RELATIONAL INVESTMENTS AND CONTRACTUAL CHOICES FOR DIVERSE ENGINEERING DESIGNS

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Abstract

Engineering design has a major impact on downstream performance, but is often guided, in both procurement and solution type, by intuition rather than a solid science base. Engineering is also increasingly collaborative, crossing organisational boundaries. However, the long-term close partnerships, as often proposed, are difficult to achieve in the context of individual engineering projects. Building on concepts related to investments in specific assets, this study *describes the underlying characteristics of engineering design investments and then prescribes the relational investment and contract forms to select them,* thereby contributing to our understanding of the engineering design and relational investments that can and should be made. We undertook multiple case study research, which is presented in two phases. The descriptive phase identifies positive outcomes for solutions based on off-the-shelf designs with fixed price mechanisms, for solutions based on adaptive designs with target cost mechanisms, and for bespoke solutions contracted either on cost-plus mechanisms or, if in bite-sized pieces, on fixed price mechanisms. Negative performance outcomes were found for adaptive solutions with Fixed Price mechanisms. A prescriptive phase, yielding a visualized model, then offers guidance for relational investments and contract mechanisms that are suitable for different engineering designs. Applicability zones and three potential transitions to challenge and guide current practice are developed to inform decision making.

Managerial relevance statement

Complex engineering projects are increasingly collaborative, involving multiple organisations, and involve innovative aspects. Sometimes these innovative aspects are developed especially for a single customer from fundamental research and development activity, whereas other times it may be possible to adapt previous engineering solutions. Clients of such projects must establish the conditions for project success through robust procurement approaches; on the one hand, contractors will be concerned that the risk and reward profile of their contracts is appropriate; on the other, there is little guidance for clients as to how to establish the right approach. Our paper focuses on establishing appropriate governance, including contractual forms and relational types, for different engineering design categories. This is operationalized through the concept of specialized investments. The descriptive model offers insights for practitioners into how governance is approached in a number of cases. The final visualized prescriptive model offers guidance for decision makers. Using our model, appropriate levels of relational investment, as well as a contract mechanism, can be aligned with different engineering design categories. Overall, we propose that the model forms an intellectual structure and rationale to form a strategy for appropriate investments, as well as a basis for facilitating discussions between clients and contractors.

I. Introduction

Tushman [1] proposed that the engineering management field has evolved towards complex contexts where innovation flourishes through intense collaboration between firms, where the latter has become a growing feature of contemporary engineering. However, collaborative engineering is characterized as more of a 'practiced art' than based on disciplined scientific rationale [2] and researchers and practitioners from engineering intensive sectors have found the types of long-term relationships proposed very difficult to adopt [3, 4]. In addition to this, when projects are complex and innovative they are typically addressed by newly formed teams. A common dilemma is that participants from inter-organizational groups must form a mutual understanding of design at the early stage of the project, but this is typically undertaken without the shared understanding accumulated from long-standing relationships [5]. Some engineering design work may be based on solutions that are well known, whereas others may be developed from first principles, involving significant uncertainty. Depending on the characteristics, different approaches, and hence different degrees of investment, for their management may be required [6, 7]. However, Dixon [4] argues that the approach is too often guided by intuition without a science base to inform decision making and organizational principles.

Through the development of Transaction Cost Economics (TCE), Coase [8] and then Williamson [9, 10] helped establish a theoretical understanding of the types of specialized investments made in transactions between firms, which act as the basis for relational ties through 'asset specific investments'. These may take the form of, for example, physical, people-based, process or technology based investments that are specific to a project or relationship, and Williamson asserts that they "have large and systematic organizational ramifications" [11] (p 53). However, the types of investments made in different engineering design environments, as well as the rationale for those investments, is less well understood. For large complex engineering projects, investments may have to be made in resources and expertise for adapting existing designs or for the infrastructure to develop novel technological solutions for bespoke designs [7].

In order to thrive, buyer-supplier relationships will need nurturing, development and a range of direct investments made [12, 13]. Relational investments can take many and varied forms in the pursuit of complex engineering solutions. It can refer to, for example, collaborating organizations establishing a Joint Venture or a consortia and committing to legal structures and requirements of that arrangement [14], or it can involve direct investments made as part of strategic relationship initiatives where direct investments are made in a long term relationship [12, 13], or it can be interpreted as project specific investments such as integrated or co-located teams [15] and alliancing approaches [16]. It is hoped that such investments align the interest of the organizations, lead to better processes and problem resolution across interfaces and a positive culture, resulting in a 'relational gain' in terms of performance outcomes [17].

Williamson [11] also underlined the critical role of contracting systems in safeguarding the interest of firms and organizing transactions. This is echoed in further studies of engineering management and complex procurement environments, which suggest that contracts influence performance outcomes and trust between the parties, as well as relational investment through incentivization and risk sharing mechanisms [18-20]. As Williamson highlighted [11], contracting systems are dependent on a complex interplay of transaction requirements, including investment characteristics and frequency. Further research proposes that appropriate contracts are required, but it is not clear what is appropriate for different engineering design scenarios [21]. The above issues are particularly pertinent in construction engineering, where prevailing procurement approaches appear to be unable to establish the appropriate conditions for success [22]. As has been noted in the construction management literature, there is little consensus for the organisation of procurement selection, and there are many potential influences on the choice of approach [23]. Systematic evidence to guide decisions is lacking.

Following Dixon [24, 25], we build on the agenda to contribute to scientific rationale and knowledge base for the management of engineering design through the development of descriptive (relating theoretical concepts to particular engineering design scenarios) and prescriptive models (providing guidance on what should be done in a particular situation). Such a design based approach has the potential to increase relevance and application potential, as it privileges knowledge pertaining to solving field based problems via the linking of problem context, potential interventions and potential outcomes [26]. Hence, the aim of this study is *to describe the underlying characteristics of the engineering design investments undertaken and then prescribe the relational investment and contract forms required to maximize the chance of project success.*

The descriptive and prescriptive models developed are important, as identifying the appropriate contracting and relational choices in engineering projects is vital for establishing conditions for success, and more guidance is required. The descriptive model represents the current situation, as derived from the case studies, and a structured approach is used to develop a prescriptive model, which can be used to guide investment decisions and contractual choices. As noted by Denyer [26], such prescriptive models rarely give a complete solution for any given business problem, but rather provide crucial inputs in specific areas of focus.

II. Literature review

Engineering Design and Management

Vollmar et al. [27, 28] suggest that a number of global forces are increasing the complexity and uncertainty related to departments managing engineering designs. Hence, different engineering approaches will be required depending on the technical complexity of engineering work, as well as the uniqueness and technological novelty involved. Vollmar et al. [28] suggest four engineering scenarios: Easy Engineering, exploiting existing standardised designs, Perfect Engineering, where the focus is on the delivery of large scale projects, requiring integration of existing technological solutions, Pioneer Engineering, where there is a high degree of complexity involving implementation of 'first-of-a-kind' projects, and Crisis Engineering, where there is a need to cope with serious situations. Organisations that operate in design intensive engineer-to-order scenarios, for instance in construction, shipbuilding, machinery and capital goods, must be vigilant to ensure that there is not an assumption that only the 'Easy Engineering' scenario exists. Hence, complexity and unexpected events cause considerable disruption because the coping mechanisms do not exist via 'Easy Engineering' approaches [27, 29].

