The Application Of Lean Principles To In-Service Support: A Comparison Between Construction And The Aerospace And Defence Sectors

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Abstract

Lean principles have shaped the automotive sector's success in reducing costs and improving performance. Other industry sectors such as aerospace and construction in the U.K. have pursued similar benefits by similar means with differing degrees of success. An acknowledged vein of research in the transaction cost economics and relational contracting fields, emphasises the importance of informal norms and formal, legal documents and doctrines in commercial relations. This research illustrates that written agreements are influenced by the parties' past relations, each one's perception of the other's reputation, future business prospects, as well as influences from the external environment.

This paper argues that a successful and thorough application of lean principles is predicated on establishing these relational contracting norms and formal contracts which, we argue, promote an environment for fully rendering lean principles. We present a comparison of the construction and aerospace and defence sectors which have attempted to follow the automotive lead and apply lean principles in somewhat different environments. Their experiences in aftermarket and in-service support operations provide preliminary evidence supporting the paper's central hypothesis. In effect, the construction and aerospace and defence sectors have adopted different positions relating to the importance of contractual structures in the pursuit of business improvement and as a result, have had varying success in the implementation of 'lean' approaches.

Keywords: Lean, Contract, Law, Relational, Incentives, Aerospace, Construction

Introduction

Background on Lean Thinking and Relational Contracting

The essential nexus between lean principles and transaction cost economics is to reduce costs by eliminating waste whilst increasing efficiency. From a cost reduction perspective, if duplication of resources is to be eliminated, all parties to the entire transaction should jointly agree processes and a commitment to co-operate. The logical extensions of these objectives are collaborative working relations, grounded in formal and informal norms. The significance of relational characteristics for commercial contracting is well-established as being as much a part of a contract as formal legal

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doctrines (Macaulay, 1963; Macneil, 1974a, 1973b, 1978, 1981, 1985; Beale and Dugdale, 1975; Deakin, Lane and Wilkinson, 1997). However, there is an entrenched perspective that contracts are placed in a metaphorical bottom drawer and consequently, they do not undermine collaborative working relations. Conversely, a contemporary line of research (Cullen, Keast and Simpson, 2002; Cullen and Hickman, 2001; Cullen, 2004), including the ECLOS[5] and LOTISS[6] research projects, challenges this perception and suggests that contract forms have a major impact on transacting parties' perspectives of their past and future relationships, which significantly influence their stance whilst they are negotiating and performing of their formal obligations. Therefore, unnecessary waste and thus transaction costs are created when contract forms fail to reflect the parties' common relational objectives. In extending this theme, formal contracts have a major impact on the efficiency gains from applying lean principles but the symbiosis between these two factors is the focus of this paper and our fundamental research strategy.

Overview of the Lean Principles

Toyota Motor Company of Japan developed the principles of Lean Production in the late 1950s and early 1960s, under the production engineering leadership of Taiichi Ohno. The application of lean production methods was one of the key success factors in the dramatic competitive advantage gained by the Japanese car industry through the 1970s and into the 1980s (Womack, Jones and Roos, 1990; and Womack and Jones, 1996.)

The concept of lean is best summed up with a direct quotation from "*Lean Thinking*":

> *In short, lean thinking is lean because it provides a way to do more and more with less and less – less human effort, less equipment, less time and less space – while coming closer and closer to providing customers with exactly what they want.*

The Lean Principles as defined by Womack et al (1990) can be summarised as follows:

- Define value from the perspective of the Customer
- Map the value stream
- Create flow
- Allow Customer demand to pace and pull production
- Manage continuous improvement and pursue perfection

The guiding ethos of 'Lean' is the identification and continuous elimination of waste in all its forms. The Toyota Production System defines seven types or categories of waste ("The Seven Wastes").

- Overproduction
- Waiting
- Transportation
- Inventory
- Motion
- Over-processing
- Defectives

The quintessential tool for the clear identification of waste within a value stream has become the technique of Value Stream Mapping. The methodology for the application of this tool is detailed in the publication "*Learning to See*" (Rother and Shook, 1998) and is advocated by Womack and Jones. The technique involves the construction of a detailed map of the value stream in its current state, which identifies the sources of waste in

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[6] *Long-Term In-Service Support*: University of Warwick, funded by EPSRC, UK Ministry of Defence, construction, defence and aerospace companies

the current condition. An ideal or utopian state is then considered, before a specifically targeted improved future state is constructed. The improvements are driven by the removal of the waste identified in the current state map. An action plan is then formulated which migrates the value stream from the current state to the targeted future state, within a defined period of time. Once that future state has been achieved, the improvement cycle is repeated continuously.

The Lean Principles, in the context of this methodology, have been extensively and successfully applied to the automotive sector and other medium to high batch size, original equipment production environments. High variety, low volume industries have been slower to apply the principles, in common with the aftermarket and in-service support operations across many sectors.

