction.

The empirical focus of the paper is on the transactions for design coordination during a design-and-build construction project in the UK, which used Building Information Modelling (BIM). Based on rich observational data from design coordination meetings and interview data with coordinating parties, the paper reveals some of the implications of using BIM on the transaction costs of coordinating design. This exposes that the impact of BIM on design coordination is not straight-forward. It shows that while BIM is supposed to reduce transaction costs by providing a shared medium that facilitates the search, negotiation and implementation of design decisions, there are additional transaction costs that arise to make such a shared digital medium functional under the existing professional and organizational arrangements. The discussion highlights the need for a comprehensive understanding of the interrelated transaction costs when digitalisation of a task is considered. The discussion further highlights Transaction Cost Theory as an adequate lens to draw out such a comprehensive understanding of the interdependent transaction costs. It is concluded that Transaction Cost Theory can help achieving better alignment between the digital tools/processes and the wider organisational and business considerations, by exposing how digitalisation changes transaction costs and their interdependencies.

## Transaction Cost Theory and Its Application to Construction

Transaction cost theory is an economic theory of organisation. It assumes a relationship between the costs of the resources required to exchange things with an economic value (both internally in an organisation and externally), and the organizational form that governs these exchanges. It emerged as a criticism of the classical economics' idea that the market self-operates based on perfect competition between independent and profit-maximizing firms for which the price is the only coordination mechanism (Williamson 2005). Hence, transaction cost theory argues for the consideration of bounded rationality (in the face of uncertainty/complexity) and opportunism (in the context of small number relationships) (Winch 1989) as central to economic exchanges. It suggests that the cost of the resources required to execute exchanges (i.e., transaction costs) are essential to understanding how those exchanges are (or should be) governed for an organization (Williamson 1981). As summarized by Walker and Kwong Wing (1999) who cite Williamson (1985) "the basic idea is that organizational variety arises primarily in the service of economizing in transaction costs and that transaction costs are assigned to governance structures which differ in their organizational costs and competencies" (p. 167).

Based on these underpinning assumptions, Williamson (1979) suggests that the key dimensions that determine the transaction costs are environmental uncertainty/complexity, frequency of transactions, and asset specificity, which is 'the degree to which an asset can be redeployed to alternative uses and by alternative users without sacrifice of productive value' (Williamson 1988, 70). Whether a certain kind of transaction is handled through market (e.g., sub-contracting), hierarchy (e.g., in-house), or hybrid (e.g., alliances) governance structure will depend on which one of these provides the optimum economies of transaction (Williamson 1985). For this reason, Coase (1991) claims that a firm "could only continue to exist if it performed its co-ordination function at a lower cost than would be incurred if it were achieved by means of market transactions and also at a lower cost than this same function could be performed by another firm" (p. 15).

These ideas have been used in construction project management research to explain the operating principles of construction firms and projects (Bygballe and Jahre 2013). Eccles (1981) suggests that the common practice of sub-contracting in construction is due to the combination of demand uncertainty and the need for specialised workforce. As these cannot be adequately addressed through pure market or hierarchy governance structures, main contractors rely on sub-contracting which provide relatively stable relationships, thus enabling a 'quasi-firm' governance structure. Reve and Levitt (1984) analyse construction contracts as ways of governing construction transactions. They argue that the contract between the client and construction contractor is a hierarchical document which "supplement the functioning of markets when transactional conditions would otherwise lead to market failure" (p. 17). By considering uncertainty/complexity, asset specificity and frequency from the distinct perspectives of clients, contractors and consultants, Reve and Levitt (1984) argue that clan and professional relationships play a key role for economizing in transactions for construction projects. Winch (1989) posits that the focus of transaction economic analysis must be the construction firm, rather than construction project. He asks the question 'why do construction firms choose to contract for construction services, rather than employ the capacity to provide those services themselves?'. As a result of his analysis, he arrives to the conclusion that this is because of the contradictions between project and contracting uncertainties/complexities, and the institutionalized and deep-rooted nature of the professions in the industry. Finally, Walker and Kwong Wing (1999) claim that project management on behalf of a client is entirely a transaction cost because its purpose is to integrate multiple organisations towards delivering what the client needs. From here, they suggest that the governance structures of projects must be decided based on an understanding of the costs of the transactions that occur as part and parcel of project management, such as enabling appropriate communication and information flow to enable decision making.

Overall, the established organizational and business practices in construction can be seen as the result of the optimization of various transactions costs that construction firms and projects need to deal with. For this reason, exploring how digitalisation reconfigures transaction costs in construction can provide valuable insights about why digitalisation has so far enabled only limited improvements in coordination and limited transformation in construction. The following brief literature review presents the impact of information technology on transaction costs to frame the empirical analysis.