One way in which complexity can be managed is by the introduction of the concept of a customer order decoupling point (CODP), which separates the supply chain into two key processes that can be categorized as make-to-order (or customer driven processes) and make-to-stock (or speculative processes) [30]. Engineering processes can be subjected to the same

logic, where some engineering activities are customer driven, and others are speculative [31]. This logic has been extended to develop a continuum of engineering design subclasses, where solutions may be developed from a very uncertain situation where a significant degree of innovative or customer specific engineering work are required, even to the point that new scientific principles, engineering testing, or new industry codes and standards must be developed for a specific client. At the other end of the continuum, existing designs can be used as a basis of a project solution with little adaptation or novelty [7]. A key idea advanced in this work is that the client or customer can engage with engineering design activities at different points in the process, resulting in different customisation and risk profiles.
Three broad categories of engineering design emerge:

- *'Off-the-shelf' designs* - take existing designs, drawings and subsystems as the starting point for the completion of engineering designs. Here we may find innovative reconfiguration of mainstream products, so parts of established designs (e.g. CAD drawings or product libraries) could be exploited to produce new customer driven adaptations. The primary risk in this category is of unsuitable customisation of existing designs [31].
- *Adaptive designs* – such engineering designs require either the creation or modification of codes and standards for a particular customer order, as well as those that develop novel designs which take such codes and standards as the starting point. Many complex civil and structural engineering schemes occupy this space, where innovative technical solutions must interact with International or National Standards, as well as codes developed by communities of practice. These have much in common with the technology standards explained in Narayanan and Chen [32]. The risk here is that adapting codes and standards will be very resource intensive and complex, if there are many interacting standards. Designs are developed on an individual basis from a 'blank sheet', or more precisely a set of codes and standards. Hence, the nature of innovation is in developing solutions that do not take existing designs as the starting point.
- *Bespoke designs* - research and development activities conducted 'to order' for the client in the development of engineering designs. Examples include customer specific scientific equipment development based on non-established principles, material science testing or engineering testing. There is a risk in this category that the proposed solution may not perform as intended, as the innovation is unique and unproven. Due to the high levels of uncertainty in co-operations in this domain, exchanges and contracts may be established under different principles [33].

Engineering and construction related industries have traditionally found relationships and partnering challenging to adopt in a formal sense, since projects have been seen as one-time transactions [34]. However, there is evidence of change, and academic models, as well as critique, have helped to specify how relational forms can be applied to engineering projects, either through strategic partnering arrangements across the supply base or through project partnering approaches [15, 17, 35], or through alliancing and collaborative procurement [16].

In order to reduce the adversarial conditions associated with traditional construction procurement, collaborative forms of procurement have been proposed to incentivize co-operation. For example, it may be possible to encourage early involvement of project team members through the procurement process, and also to establish risk sharing models where costs and benefits are shared jointly [22]. Principles of collaborative procurement can also be observed in alliancing, where mechanisms are put in place to align all project members [36], as well as integrated project delivery where there is a contractual agreement between many parties [15]. However, Thompson et al. [37] argue that relationships and contracts and relationships must be fit for purpose, but they note that there is little guidance for what is appropriate in different business conditions. Further, the evidence base for making these decisions is often piecemeal and anecdotal.

The choices for relational and contractual forms require an understanding of the project preconditions that influence procurement routes. A recent examination of formal contracts and relational governance argues that the interplay remains critical to performance, but suggest that choices are moderated by many institutional and contextual factors, which need to be more fully understood [38]. These could be the level of client experience and expertise, for example in their ability to articulate needs and requirements, as well as ability to control and manage projects [23]. Project characteristics, such as timing, complexity and risk have also been proposed as important influences [18, 21]. A key determinant is also the design solution and the associated uncertainty [7, 22]. As can be seen, a wide range of factors may affect procurement choice and no easy consensus exists to use as a basis for decision making [23].

To enable project partnering approaches, a key competence for engineering organisations is the development of a formalised and structured approach to configuring and managing the supply base [39]. This will involve a range of relationship types, including strategic relationships or very loose arms-length style relationships, high or low levels of trust, and norms that support the exchange, or alternatively, those that are more transactional [40]. More sophisticated firms will use a portfolio approach to structure the supply base so that different investments and approaches can be configured across a range of relational types [39]. The supplier development literature has begun to document efforts and investments made by industrial buying firms to improve the capability of its suppliers through different initiatives [12, 13].

Direct investments to improve suppliers may take many forms, including capital and equipment investments, financial investment, provision of human and organizational resources, and operational knowledge transfer activities [12, 13]. The reality for many engineering firms is that direct investment is only possible with a selection of close strategic partners but with less investment, or at least different types of investment, in looser relational categories [39]. This is linked with a well-developed premise in the literature that as the service provision and complexity of an exchange increases, for instance in the pursuit of an innovative solution, the intimacy between the parties should increase as firms become very interlinked [41, 42]. Hence, in a supply chain context the relationship type, from close to loose, can depend on the degree of alignment required for joint innovation [43], and a contingency approach is recommended [44].

Finally, at the project level, newer relational forms of contract have also started to blur the boundaries of contractual and relational in engineering work [36]. Contracts are a ubiquitous part of large complex engineering projects [20]. Due to the specialisations required, and scale and scope of such projects, work is typically broken down into work packages and contracted by a client. This in turn will yield levels of subcontracting. Researchers have argued that it is important to find the right contract in relation to the levels of uncertainty and investment characteristics of a project [18, 20, 21]. The fundamental way in which risk and incentives can be allocated by the contract is through financial mechanisms devised at the procurement stage [18, 19, 21]. Commonly used mechanisms, which form the basis for discourse for the contractual approach in industry settings in terms of the contract form, include a fixed fee at one end of the scale to a cost-plus model at the other [45]. Incentive schemes sit in the middle of this continuum, where employer and contractor share costs and profits according to a predefined rule or a collectively agreed target cost [46].

Transaction Cost Economics and Asset Specific Investments

TCE is primarily focused on overcoming the risks associated with opportunistic behaviours between a buyer and seller through the use of contractual arrangements. The theory is best known through the work of Coase [8] and Williamson [9-11]. TCE models the firm as a set of transactions, each of which can be conducted either in the market or by being internalized by the firm. Transaction costs represent the costs of undertaking an exchange that may occur for example between firms or within a supply chain. Three key factors are identified that impact on transactions: the presence of uncertainty, transaction frequency (one-time, occasional, and recurrent) and the specificity of the asset subject to exchange (non-specific, mixed, and highly specific or idiosyncratic) [11] (p. 79). Building on the previous phases of the literature review, we mobilize concepts to classify the degree of investment in engineering design ('off-the-shelf', adaptive and bespoke) and the relational linkages developed as a result of specific investments.

Asset specificity has emerged as a core concept in TCE, and is highlighted as the principal factor affecting transactions [47]. Investments in assets may be non-specific and re-deployable, or they may be specific to a transaction so that they cannot be redeployed elsewhere. Williamson [11] (p.95) defines this as "the degree to which an asset can be redeployed to alternative uses by alternative users without sacrifice of productive value." Since then, asset specificity has been interpreted in many different ways. De Vita et al. [48] categorize research using asset specificity and find that it has been interpreted in a number of ways, emphasizing, for instance, the degree of customization needed to support the transactional relationship or the value embedded in the continuance of the relationship. Williamson [10] (p. 526) distinguished site specificity (located 'cheek-by-jowl' to economize), physical asset specificity (e.g. specialised plant), human asset specificity (e.g. lessons learned) and dedicated asset specificity (e.g. investment in plant). In the context of our study, we are particularly interested in the specific types of investment made to support different types of engineering design. For example, when bespoke designs are developed, investments may need to be made in understanding requirements, analysing potential solution options and innovations, and mobilising resources to support these activities.

The specialized investments in assets of the types outlined above represent both a problem and an opportunity. In terms of the problem areas, specific investments create bilateral dependency or 'lock in', leading to potential contracting hazards such as opportunism by one of the parties in the transaction [47]. However, it can offer opportunities to be a source of uniqueness and competitive advantage, helping to offer customized services and solutions [49]. The challenge is to design and manage appropriate governance structures and relationships, based on the investment characteristics, to mitigate the problems and maximise the opportunities. In the construction engineering and management literature TCE has been interpreted and characterised in a number of different ways. Winch [50] notes that in the early phase of engineering projects, uncertainty is high but post-contract asset specificity is low for example in the supply of design and engineering services. For the later phases of a project, uncertainty tends to be lower, but post-contract asset specificity tends to be a lot higher due to the costs associated with replacing a contractor mid-way through the execution phase of a project.