Overview of Relational Contracting

Following Macaulay's (1963) pioneering empirical study of commercial contracting, Macneil (1974a; 1974b) proposed that present and future contracting relations are embedded with links between the corporations, which affect the progress and outcomes of transactions. This led Macneil to suggest that when parties expect to work together again in the future, they approach and manage their current transaction in the manner in which they perceive their relationship might proceed. In expanding his theme, Macneil (1978a, 1981) suggested that peoples' behaviour and the social context in which they function influences the outcome of the transaction.

Macneil (1974a; 1974b; 1978) proposes that contracts are complex bundle of relations that evolve from informal norms that include the:

- Relationship between competition and co-operation
- Implementation of planning
- Preservation of the relationship
- Parties' reputation
- Interdependence
- Morality and altruism
- Shared benefits and burdens
- Problems anticipated as a matter of course
- Adjustments to accommodated changes in circumstances
- Ongoing, flexible relations

Macneil perceives that contractual relations resemble small, nuclear societies, with their own internal system of evolving norms. In addition to these traits that are internal to the social perimeter of the transaction, Macneil also cites the external environment as a norm that affects the contract as a social structure.

Over a decade, Macneil (1981) reclassified his original five norms into relational, common and discrete traits. This concept is illustrated in Table 1, with relevant examples.

Table 1: How Norms Affect Aerospace Contracting (Macneil 1974a; 1974b; 1978)

Norms	Aerospace examples	Construction examples
1) Relational For their mutual benefit, the parties:		
Work together on the basis of flexibility and reciprocity in their mutual benefit. Remain separate economic units, whilst collaborating	'Risk and revenue share' deals incorporating asset management or 'fleet hour' arrangements. Formalised requirements development phase post contract award.	Prime contractor embedded within the client organisation, acting as Construction Manager for the client, undertaking serial construction projects within the context of a framework agreement
2) Common The parties have a united approach to:		)
Preserving their relationship as they predict that they will work together in the future Harmonious dispute dissolution rather than conflicts Changes in the external environment	Contractors collaborate on contracts whilst also competing on others Conflicts resolved internally; rarely do the parties resort to litigation or arbitration	Prime contractors retaining the services of preferred sub-contractors on serial construction projects
3) Discrete The parties freedom to contract is limited in their mutual interests by:		
Restricting their individual freedom to choose how to execute the contract Accepting that they must take the consequences of focusing on the outcome of the contract, which restricts the individual party's freedom to act in its immediate interests	The MoD standard forms of contract restrict the parties ability to negotiate Suspension of strict legal rights during performance, to focus on a successfully completed contract	'Arms length' Local Authority contracting

Macneil's theory is relevant to exchanges because contracts between aerospace and construction companies are long-term, with typical aircraft lifecycles lasting for 20 to 25 years (Cullen and Hickman, 2001; Cullen, Keast and Simpson, 2002; Cullen, Hickman, Keast, 2004). The long-term relations are embedded because aircraft must be overhauled and repaired according to regulatory requirements. Therefore, to safeguard future suppliers of spares units, airlines ensure that prime contractors are contractually bound to produce spare parts for the duration of an aircraft's lifecycle. Not only do the same contractors work together on specific aircraft, their relationship is embedded across its lifecycle and frequently across families of aircraft that share common systems.

There is evidence that relational contracting is used in the civil aerospace industry to maximise the potential benefits from implementing lean principles (Cullen, Hickman, Keast and Butcher, 2004). In the US construction sector, there are parties to public and private sector projects that are developing collaborative and flexible alliances to ensure that the neo-classical (Williamson, 1979) basis of formal contracts does not impede the efficiency gains from their transactions. In the UK, there is a discernable use of more relational contract forms (Cullen, Hickman, Keast and Butcher, 2004)

Transaction Cost Economics and Relational Contracting

The evolution of transaction cost economics (Williamson, 1974) was influenced by Macneil's perspective of the contract as a bundle of social norms, which were as

significant as legal doctrines and formal agreements. In applying Coase's (1937) reasoning regarding firms' choices, to source externally or within their organisation, Williamson recognised that contractors develop relationships and formal agreements according to their assessment of their use as means of efficiently governing projects. In extending the work of Coase and Macneil, Williamson (1996) compares how transactions are managed. In common with Macneil, Williamson's focus spans entire exchanges from their conception to post completion stages.