## Transaction Costs and Information Technology

Cordella (2006) highlights that transaction costs are essentially the consequence of the asymmetrical and incomplete distribution of information among the economic agents involved in the transaction. In line with this thinking, since the beginning of the use of personal computers, the capacity, speed, and connectivity of information technologies (IT) have been seen as reducing the transaction costs by creating efficiencies of coordination (e.g., Malone *et al.,* 1987). A similar thinking still dominates the research on IT and transaction costs, with new digital technologies being mostly interpreted as means to reduce transaction costs, for example, by providing new ways of addressing information asymmetry (Nagle *et al.,* 2020) and limiting opportunistic behaviour as well as environmental and behavioural uncertainty (Schmidt and Wagner 2019).

On the other hand, there has also been a more critical strand of research which has highlighted how digitalisation increases complexity and creates information overload, thereby increasing transaction costs (e.g., Schultze and Vandenbosch 1998). Particularly, Ciborra and Hanseth (1998) suggested considering IT as an enframing device, which entirely shifts people's understanding of the task as opposed to just executing the same task digitally (as cited in Cordella, 2006). Cordella (2006) argues that this argument has significant implications for studying the impact of IT on the transaction costs related to a task. It suggests that the change in the transaction costs due to digitalisation cannot be studied based on the original understanding and execution of the task, but rather needs to consider the wider effects that digitalisation has had on the understanding and context of the task. According to Cordella (2006), this means that a study of the impact of digitalisation on transaction costs needs a holistic understanding of how people's perception of the task as well as the context of the task change due to digitalisation. This is because in many cases this new work situation reconfigures a wider set of transaction costs for the organisation beyond the individual digitalised transactions. Indeed, digital transformation can be understood as the result of the new overall configuration of transaction costs driven by digitalisation of a certain kind of economic activity (e.g., Song *et al.,* 2022).

## METHOD

Williamson (1981) states that the transaction cost approach can be applied at three levels to study organisations. The first is the overall structure of the enterprise. The second is the operating parts that perform activities. Finally, the third is the organisation of human assets. In this research the focus is on the level of operating parts. According to Williamson (1981), the application of the transaction cost approach at this level can help reveal the "efficient boundaries" of an operating unit. Digitalisation in construction primarily aims at addressing collaboration challenges, and collaboration in construction relies on boundary objects and boundary spanning (Ewenstein and Whyte 2009; Whyte and Lobo 2010). Applying the transaction cost approach to certain kinds of activities will help reveal those activities' transactional costs, highlighting the sources of those costs and the potential ways to reduce them. Thus, this research applies a transaction cost approach to design collaboration activities, in order to explore the misalignment between the modes of organizing transactions as required by digital technologies and processes on the one hand, and by the established organisational and business practices in construction on the other.

The research uses rich ethnographic observational data collected from the design collaboration meetings of a design-and-build project in the UK, which used Building Information Modelling (BIM). The data was collected through passive observation of 23 face-to-face design collaboration meetings over 10 months. The meetings involved regular design coordination meetings, focused design coordination workshops and (information) model coordination and clash detection meetings. Each meeting was one to one-and-a-half hours long. The researcher held conversations with the meeting participants before and after the meetings to check his understanding of the issues discussed during the meetings by the participants. Additionally, four open-ended interviews were conducted with the regular participants of fortnightly design coordination meetings (i.e., representatives of the mechanical and electrical engineering consultant and architect). This enabled a better understanding of the design collaboration by revealing the activities held in individual offices.

The analysis used an adapted version of Cordella's (2006) transaction cost phases, which represents information-related costs of transactions across their lifecycles as below:

- Search costs: the costs of locating information for collaborative decision making
- Negotiation costs: the costs of having the information presented in such a way that facilitates negotiations for collaborative decision making
- Implementation (i.e., enforcement) costs: the costs of creating and applying the information that is related to the collaborative design decisions made

The field notes, informal communications (with the practitioners) and the transcripts of the interviews were coded to describe the issues with BIM-based working getting in the way of design collaboration. Subsequently, these issues were turned into 'events' which reflect the search, negotiation and implementation costs related to design collaboration. The descriptive coding and explanation of events relied on the researcher's in-depth understanding of the interactions in the studied project in line with the ethnographic tradition. The data is presented as three vignettes, each highlighting the transaction costs related to each cost phase. The events presented in the vignettes are selected from a wider set of similar events using purposive sampling.

## FINDINGS

In this section, the data from the observed project is presented through three vignettes. Each vignette highlights one lifecycle phase of information-related transaction costs due to BIM use. Overall, the three vignettes reveal a rich picture of how transactions are reconfigured as a result of using BIM, and the impact of this on the transaction costs of design collaboration.