III. Research Methods

Research Design and Setting

Dixon [24, 25] identifies the importance of descriptive and prescriptive models in developing scientific theory with respect to engineering design. Descriptive theory relates meaningful theoretical or knowledge-based constructs to particular design engineering environments, whereas prescriptive models seek to guide researchers and practitioners as to what should be done in a given environment. The logic of prescription can be seen as "offering a general template for the creation of solutions" [26], but this will often involve describing and understanding the generative mechanisms in detail first. The overall aims of such an approach are to answer 'how should things be?' (i.e. prescriptive knowledge), to build a 'design-oriented synthesis' to develop ideas on interventions, and to validate knowledge on pragmatic means to demonstrate how the knowledge may contribute to solving field problems [26].

The process of moving from descriptive to prescriptive models has been characterised by 'means-end analysis' [51]. Here, solution development and synthesis of concepts, representations of present states and desired states, understanding of generative mechanisms and potential outcomes, practical uses, as well as effectiveness of the design solution, all proceed through iterations and refinements [26, 51]. The approach is especially useful for creating practical knowledge for a challenging problem domain (in our case, determining the appropriate relational and contractual forms), and the design approach is not limited to physical artefacts, but also a wide range of design outputs such as guidelines, conceptual models, propositions, and rules [52]. In our study, the descriptive phase provided insights from the application domain to better understand assumptions, explain realities, as well as develop definitions and a work-in-progress framework.

We build on the above approach, developing firstly, from an extensive range of case studies, a descriptive model, and then, secondly, a prescriptive model of relational investments and contract forms for different engineering design investments. The overall design is visualized in Figure 1. It is also possible to see in figure 1 the nature of evaluation and iterations between models. The nature of evaluation moves from formative evaluation, feeding into the final models, to summative (as per [52]), and from describing the situation (i.e. descriptive) to developing solution guidelines (i.e. prescriptive). This iterative process involved the development of visualised models to guide prescriptions, whereby propositions are tentatively developed, and the potential consequences of prescriptions are evaluated via formative feedback and ongoing dialogue with practitioners.

The final summative evaluation concerns the potential effectiveness of the prescriptive model in use. Hence, alpha testing was conducted with case study participant interviewees along the research journey, and beta testing was conducted once the model reached a point of reasonable wholeness and completeness. The beta testing consisted, firstly, of 2 interviews, gathering feedback from a commercial director of a large main contractor and then a procurement consultant with over 30 years experience as a client procuring major projects. Secondly, the model was presented at 2 dissemination events (approximately 30 and then 100 industry participants).

Case studies should be selected with a good sense of purpose, appropriate to the aims of the study, and to best illuminate the phenomena under scrutiny [53]. Since our aim was to investigate the characteristics of investments in relationships and engineering design of complex projects, our multiple case study approach sought to include examples that illuminate different types of engineering design categories, as well as give insight into the relational and contract dimensions. This aligns with Seawright and Gerring's [54] suggestion to seek "useful variation on dimensions of theoretical interest". Our priority was to ensure coverage of the different engineering design categories (i.e. bespoke, adaptive and off the shelf), probe the types of relational investments made, and determine the appropriate contractual forms.

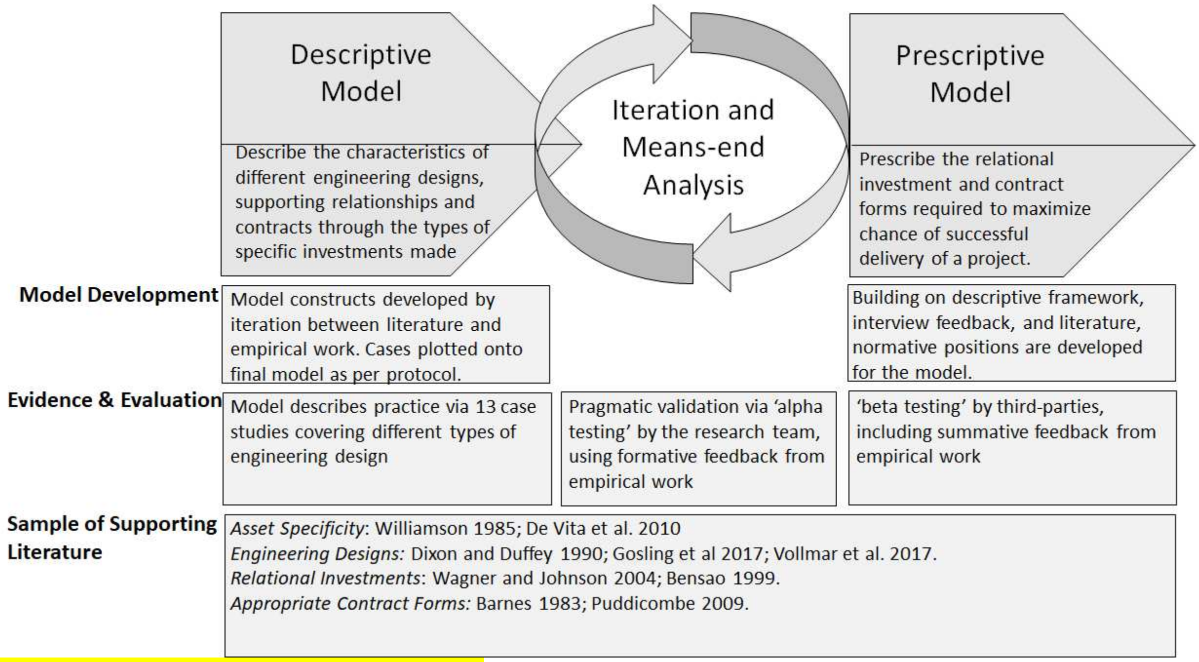

Figure 1: Overview of research design

The infrastructure sector is well placed for such exploration, as it offers a diverse and very complex range of case scenarios to study. The primary focus was on the engineering aspects, as performance outcomes are typically inhibited more by engineering design outcomes rather than manufacturing constraints [55, 56]. In addition, the sector has been slowly transforming, and programmes of reform have been encouraged to support longer term relationships and better governance [57]. Empirical investigation of relational and contractual interactions are best studied from the perspective of a dyadic relationship [58]. Hence, we sought to include these guidelines into our research design by gathering interview data from buyer and supplier. Case selection was purposively focused on, firstly, studying interesting complex engineering situations and their fit across theoretical engineering design dimensions of bespoke, adaptive and off the shelf engineering designs, and secondly, ability to obtain dyadic data and performance data in the public domain.

Case Study Research Methods, Protocol and Analysis

The case studies cover a wide range of complex engineering projects as summarised in Table 1, which also shows approximate values and duration of each project. A wide range of people were interviewed to inform the study, and these are also indicated in Table 1. For our interviewees, we sought senior people with deep knowledge of a particular exchange. We aimed to interview those who were involved in a particular contractual or relational procurement environment for (e.g. procurement directors, contract managers), technical experts to give insight into engineering designs (e.g. Chief Engineer), and more general managers or project managers. The key criteria were the extent to which an interviewee would be able to give insight into contractual and relational processes, as well as engineering processes. Interviews lasted approximately 1-2 hours but were longer if a tour of a site was included.