Relevance of Contracts and Lean to a traditional procurement model

Traditional procurement has focused primarily on the initial cost of the acquisition and the technical specification of the product to be delivered. Once acquired the product then has to be supported, often under complex contractual arrangements derived from the original procurement. Typically there was no attempt to assess and minimise the overall life-cycle costs of the acquisition making the procurement process both costly and inefficient. This was particularly true in military procurement where in the (Levene, 1987) fixed price contracting environment, the Defence Procurement Agency (DPA) has used its position and power to drive prime contractors into accepting contracts on extremely low margins (Taylor, 2001). In civil aerospace similar practices have been employed by large airframe manufacturers. Often the only way that a prime contractor can remain in business, let alone make a reasonable return on investment has been to use every possible opportunity to slash costs by taking "short cuts"[7] in the delivery of the original equipment and to attempt to make money on the after-sales spares and maintenance contracts. The differences between the defence and civil sectors of aerospace and construction with respect to the influence of prime contracts on formal and informal norms throughout the supply chain reveal an important correlation with the application of lean principles.

It can also be argued that some aspects of the traditional approach to competitive tendering and contracting can actually add waste to the process. The traditional approach can result in multiple sources of supply which clearly duplicates resources and erodes economies of scale. Even if multiple sources are avoided, traditional approaches can result in large costs for multiple protagonists involved in an extensive bidding process, all but one of which will have effectively wasted that investment. Lastly, an arms length relationship between customer and supplier will often lead to a situation where only a part of the value stream is under consideration for improvement. Typically, this comes about when the value stream crosses the organisational boundary between the parties and the customer denies the supplier access to its internal environment. There is always a risk under these circumstances that the application of the lean principles will not yield the expected benefits, simply because the rate governing constraints or 'bottlenecks' are not present in the portion of the value stream under consideration.

Contracts and Lean in Support-oriented Procurement

Since the late 1990s, with the introduction of the Smart Procurement Initiative (SPI, MoD, 1999[8]) the DPA and Defence Logistics Organisation (DLO) (Support Chain Integrated Business Team, 2001) and civil aerospace contractors have endeavoured to consider the impact of long-term support by contracting for complete packaging of projects. The overriding objective is to minimise the total cost of ownership of a particular aerospace product whilst promoting good working relationships and securing the future of the aerospace supply chain. In civil aerospace this has lead to the increasing popularity of 'power by the hour' or 'fleet hour' (Cullen, 2004) agreements.

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7 Private conversations with industry managers 1999-2005

8 Ministry of Defence (1999) T*he Acquisition Handbook: A Guide to Smart Procurement*, Ministry of Defence, London

These contracts are drafted on the basis that the product provider bears the full cost of support and in return, it is paid a set amount for each flying hour.

Empirical research suggests (Cullen, 2004; LOTISS; ECLOS) that the common elements in Power-by-the-Hour (PbH) and Asset Management Agreements (AMA) are long-term contractual relations, normally of between 5 and 7 years, with a supplier's obligations involving high degrees of product support in addition to supplying equipment. In both PbH and AMA contracting, the operators' acquisition and lifecycle support costs are spread over the duration of the contract, with the price being fixed and payable at monthly intervals. From the suppliers' perspective, they have predictable markets and revenue streams during the contract terms, in addition to being incumbent suppliers when the contracts are due for renewal.

The PbH form of contract provides an enhanced level of support in comparison to contracts for the sale of equipment; they are essentially time and materials contracts. In comparison, an AMA represents an extension of the PbH arrangement that provides the highest level of support to airline operators. The formal agreement represents an overriding agreement to govern the business relationship between an airline and producer/service provider. In addition to the normal "boiler plate clauses," (Berg, 1991) the AMA covers the management and planning of the physical stock and long-term service-support. It also includes the planning and management processes, with the supporting communications and logistics structures to manage both predicted and unforeseen events.

These transactions give the customer a fixed cost base and provide a strong incentive for the suppliers to reduce their own costs and increase the profitability of the transaction. There is broad interest within both civil and military aerospace in initiatives to reduce the high costs of in-service support and thus it is developing strategies to tackle both the relevant symptoms and the root cause. This two-pronged attack can be supported both by internal improvement initiatives and by longer-term research into possible approaches to the root causes and their solutions.

While there are common strands between principles of relational contracting and lean practices that collaboration is an essential factor in realising economic efficiencies, there are also divergences. Lean theorists exclude the role of formal legal doctrines and documents, whilst relational schools have not considered manufacturing strategies. This paper attempts to synthesise both strands by establishing a link between them by presenting evidence from our research into the business relationships between the UK's Ministry of Defence (MoD) and its aerospace and construction supplier.

Background on LOTISS Research and Current Context

The long-term research objective of the LOTISS team is to improve the efficiency of inter-firm relations by comparing four principal facets of typical construction and aerospace transactions. These facets are classified into the two broad groups of contractual or managerial elements. The contractual element contrasts the developments in parties' relations and the attendant procedures that culminate in a formal agreement, then how they plan and manage these arrangements. Similarly, the managerial element assesses the principles and their supporting processes whereby the parties govern the transaction to achieve economic efficiency and maintain their competitive position. This broad objective was initially developed during the ECLOS research programme, based on the hypothesis that current standard forms of contracts and arms length contractual relations leads to adversarial working relationships between contract parties. The effect was proven to increase transaction costs and undermine the efficiency gains that parties intended from reengineering strategies. This line of research is being developed by the LOTISS team, to develop strategies for minimising the cost of long-term support of aerospace and construction programmes.