### Vignette 1 - Search Costs

The mechanical and electrical (M&E) subcontractor had two design processes running in parallel. They used their proprietary design software to develop M&E design, and then used the shared modelling platform for design collaboration (as required by the project's BIM Execution Plan). This approach was criticised by the architect and the main contractor on an ongoing basis in meetings highlighting that it reduced the value of using BIM. However, the representative of the M&E contractor would repeatedly state that the shared modelling platform was not geared for mechanical and electrical design, and that it would take them much more time to develop design in the shared modelling platform. To be able to use the shared modelling platform as the design medium for M&E engineering, they had to model the entire mechanical and electrical systems as 'closed' systems for the software to conduct necessary engineering calculations. However, this was very inefficient because every time something was updated in the design model, the software would take time to recalculate the entire system.

In one of the meetings the M&E subcontractor was criticised for delaying the modelling of the lights in the atrium area because the architect needed them in the model to do detailed coordination of the lights with other architectural elements in that area. The M&E subcontractor revoiced the reasons why their modelling in the shared platform was lagging, and also recalled a previous situation where the M&E subcontractor provided the model to the architect for detailed coordination, but then the architect amended that part of the building, wasting all that modelling effort. As a response to his reaction, the other participants in the meeting suggested that the M&E sub-contractor only delivers the geometry instead of the model as 'closed' and 'calculated' systems, but this was against their original argument that the shared modelling platform must also be the design development platform. The M&E subcontractor reminded the others that the accuracy of the system calculations was key to a good design, and therefore their site team expected all the modelled systems as 'closed' and 'calculated'. The discussion ended with the M&E subcontractor agreeing to work with the architect to prioritize their modelling in the shared platform based on the architect's needs, while noting that it was impossible to address all their requests at the same time.

This vignette shows that the impact of BIM-enabled digital integration on the search costs of design collaboration is not straight forward. While the shared modelling platform was introduced to facilitate design information sharing to improve collaborative decision making, it was apparent that developing the design in the shared modelling platform would mean higher transaction costs for the M&E subcontractor. This led to a situation where the M&E sub-contractor ended up designing the M&E systems twice: once using their own proprietary software for engineering calculations and then in the shared modelling platform for BIM-based design coordination. Besides, the level of detail required in the model for design coordination seems to be inadequate for some cases, as highlighted in this event when the M&E sub-contractor referred to a wasted modelling effort. This also points to an added transactional cost.

**Vignette 2 - Negotiation Costs**

Automated clash detection, which was one of the most advertised collaboration features of BIM-enabled design, was a constant struggle in the observed project. The automated checks would detect thousands of clashes, and then the designers would apply filters and go through them in order to separate real design problems from pragmatic non-detailed modelling. For example, when there were clashes between the screed on the slab and structural columns, these were marked as 'approved' clashes to indicate that they could be ignored by the software for the future automated clash checks. This is because it would take a lot of time to model the screed without clashing with the structural columns, and because anyone who is familiar with the construction process would know that the columns would be in place by the time the screed would be applied. Therefore, the benefit of automated clash management for collaborative decision-making was dependent on working through numerous clashes, a sizeable amount of which were negligible modelling issues. Thus, the large number of clashes and the uncertainty about the underlying reasons created tense negotiations around collaborative decision-making.

The client's representative and the main contractor's design manager were always critical and anxious about the high number of clashes found through automated clash checks. Additionally, they would also repeatedly state that the designers' responsibility for a clash-free construction persists even if they produce clash-free design models, showing their lack of trust for the process. They suggested that the designers also consider traditional design coordination measures to guarantee a clash-free construction. On the other hand, the designers held the view that the iterative way of developing the design meant that the models that they bring for clash detection were always work-in-progress, and therefore, it was unrealistic to expect to find only the clashes that mattered for the construction phase.

In one of the clash-detection meetings, the architect's model returned a high number of in-discipline clashes, which again attracted criticism by the client's and main contractor's representatives. The architect responded that he was aware of the clashes between the furniture and internal walls, and that these were not important at that stage as the locations of the furniture were not finalized yet. Nevertheless, having so many clashes created anxiety, leading the main contractor's representative to tell him not to export unfinished families into the model for clash-detection. The architect's representative objected, saying that, although clashes between furniture and internal walls were not relevant at that stage, he needed to check for the clashes between some of the fixed furniture and other subcontractors' objects. This was crucial for negotiating the best way forward regarding the design of the fixed furniture and internal walls.