Project	Description	Value	Duration / Phase / Site Tour	Position of Interviewees
A	Aggregates and Materials for Road Schemes	£1.5bn (Whole Programme)	5 Years/ Mid project	Supply Chain Manager (Client) Programme Manager (Main Contractor) Account Manager (Subcontractor)
B	BEBO® style Bridge	£90m	2 years / Complete / Site tour and Tour of Engineering Office	Procurement Director (Client) Technical Manager (Main Contractor)
C	Wind Energy Towers	£20m	2 years / Complete / Tour of Manufacturing Facility and Engineering office	Operations Director (Main Contractor)
D	Motorway Improvement Project	£148m	2 years / Complete / Site Tour	Supplier Development (Client) Project Manager (Main Contractor)
E	Smart Motorways Scheme	£300m	4 years / Mid Project	Major Projects Manager (Client) Programme Manager (Main Contractor)
F	Viaduct 1	£150m	6 years / Complete	Procurement Director (Client) Performance Improvement Manager (Main Contractor)
G	Viaduct 3	£90m	3 years / Complete	
H	Railway Station Upgrade	£250m	4 years / Mid Project / Site Tour	Chief Engineer (Client) Project Manager (Main Contractor)
I	Major Rail Hub	£1bn	5 years / Mid Project / Site Tour	Chief Engineer (Client) Commercial Director, Contract Manager (Main Contractor)
J	Rail Tunnelling	£1.25bn	Mid Project / Tour of Project Office	Chief Engineer (Client) Technical Director (Main contractor)
K	Intelligent Concrete Trial	£1.6m	3 years / Mid Project / Tour of lab equipment	Principal Investigator (Contractor)
L	Mirror Segments	£5m	5-10 years / Mid Project / Tour of	Consortium Manager (Client/Contractor)

			Manufacturing Facility	Company Director (Technology Supplier)
M	Rail Electrification Scheme	£500m	3 years / Early Stage	Commercial Manager, Contract Manager (Main Contractor)

Table 1: Overview of Case Studies

Interviews followed a semi-structured protocol as shown in Table 2. The protocol proceeded through six stages, moving from more general introductions, to engineering design characteristics, and then discussions of the specific types of investment, contracts and governance, through to discussion of the performance implications. In addition to the interviews, guided site tours were included, which are indicated on the table. Interviews and tours were followed up with email validation of notes and key ideas discussed. For each case, a number of related documentary sources of information were sought. First, news and media releases which were in the public domain were reviewed. In particular, those that commented on project performance were of interest (e.g. time or cost). Second, in internal documents, such as project descriptions, project case studies written by companies, as well as project summaries were reviewed. These often gave information regarding technical/engineering design aspects.

Stage	Key topics and questions
Stage 1 – Establish Scope and Purpose	• General introductions and presentation • Agree an area to focus the discussion on
Stage 2 – Identify Engineering Design Category	• Key characteristics of engineering designs? Risks? • Nature of bespoke engineering work? • Nature of exchange relationship, and joint working on the engineering solution developed?
Stage 3 – Discussion of Relational Investments	• Exchange Partners? Relational initiatives in place? Type of linkages? • What investments have been made by the parties? • Recognised partnering, collaborative, alliancing forms?
Stage 4 – Discussion of Contracts	• Relational Structures? Informal ways of working? • Legal structure of relationships and contract form used? • Payment mechanisms and risk allocation within contract?
Stage 5 – Site Tour and follow up, including assessment of performance outcomes	• Summarise key points and give opportunity for further comment and clarification. • Interactions between relational and contractual arrangements, as well as impact on behaviour and performance?
Stage 6 – Coding, Analysis and Sense making	• Coding of different types of engineering design and associated characteristics. • Coding of relational investments. • Visualisation through models.

Table 2: Research Protocol

While success in projects is often seen as a difficult metric to fully quantify [59, 60] many revert to the so-called 'iron triangle', of time, cost and quality [61]. Absolute measures are not always easy to exploit for comparative purposes given the varying types, sizes and complexity of projects. Hence, in our cases, we have assessed the time variation, which is the difference between the actual and contracted timescale, and any cost overrun or underrun [59]. We determined if a project ran to time and budget by accessing either public domain data, given that a number of projects involved publicly funded infrastructure, and / or the project teams' own archived documents. Quality, whether as an absolute or relative performance measure is often associated with intangible perceptions as well as quantifiable attributes [62]. For our case studies we have exploited participant satisfaction as a proxy for overall quality, seen as an emergent property of a project as a whole system [79], based on interviewees satisfaction levels. Participants' satisfaction is a measure often exploited in recent research on construction performance [63] as it takes a whole systems perspective that is often difficult to quantify. This issue was explicitly addressed in stage 5 of the research protocol, where we asked 'How did the project perform and how did the relational and contractual conditions affect the performance of the project'. The case evidence was evaluated and analysed via regular reviews and debriefing sessions were undertaken by the co-author team. Cases were coded based on the characteristics of engineering design, as well as the characteristics of the relational investments. The contract types and form were also classified.

IV. Results and Analysis

Investment characteristics for different engineering design categories

Figure 2 provides an analysis and synthesis of the main investment characteristics for different engineering designs. They have been organized according to Asset Specificity concepts, as well as the engineering design categories established through the literature review. For brevity, figure 2 highlights the key investments that support the transaction.

	Site	Human	Physical/Digital	Dedicated
Off-the-Shelf Engineering Design		Achieving specific accreditations ensuring compliance against specifications (A)	Drawings for adaptation to system design to include bevelled ends (B)	Investments in adapting the assembly processes to suit design (C)
Relational		Dedicated technical teams to oversee adaptations (B)	Investments in good practice manufacturing for client specification (C)	Long term agreements on pricing and supplier investments in capacity (A)
Adaptive Engineering Design		R&D activities for girder connections and painting systems for confined spaces (G)	Investments in track realignment and signalling models (I)	Specific people and assets to design new tunnel boring technologies, techniques and equipment (J)
Relational	Integrated structure for site, people and assets (E, J). Co-location of teams (D, G, H)	Partnership formation activities at the tender stage to allow informal relationships to form (G)	Joint IT systems (J)	Integrated project team with dedicated resources (E, I, J)
Bespoke Engineering Design		Joint problem solving: new techniques in uncertain geographical conditions (M)	Investments in devloping 'new to the world' polishing programs (L)	
Relational	Consortia formed between start-ups and academics (L)	Knowledge and human related investments for the Consortia (L)	Investments in novel testing equipment (K)	Dedicated investigator time (K)

Figure 2: Synthesis of Investment Characteristics for different Engineering Design Solutions

For the 'off-the-shelf' solution category, which includes cases A, B and C, cases are characterised by commitments to longer-term supply arrangements, and the investments required to facilitate such relational time horizons. Case A refers to the supply of Aggregates and Materials for Road Schemes. Specific investments include commitments and administration costs relating to long-term supply arrangements through the category management framework, such as prices, amounts, and particular contractual provisions. Case B refers to a BEBO® Bridge Concrete Arch System standard design, which articulates construction standards and procedures to follow, including fabrication, handling and transportation, construction and installation, backfilling and inspection. Investments include technical teams, licensing fees, as well as commitments to manufacture pre-cast elements. Case C relates to the design of wind turbine towers. Designs are standard, meeting international guidelines and quality accreditation criteria, but are manufactured to order with no speculative stockholding. Investments include long term commitments to manufacturing capacity.

The adaptive engineering design solutions category includes cases D to J. Cases D and E relate to road infrastructure, where Case D refers to a Motorway Improvement Project near London and Case E is a 'Smart Motorway' scheme, which is being installed in various parts of the UK. The latter employs modern technology to manage, monitor, and increase the safety and reliability of journeys. The collaborative structure constitutes a Joint Venture, which includes specific employees and resources. This involves either new infrastructure, or significant upgrading of existing assets, and is procured under a Collaborative Delivery Framework, which has a longer-term focus with programme rather than project incentives.

Cases F and G are viaduct schemes. Both projects are large and complex, involving significant engineering work, including updating, strengthening and structural testing. Cases H, I and J are linked to the rail sector. Case H is a redevelopment of a major London station, including a new ticket hall, extended platforms and integration of existing lines and routes. Case I is a further station development project. To support the relationship, a formal partnership agreement developed with articulation of collaborative principles. This included alignment mechanisms, incentive payments, interface management protocols, and problem resolution. For the remodelling and redevelopment of a station, which is increasing passenger capacity through the station from approximately 50 million to 75 million per year. Case J refers to the tunnelling contracts for a major engineering programme to extend the underground infrastructure in London. The broader programme of work is managed as a Special Purpose Vehicle established by client, which includes framework mechanisms to encourage collaboration, training schemes, a structured innovation programme and specialist IT systems to support the project.