The overbidding of LOTISS is to increase the efficiency of long-term support projects provide a migration path from existing modes of support to those proposed by the research, focusing particularly on contractual issues. Within this objective, the particular focal points contractual issues, risk identification and reduction and the applicability of lean principles to long-term transactions.

Methodology

The methodology was constructed from five principal sources. These were: a review of the theories of lean principles, contract, and industrial economics research methods (Leedy, 1998), and the contextual basis of the aerospace and construction industries (ECLOS). The research process is illustrated in Figure 1:

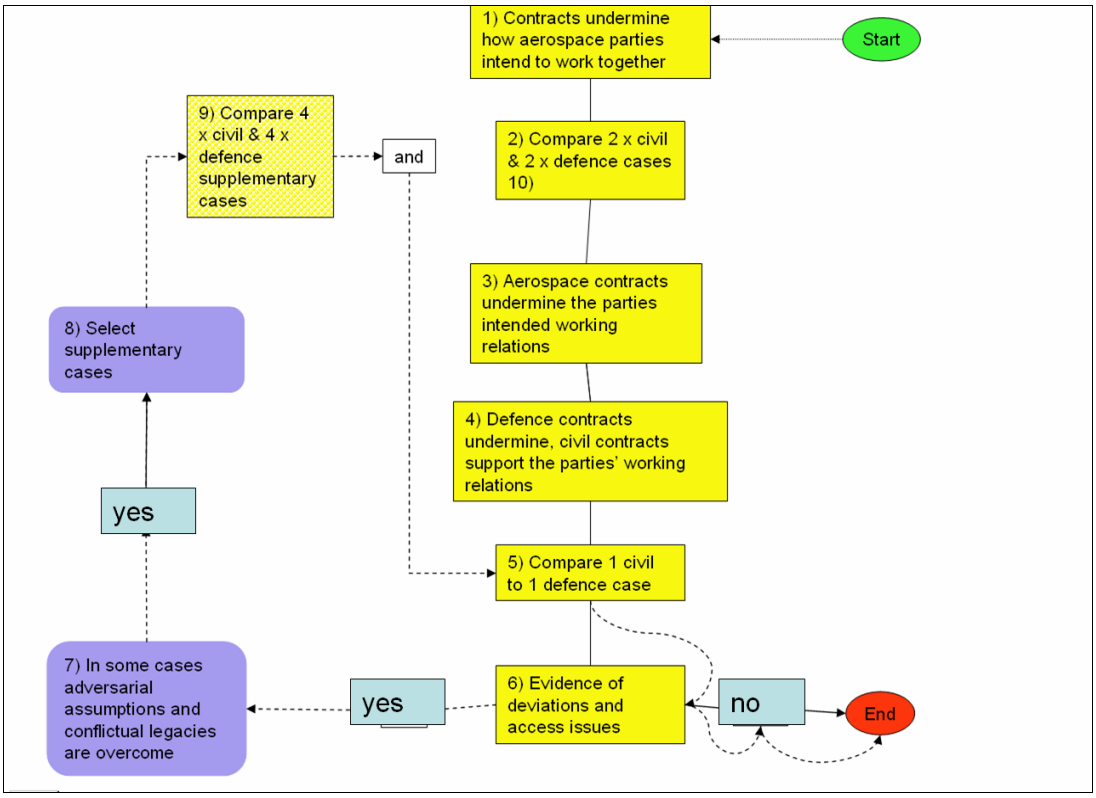

Figure 1: Principal Aspects of the Research Related to the Data Gathering and Review Process. (Based On Hamersley's And Atkinson's Model, 1993)

The impetus that underpins the ECLOS-LOTISS research stream is that the classical foundations of contract law in Common Law jurisdictions, which is embodied in formal agreements, conflicts with the real-world phenomena of contractual relations.

Comparative Analysis of Aerospace and Construction

Relational Contracting

Despite endemic differences between the two industrial sectors studied, there are common elements which relate to the uncertainties in both product and business environments. Moreover, both sectors traditionally rely on detailed forms of contract.

On the other hand, the differences between them allow a broader appreciation of the elements that influence the link between lean and relational contracting. Broadly speaking there are clear differences. There is wide acceptance that the aerospace industry is limited in how it can diversify when there is a fall in demand in a particular market, whereas the construction industry has more prospective sources of demand.