This vignette shows that one of the most advertised features of BIM-enabled coordination requires extensive leg work to be useful. At a first glaze, it seems clear that the ability to append discipline-specific design models and the ability to visualise them together would reduce the negotiation costs for collaborative decision making by making all the relevant information available. However, a more detailed look into the process of automated clash detection reveals that the software is unable to differentiate between the 'normal' clashes that would be expected at a particular stage of iterative design development, and real clashes that are due to errors in design. The many clashes resulting from this deficiency seem to increase the negotiation costs by pushing designers to exclude unfinished parts of the design which cannot be clash-detected but are nevertheless essential for collaborative decision-making.

**Vignette 3 - Implementation Costs**

The client's representative, who was not a designer himself, believed that the design can be fully detailed and resolved through BIM-based design collaboration and that this would be enough for a much more straight-forward application of the design on the site. However, in the observed project, several installations needed to be redocumented in 2D drawings with a much finer level of detail and measurements from the site. This was because the installation tolerances rendered the model's setting-out details irrelevant.

In a similar way, the interviews with the architect and M&E sub-contractor revealed that in theory, the design could be perfectly detailed and coordinated using BIM, but this would take so much modelling time and coordination of very detailed elements that in practice this was not viable considering the time and cost. Therefore, it was decided that anything more detailed than at 1/50 scale would not be modelled, and rather be documented as linked 2D detailed drawings instead. Besides, some objects that were considered insignificant for design checks (e.g., brackets, brick supports, seals etc.) would not be modelled at all (i.e. even if they were larger than 1/50), but only shown in 2D detailed drawings. This 'in-model' vs. 'out-of-model' documentation of design eventually required extra interdisciplinary discussions to clarify what was left out of the models and how the decisions made relating to them would be coordinated both during design and between design and construction.

This vignette shows that there are implementation costs associated with the documentation, coordination, and physical implementation of collaborative design decisions due to the time (and cost) required to achieve a model that is coordinated to the smallest details. In practice, the designers drew a line between what was reasonable to model and what was not and resorted to 2D design for pragmatic reasons. However, ultimately, this separation of the documentation as 'in-model' and 'out-of-model' caused increased transaction costs to operate and maintain such separation.

## DISCUSSION

Digitalisation in construction aims to improve coordination by better information management among construction project actors. This is supposed to lower transaction costs across the lifecycle by reducing the search, negotiation, and implementation costs of information via a shared digital medium. However, the analysis suggests that additional transaction costs arise to make such a shared digital medium functional under the existing professional and organizational arrangements. This highlights the need to understand the implications of digital technologies and processes on the interrelated transactions for both firm-level and project-level activities, to develop more viable technological, organizational, and business solutions.

In line with Reve and Levitt (1984) and Winch (1989), the analysis highlights that increased transaction costs arise because of the divergent interests of various actors, institutionalised and deep-routed traditions of professions as well as because of the diverging strategies needed to improve the performance of construction firms and projects. The ambition of integrating all the project information through a shared digital medium is mainly a strategy for improving project performance. However, this clashes with individual companies' requirements and interests which are different from each other. With the influence of deep-routed professional considerations, previous organizational relationships and the major concern of profit maximization, each project actor experiences different transactional costs for being integrated around a shared digital medium. This leads to various attempts of limiting the increasing transactional costs by pragmatic adjustments, which were previously captured by the organisational research on BIM, for example, as hybrid practices and workarounds (Çıdık and Boyd 2022).

In this context, the impact of digitalisation on transaction costs is not straightforward and can be expected to be different even from one project to another considering the different clan and professional relationships (Reve and Levitt 1984) that might exist as well as various formal procurement arrangements. Therefore, although developing an understanding of the shifting context of individual and collaborative working due to digitalisation (Çıdık *et al.,* 2017) is key to identifying the emerging and disappearing types of transaction costs of various activities, this would still show variations from one project to another. Thus, following Walker and Kwong Wing's (1999) argument that project management is itself a transaction cost, it can be argued that there is a need to tailor project and digital governance mechanisms on a project-by-project basis. This would need to taken into account both the previously established factors affecting transaction costs in construction and transaction costs that emerge, disappear, get reinforced or attenuated by digitalisation. Through such a wider understanding of transaction costs, it would be possible to decide the necessary arrangements at various levels of organisation and business arrangements.

## CONCLUSIONS

In conclusion, this research reveals that Transaction Cost Theory is an under-used theoretical tool that can expand the understanding of the misalignment between digital technologies and processes, and the established organisational and business practices in construction. More research is needed to develop a better understanding of the changing transaction costs for different types of activities for delivering, operating, and maintaining construction projects. This needs to consider the institutional, relational, professional, contractual, organisational, and business arrangements as well as the shifts in the contexts of these arrangements due to digitalisation.

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