Bespoke engineering design solutions are characterised in cases K, L and M. Case K documents the developing of the use of intelligent concrete through real world trials of different concrete healing technologies in collaboration with an industrial partner. Case L refers to a next generation manufacturing technology feasibility study for large scale optics. The project, to provide seven segments for a large-scale telescope, makes use of a new process, and new developments in nanotechnology, so that the surface of each segment is polished to an extremely well defined profile within close tolerances. Case M relates to a special purpose joint venture was employed to manage the electrification of a section of rail infrastructure.

A descriptive model: categorizing cases, practices and outcomes

Figure 3 plots the cases onto a descriptive model. Building on the concepts established in the literature review, and the characteristics explained in the previous section, it brings together the design engineering category (i.e. the extent to which customer specific designs are developed) and the extent of specific relational investments made in the exchange (characterized as loose, moderate or close linkages between the organisations in the exchange). It also includes key elements of governance, including whether it is a recurrent or a single transaction and the type of contract payment mechanism used, as indicated in the key.

As shown in Figure 3, Cases A, C, E, J, and M are Recurrent transactions, where there are multiple transactions as part of the exchange, such as ongoing supply arrangements or multiple installations. All other cases are one-off projects, albeit some of which are projects of considerable complexity, value and duration. In the existing design category, Cases A and B display a greater degree of relational linkages. Both were linked via joint commitment to longer-term programmes of work, whereas Case C relates to a single transaction. In addition, cases A, B and C all used priced contracting mechanisms. In the solutions from adaptive engineering designs category, many of the exchanges had a relatively high degree of relational interlinkages. This reflects the sheer scale and complexity of some of the projects, and the investment that accompanies them. Cases J, E and I, in particular, displayed high levels of relational linkage. Cases G, D, H, I, E and J employed target cost mechanisms, whereas Case F was procured using a priced contract. In case G, the approach resulted in *an open and honest culture regarding the commercial aspects of the contract…with partners fully engaged as an integrated team" (Performance Improvement Manager).* In the bespoke solutions category, case K displays a transactional approach with very little linking of the organisations in the contract. Cases L and M had much higher levels of linkage through a Joint Venture and consortia structures. Case M initially employed a cost/time reimbursement contract, whereas L and K used priced mechanisms.

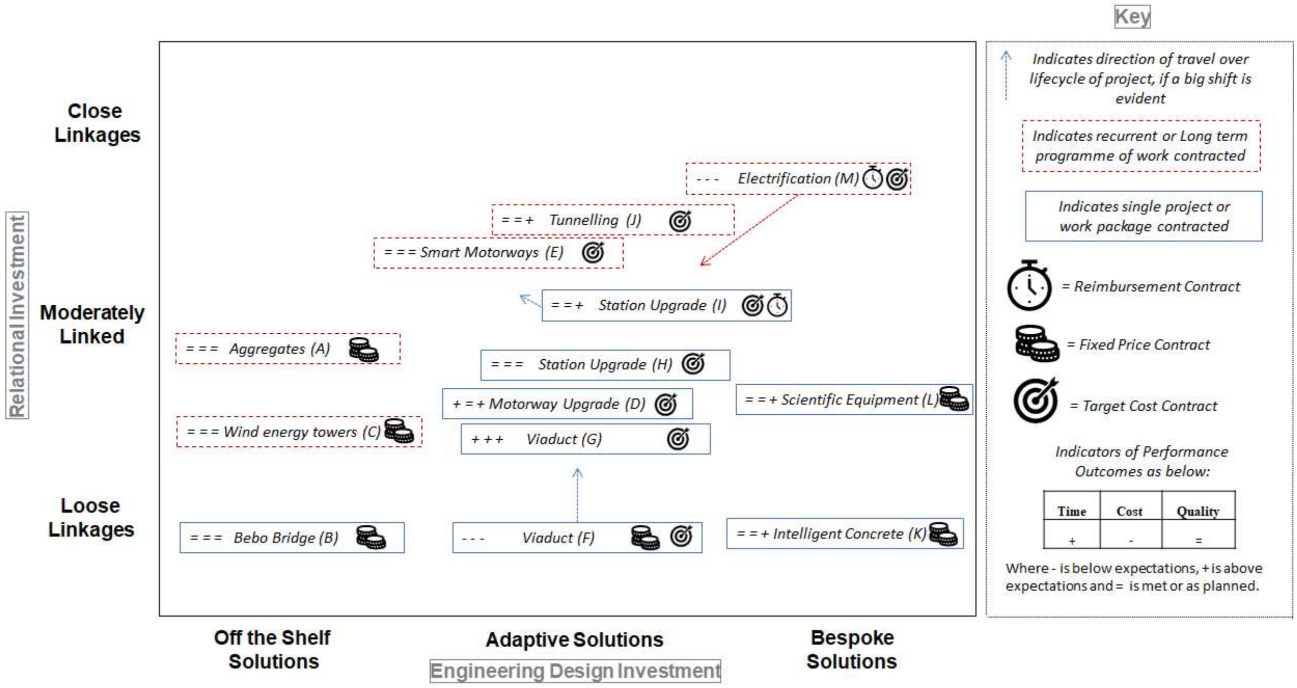

Figure 3: Descriptive model showing investment characteristics

The characteristics of Cases M and F altered significantly over time. Case F, a viaduct project, was initiated using a Fixed Price mechanism. However, problems with unforeseen conditions in the existing infrastructure led to increasing complexity of the engineering work. A Target Cost solution was developed and a 'partnering charter' was signed mid-way through the project to commit the different parties to joint working, hence increasing the level of relational investment. For the rail electrification project (Case M), the project began on a time and cost reimbursement basis. This later transitioned towards a target cost once greater technical certainty was established. Geological conditions, including consent, access and planning, all contributed considerably to uncertainty and complexity during the early phases of the project, as stated by the Contract Manager *"we developed detailed risk identification and mitigation plans, but these were difficult to assess and formalise, and discussions in this area had to be very sensitively handled"*.

In Case I, the project coalition started by working under a cost reimbursement plus fee structure, and moved to a bespoke target cost contract with gain sharing agreements, where profit is shared in an agreed portion above a specified target. To align the different parties and contracts, 'gives and gets' clauses were used, where incentive payments were stipulated for shared dates. These were in the form of Conditional Partnering milestones, and if collaborative milestones were met by delivery partners, a payment was made. Additional payments were made for partnering milestones to facilitate joined up thinking and objectives between delivery partners.

Figure 3 also gives indicators for the performance outcomes of the governance approach for the cases at the time of the data collection. Performance outcomes for off-the-shelf solutions are best described 'as planned'. Aside from Case F, other projects in the adaptive design category projects either exceeded performance expectations or were as planned. In Case F, *"Difficulties with technical changes and the form of contract led to a managerial focus being drawn towards time consuming contractual issues" (Performance Improvement Manager).* Whereas for Case I, the commercial director stated *"It is important to understand the capabilities of the client and the contractor, as well as the depth of relationships and entanglement of people and processes within the governance structure. Relationship is the most important dynamic for solving problems"*. For bespoke engineering designs, Cases K and L had largely positive performance outcomes, whereas Case M was negative.

Towards a prescriptive model for different engineering designs

Figure 4 provides a prescriptive model to help guide decision making for different types of engineering design. It gives guidance frontiers for appropriate contract types in different interaction zones of the model, as well as highlighting potential transitions. Positioned at the bottom left of the model, off-the-shelf engineering designs are developed and there is a relatively low level of relational investment. The joint commitment to innovation in engineering design is low, since there will be some form of off-the-shelf solution. Hence, a Fixed Price payment mechanism is appropriate in this scenario, and our analysis indicates that this approach leads to as planned performance outcomes, but only if there is certainty of requirements, expectations, operating environment and scope. This zone of the model is suitable for 'occasional supply contracts', where there is no longer term intent and uncertain prospects of future requirements.