This inability to diversify adds more sources of inefficiency to the aerospace sector in comparison to the construction sector. The prevalence for inefficiencies also increases the complexity of contracts, which suggests that contracts should incorporate the flexibility that is required to manage unforeseen circumstances. Furthermore, the level of technical complexity of aircraft is higher in comparison to buildings

At the level of contractual relations, differences exist not only between the aerospace and construction industries but also between the civil and defence segments within the aerospace industry. In terms of these civil to defence differences, the UK MoD standard forms of contract[9] require evidence that contracts have been awarded competitively (Levene, 1987; SDR, 1998; SPI, 1999). This constrains its freedom to draft contracts that reflect its "partnering" (SPI, 1999) policy with which to develop collaborative relations with its suppliers. In contrast to its public sector counterparts, civil contractors broke with the tradition of competitive tendering. Instead of forming agreements at the outset of the transaction, primes persuaded their subcontractors to agree new forms of contract that underpinned their objective to improve their efficiency by taking a long-term view of how they could collaborate beyond project terms

With regards to the public sector business of the UK construction industry, the public sector aerospace traits were evident when Joint Council Tribunal (JCT) contracts and competitive tendering were the norm. However, in an apparent contrast to the MoD's agencies, (the DPA and DLO), the government's Estates Department reviewed how it could demonstrate the competitive requirement whilst changing its contracting policies and forms to develop relational contracting with its prime contractors (Department of the Environment Transport and Regions, 1999).

In relation to private sector construction projects, the evolution of relational contracting has been supported by the industry developing standard forms of contract (NEC, PPC2000, Be) that reflect the collaborative norms that the parties intend to develop in pursuance of transactions that yield mutually beneficial outcomes from their contracts.

Lean Principles

When compared with construction, the aerospace and defence sector has been more consistent and coordinated in the way in which models for the application of the Lean Principles have been developed and then applied to the In-Service Support (ISS) value stream.

Within the construction sector, the very definition of what ISS means varies significantly from segment to segment. For some companies, in-service support means the undertaking of serial, 'one off' construction projects for a single customer, under the auspices of a framework agreement, in effect acting as the construction manager for that client, embedded within the client organisation. For other companies, this activity refers to post construction management of facilities or the long term maintenance and repair of facilities or utilities. These different interpretations may require the development of different implementation models, which reflect those differing requirements. Without effective and coordinated leadership in the construction sector, these models are developing slowly and in a 'piece meal' fashion, within different companies and institutions. Therefore, the implication is that a practical template for what constitutes a "lean" implementation is still evolving in many segments of this sector

[9] known as "DefCons"

Results and Implications

The results of the empirical studies are summarised in the following tables and attached in Appendix 1: "The Application of Lean Principles on ISS Contracts". The study results confirm that whilst the effectiveness with which the Lean Principles were applied varied considerably between the various case study projects, effective implementations tended to exhibit similar characteristics:

- A good understanding of the lean principles by the senior managers involved in the project
- Commitment to implement those principles on both sides
- Creation of an environment of relatively level demand
- A focus on the flow velocity of the value stream
- Ruthless and continuous elimination of waste

Mutual recognition that lean principles must be supported by collaborative relations

Table 2 ranks the case study projects according to the relative proportions of these characteristics exhibited.

Table 2: Effectiveness of Lean Implementations

Characteristics	Aerospace examples	Construction examples
MORE ⇧ Number of effective characteristics ⇩ LESS	Military case study A Civil sector AMA case study Military case study B Military case study C	Civil Transportation case study Local Authority contracting case study

Table 3 applies Macneil's norms (1975) to the contractual characteristics of the case study projects in both sectors. The source material for these tables comes from Appendix 1 which synthesises the respondents' responses in relation to the application of lean principles to ISS contracts and classifies the responses according to whether they relate to the aerospace or construction industry.

Table 3: The Application of Macneil's Norms to the Aerospace and Construction Industries

Norms	Aerospace examples	Construction examples
1) Relational For their mutual benefit, the parties:		
Work together on the basis of flexibility and reciprocity in their mutual benefit.	Civil Sector AMA case study Military case study A	Civil Transportation case study
Remain separate economic units, whilst collaborating		
2) Common The parties have a united approach to:		)
Preserving their relationship as they predict that they will work together in the future	Military case study B	Retail Chains, Food Outlets (Modules Check together) Long term commitment based on joining developed norms (formal and informal
Harmonious dispute dissolution rather than conflicts		
Changes in the external environment		
3) Discrete The parties freedom to contract is limited in their mutual interests by:		
Restricting their individual freedom to choose how to execute the contract	Military case study C	'Arms length' Local Authority contracting case study
Accepting that they must take the consequences of focusing on the outcome of the contract, which restricts the individual party's freedom to act in its immediate interests		

The correlation between Table 2 and Table 3 is striking and suggests that effective implementations of the lean principles tend to be associated with contractual structures that reflect Macneil's relational norms. This result provides evidence that flexibility and collaboration (i.e. Macneil's relational norms) increase the likelihood of fomenting an environment that delivers the key success characteristics for effective lean implementation. There is clear conceptual reasoning to support the study results. At the relational norms, the parties cooperate for the common benefit of the transaction. The further away from the relational norm the contract moves, the more difficult an effective implementation becomes, until at the discrete end of the spectrum, contractual conditions are actively inhibiting a successful implementation as the parties play "tit for tat" games (Hviid, 1996, 1999) that engender destructive competition (Deakin et al,1997).