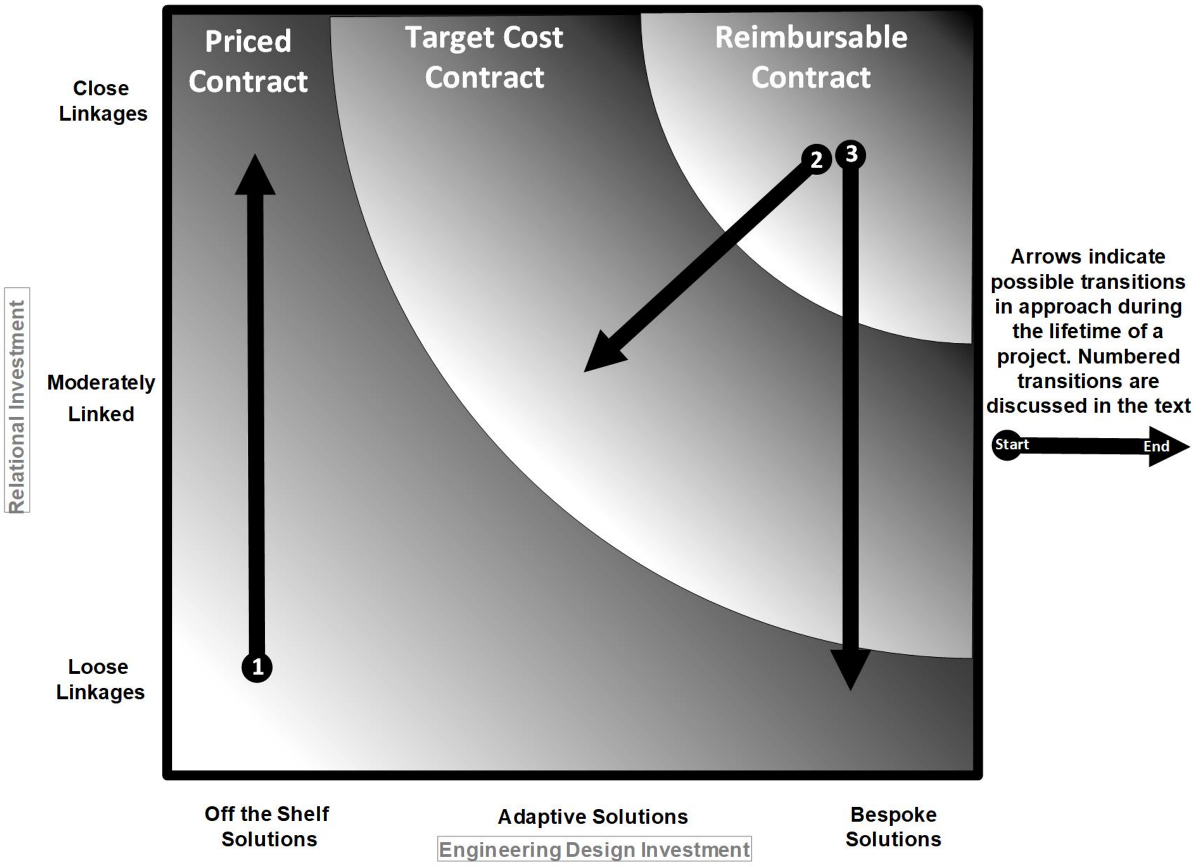

Figure 4: Prescriptive model showing investment characteristics and appropriate contract mechanisms

Situated at the top left of the model, solutions are still off-the-shelf, but here there may be a very long programme of work or set of recurring requirements, possibly over many years, hence, much more suitable for 'Long term supply contracts' or strategic partnering arrangement (as per [39]). While investment in engineering designs is low, the relational linkages will need to be high due to the longitudinal commitment. Fixed Price payment mechanisms may be appropriate here, but likely governed by an overarching framework agreement. Bespoke agreements may be needed to account for the characteristics of each long-term relationship.

Occupying the middle ground, adaptive designs interact with increasing investments in the relationship due to the complexity of projects. Target cost contracts, where the risks are shared between the parties, are more appropriate for this category, since scope may be difficult to determine at the outset. Hence, if a contractor must apply or integrate codes and standards as per adaptive engineering designs as a basis for an original design in order to arrive at the project solution, our empirical work indicates that a target cost payment mechanism will increase the likelihood of positive performance outcomes. Joint commitment may take the form of partnering charters, co-location, or joint ventures and special purpose vehicles for larger projects. Many 'major project governance' and project partnering approaches (e.g. [15]) may be positioned in this zone of the model.

Located at the top right of the model, bespoke solutions from research are developed, and large relational commitments are required to allow innovation to prosper. A reimbursement contract is more appropriate here. Consortia or Joint Ventures will likely be required to bring together the expertise and joint commitment to innovation. Hence, this is much more characteristics of the 'pioneer projects' described by Vollmar et al. [27, 28]. Situated at the bottom right of the model, bespoke solutions are developed but with lower relational linkages. In this category, novel work is likely to be packaged into a clearly scoped and manageable chunks of work, moving the area of endeavour towards its eventual endpoint in a series of discrete steps, any one of which will have limited consequences if it failed. Hence, the approach resembles 'bite size research and development'. A Fixed Price payment mechanism can be used in this category, although a bespoke arrangement may have to be considered depending on the needs of each bite size project.

The prescriptive model also identifies a number of potential transitions, which are identified via the arrows in Figure 4. The transitions challenge some typical industry practices, and it is envisaged that clients and contractors can create mechanisms to support these transitions as projects, programmes and requirements progress and become clearer. The proposed transitions can also guide potential two-stage contract designs. Transition 1 relates to off-the-shelf engineering designs. It begins with a loose linkage but moves the approach towards much closer relational linkages. This may be initiated due to a recognition of the strategic importance of a relationship, for example. as a result of very frequent need or rarity of the goods and services. This challenges the dominant logic across the construction industry, as noted in the literature review, for short term loose, transactional approaches. Where high volumes or regular demand can be stimulated, clients and contactors are encouraged to develop strategic partnering programmes to introduce stability and consistency to relational arrangements.

Transition 2 begins in the cost reimbursable zone, along with close linkages and bespoke engineering designs. However, as design factors become more certain and project environment is more settled, it may be appropriate to transition towards a target cost contract, along with more adaptive mode of design (as in case study M). This represents a more 'evolutionary' approach, allowing for more flexibility as project requirements unfold. Transition 3 charts a potential route from the same starting point as Transition 2, but follows a different trajectory. If the uncertainty and innovation is such that Transition 2 is not feasible, an alternative approach would be to split the bespoke solutions into small bite size chunks to be managed as a series of Priced contracts. This approach requires careful management, since discrete contracts will have to be scoped and delivered in line with a broader goal. Hence, good client capability and management of interfaces between contracts will be required, as well as the ability to articulate clear requirements and objectives for discrete bundles of work.

Building on the Beta testing, we conclude with table 3, which shows an evaluation of the implications for practice, strengths and weaknesses of the model. Based on this, we suggest that the model can be a starting point for client and contractor to open discussions about the type of engineering work to be undertaken and the potential choices to be made, particularly if there is an inexperienced client.

Source	Feedback	Implications / Strengths / Weaknesses
Interview 1	"The model does focus on key themes, and I have not seen it represented in this way….it helps to break the illusion that fixed price is the answer" "the overall procurement strategy relies on the interaction between a wide range of factors..…it's very difficult to rationalise	-Challenges the one-size-fits all approach to lump sum contracts, and gives new and different way of looking at procurement. -Helps to guide choices, particularly for those who are inexperienced. -There is a need to reflect more on when/ and where in the procurement process the

	this into a comprehensive logical model, as deep contextual knowledge is required".	model fits, and how the broader drivers of procurement approach are accounted for.
Interview 2	"The model provides a useful structure for governance or strategy document for clients" "There is a need to consider the client preparation that comes before the main procurement decision: development of requirements, vision, outcomes, specifications, knowledge needed" "Clients often overestimate their abilities to undertake true collaboration"	-Useful theoretical foundation for decision making, which can form the basis for formalising client approaches. - Helps to consider realities of partnering and the investment required. -There is a need to reflect more on the position of the client prior to the main procurement decision.
Dissemination Events	Example comments: "The model might be interpreted differently if you were a one off vs a repeat clients"..."Transition 2 is very similar to the ECI approach, where a contractor is involved early and then shifts into a different approach"..."the Oil and Gas industry suffers from similar challenges"	-There is a need for organisations contextualise the model for their purposes, situation and drivers. Some areas of prescription are recognised as valid approaches. -The model may be applicable in different engineering sectors, but further testing is required.