From the outset, the results support the view that the aerospace and defence sector has applied the lean principles more extensively than the construction sector. In relation to the construction sector, the aerospace and defence sector has:

- Been more customer led in its approach to "lean"
- Claimed a wider range of benefits from the implementation of the lean principles
- On average, been prepared to share more of those benefits with the customer in order to enhance value
- Used more of the control tools and techniques classically associated with the Toyota Production System
- Demonstrated more easily identifiable applications of customer demand directly pulling and pacing production
- Built continuous improvement into business planning routines more comprehensively

Other Important Considerations

Industrial Environment

The initial study observations must be placed into their proper context especially given the way the industry environment of the two sectors plays a role in determining the extent of lean implementation:

- Aerospace and defence contractors were traditionally seen as high cost, high margin operators. Lean has been seen by the industry as a tool for restructuring to meet the threat of foreign competition and by customers as a vehicle for 'cutting out some fat' and redressing the perceived imbalance of risk and reward. Implementation of lean has therefore been defined, supported and driven by a variety of stakeholders in the sector. Consequently, progress has been made with its application to in-service support.
- Conversely, construction has been living off thin margins and poor cash flow for decades (Latham 1994). Within its famously adversarial structure, hierarchy and niche market segmentation, collaborative approaches are at best fraught with difficulty. Attempts to define a lean agenda for the industry (Egan 1998) were met with scepticism by the protagonists. No consensus has been developed which defines what is meant by 'lean' in the context of the sector, let alone its application to in-service support, a term which itself has different meanings in different construction industry segments.

The ability of the construction sector to develop such templates should not be discounted. Earlier work on this research project [ECLOS] has already added to the body of evidence that suggests that operational construction managers within the industry are developing innovative reinterpretations of the lean principles and are attempting to apply them in real situations despite the institutional barriers and widespread scepticism within the Industry.

Furthermore, our research indicates that there are areas that enable the adoption of lean practices, in which the construction sector is more developed than the aerospace and defence sector. These are:

- Project management disciplines
- Effective use of risk analysis and management
- Supply chain integration
- Continuing education and training

The Role of the Customer

In continuing the theme of the ECLOS project, the results lead the LOTISS team to suggest that customers, in the sense of the users of the subject-matter of the contract, can exert profound influences on relationships from prime contractors throughout the supply chain. In our view, recent research (ECLOS, LOTISS, Cullen, 2004) shows that the MoD's standard forms of contract fetter primes' discretion in relation to their own operations and makes their working relations with their suppliers contentious. Furthermore, its procurement policy is limited to competitive tendering on a project-by-project basis, instead of developing relations that extend over the operational lifetime of the project. The incentives for suppliers are perverse, providing the opposite effect to the cooperation than the MoD requires. Instead of inducing suppliers to remain efficient, the narrow and even non-existent profit margins lead the industry to use variation clauses to recoup their costs. Furthermore, original equipment manufacturers apply margins to spares in the aftermarket that provide them with acceptable returns on investment. Clearly it follows that the iteration of tit-for-tat games and destructive competition militates against ISS contracts that are beneficial to both customers and the supply chain.

There is a particularly interesting facet that has influenced the propositions in this paper. Whilst industry has generally applied lean principles, there is no evidence of an overall trend to adopt relational contracting. There is evidence that the UK defence sector recognises the role of informal norms and lean principles in achieving efficiency gains but there is no basis for suggesting that this is supported in the terms of formal contracts. There is strong evidence that the UK construction industry is recognising that contract forms must reflect the collaborative basis of lean strategies. However, the UK MoD failed to recognise that their current forms of contract blight relations with their defence and construction industry providers.

Despite this, there is some albeit not extensive evidence that the construction and civil aerospace sectors recognise that relational contracting is the efficient way to apply lean principles. Indeed our research corroborates our earlier work on the ECLOS project and allied research by the LOTISS and ECLOS teams, that forms of UK defence contracts undermine collaborative relations

Therefore, we reiterate that the MoD's general interpretation of competitive procurement and its contract forms conflict with the objectives that it hopes to gain from the Smart Procurement (SPI, MoD 1999). "Partnering" requires the parties to have sufficient mutual confidence and trust to share sensitive information. However classical contract forms militate against collaboration. We contend that as the UK construction industry delivers economically efficient results to both the public and private sector customers, whilst forming long-term alliances that transcend individual projects, there is scant logic in the MoD continuing to espouse the benefits of each transaction being competitively tendered

Interestingly, both the ECLOS project and the present state of knowledge within the LOTISS environment strongly suggest that appropriately developed incentives can overcome a negative legacy and thus reduce transaction costs. For instance, competitive tendering for every phase of the product lifecycle, coupled with excessively detailed, prescriptive contract forms leads to 'arms' length rather than collaborative relational contracting. However, the transaction costs of defensive behaviour and iterative cycles of renegotiations are not endemic and can be reduced by a balanced portfolio of competition, relational norms, appropriate incentives, lean practices and crucially, legally binding agreements that formally support the parties' joint commitment to increasing their mutual economic benefit. This was clearly indicated in civil aerospace and certain construction case studies, where the parties expressly overrode formal contract terms because to do otherwise would have serious consequences on the parties' finances and reputations.