Table 3: Beta testing and evaluation by experienced practitioners

The prescriptive model indicates the implications of customer penetration concepts to guide the management of engineering designs, showing the implications of this for investment choices (e.g. how much relational investment should be undertaken). This is important, since, as previously noted, engineering work is becoming increasingly innovative, complex and collaborative. The model also offers more specific guidance for the types of investments within project contexts, where site teams are typically created and dismantled for one-off situations, so are different to prevailing business transactions that are accommodated more sufficiently by the theoretical frames. Finally, the model brings together related, but distinct concepts for engineering and construction procurement, synthesising different theoretical elements to offer new insights, and potential choices. The transitions offer novel approaches to challenge or guide existing practices.

V. Conclusions

At the outset, this paper aimed to describe the underlying characteristics of the engineering design investments undertaken and then prescribe the relational investment and contract forms required to maximize the chance of project success. We designed an empirical study to investigate the above aims and research issues with complex engineering projects as the research setting. This informed two phases: a descriptive and then prescriptive model development phases. The descriptive model characterises the types of investments made in different engineering designs with a focus on explaining the relational investments made across the case studies. Using indicators of cost, time and quality, the results of the empirical work show as planned performance outcomes for solutions based on off-the-shelf design with Fixed Price mechanisms, positive performance outcomes for solutions based on adaptive designs with target costs mechanisms, as well as bespoke solutions contracted on a Fixed Price basis. Negative performance outcomes were found for adaptive solutions with Fixed Price mechanisms and mixed results with cost reimbursement mechanisms. Relational initiatives, in terms of the strength and duration, likely play a moderating role in the above outcomes.

The prescriptive model builds on the previous phases, and supports decision making for different engineering design environments. It is intended to inform the choice of an appropriate strategy and structure for the nature of the products and services sought, and the long -term character of the relationship. It can inform different procurement approaches, including providing a rationale for when occasional supply contracts, long term supply contracts, project partnering and bite size research contracts may be appropriate. The model gives guidance frontiers to indicate the contract types that may or may not be suitable for the different areas of the model, as well as three transitions to challenge current practice and guide choices. In doing so, the paper contributes to a more systematic understanding of appropriate procurement approach in construction engineering. In particular, we develop knowledge related to TCE with respect to the types of specific investments made in different engineering design environments, and the digital assets that underpin those investments.

There are a number of implications for the management of engineering. First, there is the issue of how to procure innovative R&D engineering work. The model offers two different models for this. First, there is the option to undertake bite size R&D. In this case a client may choose to separate complex work into a number of distinct phases, and offer lump sum contracts for each. Alternatively, a client can procure R&D on a re-imbursement contract in the pioneer project space. The buyer and supplier would have to work closely to understand the problem, and the potential solutions. This would depend on the risk appetite and expertise of the client, as well as the nature of the problem, and the strength of the supply market. Then there is the issue of procuring solutions from existing designs. This may be done on a very transactional basis on a priced basis, with little relational commitment. Alternatively, if the work contributes to a long term pipeline of work, then it may be possible to justify longer term relational investments based on the promise of performance gains over time. The study also underlines to practitioners the important role of relational investments (which come at a cost) and the need for them to be tailored to the types of engineering being undertaken.

The insights and findings may be used by organisations to form a strategic justification and holistic approach, as well as a starting point for the planning of relational initiatives and investments. It provides an intellectual structure to establish the appropriate collaborative climate and incentivization through their contracting practices. Ideally, the engineering design category is identified early, there is early engagement between client and contractor, and then there are safeguards and processes in place to ensure that organisations stay connected in the right way over the exchange. The main limitation of the study is the ability to generalise. This is exploratory research, developed within the context of infrastructure projects, which we hope is repeated, reviewed and evaluated by subsequent studies. Further work is needed to extend the work beyond this context and establish the validity of the prescriptive model. The categories, zones, frontiers and transitions within the model represent somewhat idealised forms. In reality, it is likely that the zone boundaries are fuzzier than displayed in our model. It may also be possible that a reimbursable contract could be employed with loose relational linkages, if there is trust in professional credentials and reputation. Finally, we have focused on engineering design as a basis for decision making, but there may be a range of other factors, such as business planning, environmental factors, and health and safety, which may form the basis for project delivery structures. The transitions highlighted in the prescriptive model also require further research to test, substantiate, and better understand how they may be realised.

VI. References

[1] M. L. Tushman, "From engineering management/R&D management, to the management of innovation, to exploiting and exploring over value nets: 50 years of research initiated by the IEEE-TEM," *IEEE Transactions on engineering management,* vol. 51, pp. 409-411, 2004.
[2] S.-Y. Lu, W. ElMaraghy, G. Schuh, and R. Wilhelm, "A scientific foundation of collaborative engineering," *CIRP annals,* vol. 56, pp. 605-634, 2007.
[3] M. Bresnen and N. Marshall, "Building partnerships: case studies of client–contractor collaboration in the UK construction industry," *Construction Management & Economics,* vol. 18, pp. 819-832, 2000.
[4] J. Sanderson and A. Cox, "The challenges of supply strategy selection in a project environment: evidence from UK naval shipbuilding," *Supply Chain Management: An International Journal,* vol. 13, pp. 16-25, 2008.
[5] N. A. Gil, G. Biesek, and J. Freeman, "Interorganizational Development of Flexible Capital Designs: The Case of Future-Proofing Infrastructure," *IEEE Transactions on Engineering Management,* vol. 62, pp. 335-350, 2015.
[6] H.-B. Jun and H.-W. Suh, "A modeling framework for product development process considering its characteristics," *IEEE Transactions on engineering management,* vol. 55, pp. 103-119, 2008.
[7] J. Gosling, B. Hewlett, and M. M. Naim, "Extending customer order penetration concepts to engineering designs," *International Journal of Operations & Production Management,* vol. 37, pp. 402-422, 2017.
[8] R. H. Coase, "The nature of the firm," *economica,* vol. 4, pp. 386-405, 1937.
[9] O. E. Williamson, "Transaction-cost economics: the governance of contractual relations," *The journal of Law and Economics,* vol. 22, pp. 233-261, 1979.
[10] O. E. Williamson, "Credible commitments: Using hostages to support exchange," *The American Economic Review,* vol. 73, pp. 519-540, 1983.
[11] O. Williamson, *The Economic Institutions of Capitalism*. New York: The Free Press, 1985.
[12] S. B. Modi and V. A. Mabert, "Supplier development: improving supplier performance through knowledge transfer," *Journal of operations management,* vol. 25, pp. 42-64, 2007.
[13] D. R. Krause, R. B. Handfield, and B. B. Tyler, "The relationships between supplier development, commitment, social capital accumulation and performance improvement," *Journal of Operations Management,* vol. 25, pp. 528-545, 2007.
[14] B. Garrette and B. Quelin, "An empirical study of hybrid forms of governance structure: the case of the telecommunication equipment industry," *Research Policy,* vol. 23, pp. 395-412, 1994.
[15] P. Lahdenperä, "Making sense of the multi-party contractual arrangements of project partnering, project alliancing and integrated project delivery," *Construction Management and Economics,* vol. 30, pp. 57-79, 2012.
[16] E. W. Cheng, H. Li, P. E. Love, and Z. Irani, "Strategic alliances: a model for establishing long-term commitment to inter-organizational relations in construction," *Building and Environment,* vol. 39, pp. 459-468, 2004.
[17] J. Gosling, W. Abouarghoub, M. Naim, and B. Moone, "Constructing supplier learning curves to evaluate relational gain in engineering projects," *Computers & Industrial Engineering,* 2018.
[18] M. Barnes, "How to allocate risks in construction contracts " *International Journal of Project Management,* vol. 1, pp. 24-28, 1983.
[19] R. Patterson, "Using NEC contracts to manage risk and avoid disputes," *Proceedings of the Institution of Civil Engineers–Management, Procurement and Law,* vol. 162, pp. 157-167, 2009.
[20] M. S. Puddicombe, "Why contracts: evidence," *Journal of Construction Engineering and Management,* vol. 135, pp. 675-682, 2009.