Recent research (LOTISS, Cullen, 2004) suggests that there are significant differences in how the customer influences the forms of prime and sub-contract. It has also been established (ECLOS, Cullen, 2004; Cullen et al, 2004) that contract terms affect the parties' working relations and their economic outcomes of the transactions.

Interestingly, whilst the MoD has no apparent intention of changing its classical contract terms in relation to procuring equipment and ISS, it piloted a more relational approach to construction contracting (Nicolini. Holti, Smalley, 2001). Furthermore, the MoD's participation in developing and managing transactions, throughout the ex ante and ex post phases, has a negative effect on contractual relations. The basis for this proposition is a combination of classical contracts, arms' length relations (LOTISS; ECLOS) and its intervention in managing transactions. The outcome is that suppliers create defensive barriers, which undermines the collaborate objectives of SMART Procurement and adds transaction costs.

In contrast, construction customers and their professional advisors do not intervene in contract management matters. Traditionally in UK construction, contracts are based on

a triad, with an architect being appointed by the customer to ensure that the prime contractor constructs the works according to the design and specification

Although airlines are involved in specifying the performance criteria that they require, they limit their involvement in the progress of the contract. As airlines also do not fetter prime contractors' freedom to draft the terms in their subcontracts, forms such as risk-revenue-sharing agree can reflect the parties relational and lean objectives.

Conclusions

In previous work (ECLOS) we examined the synergy between written contract forms, whilst relating their impact on both the contracting and technical processes. This study focused on the product introduction phase of procuring original equipment. The results of this research unequivocally indicated that for all the three sectors studied, the form of contract heavily influenced the parties' relations, from the ex ante to ex post phases of the transaction. Furthermore, in concurring with Macneil's fifth norm, the transaction environment had a crucial effect on the economic outcome of the transaction. A history and contemporary social context engendered hostile and defensive behaviour that added transaction costs and undermined the efficiency gains that were envisaged from the application of lean principles.

Future Research

This research project will be continued to verify and develop these initial conclusions. On the basis that there is no consensus of what constitutes 'lean' implementation, the LOTISS project will continue this line of research, with the objective of identifying the patterns that evolve from different segments within the sectors. The objective behind this line of investigation is to develop one or more frameworks that embody the practices that lead to efficiency gains from a holistic supply chain perspective as well as between contracting parties.

Further study could be conducted regarding how the architect's design could be integrated with lean practices and relational contracting. In terms of linking the relational and lean elements of collaborative contractual alliances, the LOTISS team proposes the adaptation to Lamming's (1993) four phase evolution of working relations between aerospace and construction parties (see Table 4: below) as a basis for future study. The development of the LOTISS research will also examine the roles of incentives in developing more efficient (Williamson, 1996) relationships that are characteristic of the contemporary industrial environment.

Therefore the LOTISS team will extend this line of research to examine the role of contract documents and inter firm relations in the three focal sectors and will investigate the wider context of practices in other industries. This line of research accords with Williamson's (1996) proposition, that future research should construct a model that reflects the economic facets of contractual relations between organisations in the early twenty-first century

In relation to the influence of contract law, both relational contracting theorists and transaction cost economists recognise that the doctrinal principles of contract law influences forms of contracts and the allied informal traits. Therefore, future research should also compare how contract law relates to contemporary exchange relations. This line of research has profound implications for the economic outcome of transactions and whether the parties' investment in applying lean principles is efficient. This is especially relevant in relation to long-term, in-service support contracts, where the legacy of previous trading and future expectations have significant effects on how support contracts are negotiated, drafted and managed.

Table 4: Four Phase Evolution of Relationships between Aerospace Contractors (Modified From Lamming, 1993 (Cullen, 2004))

4 Phases Characteristics	1 **Traditional** (Pre-1970's)	2 **Stress** 1970's	3 **Resolve** Early-mid 1980's	4 **Partnering** Late 1980's-early 90's
Hierarchy	Manufacturers owned most of the means of production	Consolidation	Consolidation continued	OEM/main contractors divested other than core activities; focused on specific expertise and assembly modules
Contracting	Market testing by competitive tenders followed by annual contracts for components	Competitionforced down prices, further reduced by best and final bids	Quality demands from purchasers; Logistics[10] with progressive price reductions	Long-term framework agreements; quality + reliability; elimination of duplication; economics of scale and scope; supply of pre-assembled modules; progressively reduced prices
Industry and environmental conditions	Mass production; short-term commitment	Oil crisis: 25% global overcapacity; increased pressure on subcontractors to reduce costs	Challenge from Japanese rivals. Subcontractors demand more commitment from purchasers; demands for investment in plant and equipment to achieve quality and logistics rqmts	Specialisation; long-term collaboration
Supply/demand	Buoyant demand	E x c e s s s u p p l y		

In comparison to the construction and civil aerospace sectors, the level of the MoD's intervention during original equipment and ISS transactions is significantly higher than in the construction and civil engineering industries. The difference lies in the MoD's perception it is "an expert customer[11]". Consequently, the role of the customer forms a strand for future research by the LOTISS team, to propose how to resolve this conundrum between non-interference and using a customer's expertise to enhance the mutual benefits for contract parties.

[10] e.g. "Just-in-Time"

[11] private conversation with senior manager in the Ministry of Defence, March 2004

Appendix 1:

Application of Lean Principles on ISS Contracts

Principle	Aerospace Responses	Construction Responses
1. Definitions		
Lean	More external focus on customers, industry expectations and the provision of customer service.	Strong internal focus on 'getting more out of less'. No references to customer.
In-Service Support	Consistent responses: 'Long term maintenance, repair, overhaul and support of product, equipment or facilities in the field.'	Responses varied by market sub-segment: 'Facilities management' 'Serial construction project management on behalf of client' No definition
2. Identification of Value from the Perspective of the Customer	Tendency to adopt formal/informal procedures processes or mechanisms for identification of customer value within in-service support (ISS) process.	Tendency to focus on traditional project evaluation criteria of time-scale, cost and quality (TCQ)
	Relationships seen as important in the successful delivery of customer value. Relationships regarded as critical in military segment.	Relationships seen as important in the successful delivery of customer value.
	Changes of personnel seen as disruptive	Changes of personnel seen as disruptive
	Evaluation and resolution of project risk seen as particular source of conflict in military contracting segment. Transience of political direction and resulting impact on funding seen as major barrier to innovative, long-term agreements that deliver value.	
	More innovative long-term agreements which deliver value to both sides seen as easier to do in civil segment.	Some evidence of innovative approaches driven by individual managers
	Value delivered most effectively in environment where performance measures developed and managed jointly.	Value delivered most effectively in environment where performance measures developed and managed jointly.
3. Mapping the Value Stream	Majority of respondents used mapping techniques to evaluate current state of the value stream.	Majority of respondents used mapping techniques to evaluate current state of the value stream.
	Less than half generated a target future state map	Less than half generated a target future state map
	Less evidence of involving key suppliers in mapping of current states	All respondents involved key suppliers in mapping of current states

Principle	Aerospace Responses	Construction Responses
4. Creating Flow	Majority of respondents claimed successful implementation of action plans that improved flow in the value stream. All respondents reported benefits in: Due date compliance Improved service Reduced lead-times/throughput times Improved customer/supplier relationships All respondents also reported benefits in: Costs and hence prices to customer Improved responsiveness Space utilisation Intention to share both cost and lead-time benefits with customer. More use of classical Toyota Production System tools and techniques including: Inventory management Demand smoothing Visual control systems Standard operations Single piece flow Ergonomics Housekeeping systems 'Takt' time	Majority of respondents claimed successful implementation of action plans that improved flow in the value stream. All respondents reported benefits in: Due date compliance Improved service Reduced lead-times/throughput times Improved customer/supplier relationships All respondents also reported benefits in: Improved quality Either cost or lead-time benefits shared with customer, not both. Much less use of classical Toyota Production System tools and techniques incl: Visual control systems Standard operations Housekeeping systems More effective use of risk analysis and management. More use of training, development and team based mechanisms to improve flexibility of people More evidence of effective supply chain integration and integrated project teams
5. Letting Customer Demand Pace and Pull Production	Considerable variation in extent to which 'pull' versus 'push' type systems are being used.	Little general application of 'pull' systems. However, individual examples of innovative interpretations were found.
6. Managing Continuous Improvement and the Pursuit of Perfection	All respondents described themselves as team based organisations and all were running some form of team based improvement activities All claimed to be involving all levels in the organisation, including customers and suppliers All claimed to be monitoring improvement trends and majority were displaying or routinely communicating this information. All claimed that improvement targets were embedded in business plan 80% claimed development of high speed product modification process	All respondents described themselves as team based organisations and all were running some form of team based improvement activities All claimed to be involving all levels in the organisation, including customers and suppliers All claimed to be monitoring improvement trends and majority were displaying or routinely communicating this information. Only two thirds claimed improvement targets were embedded in business plan None claimed development of high speed product modification process All claimed use of risk analysis to support problem solving activity

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