[21] C. M. Gordon, "Choosing Appropriate Construction Contracting Method," *Journal of Construction Engineering and Management,* vol. 120, pp. 196-210, 1994.
[22] P. J. C. M. Lahdenperä, "Conceptualizing a two-stage target-cost arrangement for competitive cooperation," *Construction Management*

Economics, vol. 28, pp. 783-796, 2010.
[23] P. E. Love, M. Skitmore, G. J. C. M. Earl, and Economics, "Selecting a suitable procurement method for a building project," vol. 16, pp. 221-233, 1998.
[24] J. R. Dixon, "On research methodology towards a scientific theory of engineering design," *Ai Edam,* vol. 1, pp. 145-157, 1987.
[25] S. Finger and J. R. J. R. i. e. d. Dixon, "A review of research in mechanical engineering design. Part I: Descriptive, prescriptive, and computer-based models of design processes," vol. 1, pp. 51-67, 1989.
[26] D. Denyer, D. Tranfield, and J. E. Van Aken, "Developing design propositions through research synthesis," *Organization studies,* vol. 29, pp. 393-413, 2008.
[27] J. Vollmar, M. Gepp, H. Palm, and A. Calà, "Engineering framework for the future: Cynefin for engineers," in *Systems Engineering Symposium (ISSE), 2017 IEEE International*, 2017, pp. 1-5.
[28] J. Vollmar, M. Gepp, and A. Schertl, "The future of engineering—scenarios of the future way of working in the engineer-to-order business," in *Systems Conference (SysCon), 2017 Annual IEEE International*, 2017, pp. 1-5.
[29] J. Gosling and M. M. Naim, "Engineer-to-order supply chain management: A literature review and research agenda," *International Journal of Production Economics,* vol. 122, pp. 741-754, 2009.
[30] J. Wikner, M. M. Naim, and M. Rudberg, "Exploiting the order book for mass customized manufacturing control systems with capacity limitations," *IEEE Transactions on Engineering Management,* vol. 54, pp. 145-155, 2007.
[31] J. Wikner and M. Rudberg, "Integrating production and engineering perspectives on the customer order decoupling point," *International Journal of Operations & Production Management,* vol. 25, pp. 623-641, 2005.
[32] V. Narayanan and T. Chen, "Research on technology standards: Accomplishment and challenges," *Research Policy,* vol. 41, pp. 1375-1406, 2012.
[33] J. Lerner and U. Malmendier, "Contractibility and the design of research agreements," National Bureau of Economic Research2005.
[34] G. Briscoe and A. Dainty, "Construction supply chain integration: an elusive goal?," *Supply Chain Management,* vol. 10, pp. 319-326, 2005.
[35] M. Bresnen and N. Marshall, "Partnering in construction: a critical review of issues, problems and dilemmas," *Construction Management & Economics,* vol. 18, pp. 229-237, 2000.
[36] P. Davis and P. Love, "Alliance contracting: adding value through relationship development," *Engineering, Construction and Architectural Management,* vol. 18, pp. 444-461, 2011.
[37] I. Thompson, A. Cox, and L. Anderson, "Contracting strategies for the project environment," *European Journal of Purchasing & Supply Management,* vol. 4, pp. 31-41, 1998.
[38] Z. Cao and F. Lumineau, "Revisiting the interplay between contractual and relational governance: A qualitative and meta-analytic investigation," *Journal of Operations Management,* vol. 33, pp. 15-42, 2015/01/01/ 2015.
[39] J. Gosling, M. Naim, D. Towill, W. Abouarghoub, and B. Moone, "Supplier development initiatives and their impact on the consistency of project performance," *Construction Management and Economics,* vol. 3, pp. 390-403., 2015.
[40] A. Cox, "Relational competence and strategic procurement management: towards an entrepreneurial and contractual theory of the firm," *European Journal of Purchasing & Supply Management,* vol. 2, pp. 57-70, 1996.
[41] J. T. Mentzer, S. Min, and Z. G. Zacharia, "The nature of interfirm partnering in supply chain management," *Journal of Retailing,* vol. 76, pp. 549-568, 2000.

[42] A. H. Bask, "Relationships among TPL providers and members of supply chains - a strategic perspective," *The Journal of Business and Industrial Marketing,* vol. 16, pp. 470-486, 2001.

[43] N. F. Piercy, "Strategic relationships between boundary-spanning functions: Aligning customer relationship management with supplier relationship management," *Industrial Marketing Management,* vol. 38, pp. 857-864, 2009.

[44] D. Prajogo, C. Mena, and A. Nair, "The fit between supply chain strategies and practices: A contingency approach and comparative analysis," *IEEE Transactions on Engineering Management,* vol. 65, pp. 168-180, 2018.

[45] A. Davies, M. J. Dodgson, and D. M. Gann, "Innovation and flexibility in megaprojects: A new delivery model," 2017.

[46] J.-J. Laffont and J. Tirole, *A theory of incentives in procurement and regulation*: MIT press, 1993.

[47] M. H. Riordan and O. E. Williamson, "Asset specificity and economic organization," *International Journal of Industrial Organization,* vol. 3, pp. 365-378, 1985.

[48] G. De Vita, A. Tekaya, and C. L. Wang, "The many faces of asset specificity: A critical review of key theoretical perspectives," *International Journal of Management Reviews,* vol. 13, pp. 329-348, 2011.

[49] S. Balakrishnan and I. Fox, "Asset specificity, firm heterogeneity and capital structure," *Strategic Management Journal,* vol. 14, pp. 3-16, 1993.

[50] G. M. Winch, "Governing the project process: a conceptual framework," *Construction Management & Economics,* vol. 19, pp. 799-808, 2001.

[51] J. Holmström, M. Ketokivi, and A. P. Hameri, "Bridging practice and theory: a design science approach," *Decision Sciences,* vol. 40, pp. 65-87, 2009.

[52] J. Venable, J. Pries-Heje, and R. Baskerville, "A comprehensive framework for evaluation in design science research," in *International Conference on Design Science Research in Information Systems*, 2012, pp. 423-438.

[53] R. K. Yin, *Case study research: design and methods*, 3rd ed. London: Sage publications, 2003.

[54] J. Seawright and J. Gerring, "Case selection techniques in case study research a menu of qualitative and quantitative options," *Political Research Quarterly,* vol. 61, pp. 294-308, 2008.

[55] J. R. Dixon and M. R. Duffey, "The neglect of engineering design," *California Management Review,* vol. 32, pp. 9-23, 1990.

[56] C. Y. Baldwin and K. B. Clark, *Design Rules: The power of modularity* Cambridge, MA: MIT Press, 2000.

[57] S. M. Latham, "Constructing the team," Department of the Environment1994.

[58] M. Howard, J. K. Roehrich, M. A. Lewis, and B. Squire, "Converging and Diverging Governance Mechanisms: The Role of (Dys) Function in Long-term Inter-organizational Relationships," *British Journal of Management,* 2017.

[59] A. P. Chan and A. P. Chan, "Key performance indicators for measuring construction success," *Benchmarking: an international journal,* vol. 11, pp. 203-221, 2004.

[60] K. Jha and K. Iyer, "Commitment, coordination, competence and the iron triangle," *International Journal of Project Management,* vol. 25, pp. 527-540, 2007.

[61] R. Atkinson, "Project management: cost, time and quality, two best guesses and a phenomenon, its time to accept other success criteria," *International journal of project management,* vol. 17, pp. 337-342, 1999.

[62] B. G. Dale, T. Van der Wiele, and J. Van Iwaarden, *Managing quality*: John Wiley & Sons, 2007.

[63] S. Kärnä, J.-M. Junnonen, A.-P. Manninen, and P. Julin, "Exploring project participants' satisfaction in the infrastructure projects," *Engineering Project Organization Journal,* vol. 3, pp. 186-197, 2013.