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Construction industry productivity and the potential for collaborative practice

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Abstract

The construction industry is widely recognised as a laggard in terms of productivity improvement. This research study identifies the factors inhibiting collaboration and provides a model for developing a collaborative network approach. The case studies conducted examine the factors impacting on collaboration in the project networks of three large construction organisations. It was found that excessive fragmentation in the industry together with disparate project management processes and non-standardised information is impeding efficiency gains. A panel of project experts reviewed the findings to explain the basis of the practices. This has led to four primary conclusions: (1.) the construction industry lacks the 'strength' of relationships necessary to create a network of organisations that trust and have shared values; (2.) design processes should include both value engineering and lifecycle costing; (3.) procedures and information need to be standardised; (4.) there should be more emphasis on value adding project management activities.

Keywords: Managing partnerships and alliances; Managing projects; Project management procedures; Project management information systems

1. Introduction

Numerous researchers have highlighted the construction industry's poor productivity levels and assert that it lags behind other industries in terms of efficiency improvements (Bankvall et al., 2010). The Australian Bureau of Statistics reported that the construction industry had negligible multifactor productivity[1] gains between 1986 and 2008 (Australian Bureau of Statistics, 2011). The USA actually saw a reduction in multifactor productivity in the construction industry between 1987 and 2008 (USA, Bureau of Labor Statistics, 2011). It might be claimed that the global financial crisis had an effect, however, there was not any improvement in construction industry multifactor productivity in Australia between1986 and 2002 or in the USA between 1987 and 2003. There have been some positive years of productivity growth but there is clearly an underlying problem.

Productivity improvements in many sectors have been driven by investments in information technology. Prior to the late 1980s there was, what was coined by American economist Robert Solow, a productivity paradox where expenditure in information technology (IT) did not result in multifactor productivity gains (Solow, 1987). However, since then most industries have seen a marked improvement that has been largely attributed to IT enabling collaboration between organisations in terms of partnerships and logistics (David, 1990). These collaborative practices have been underpinned by industry wide diffusion of IT and standardisation of processes (Brynjolfsson & Hitt, 1996). Connolly and Fox (2006) of the Reserve Bank of Australia identified productivity gains to be very positive for industries that invest in high-tech capital. However, investment in technology in the construction industry lags behind many other industries such as consumer goods, home electronics and the automotive industry (Lönngren et al., 2010).

Collaboration is seen as a mainstay of efficiency improvements as it enables integration and automation of processes (Mehrjerdi,

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[1] Multifactor productivity (MFP) is the part of output growth that cannot be attributed to the growth of labour or capital inputs. MFP reflects such things as business process innovations, advances in technology, or almost any other type of improvement in the efficiency of a firm's operations (Australian Bureau of Statistics, 2011).

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2009). A study by AMA Research demonstrated that collaboration can improve profits for all supply chain partners by as much as 3% (Attaran and Attaran, 2007). Collaborative partnerships can also improve product design.

There have been few studies concerning collaboration in the industry (Xie et al., 2010). This study takes an explorative view of the processes that underpin the relationships in the construction industry to ascertain how collaboration occurs and identifies factors inhibiting productivity improvements. The objective of this study is to identify factors inhibiting collaboration and to determine how collaboration might be improved in the construction industry. The interpretive study has its basis in supply chain management. Supply chain management theory is used to establish a backdrop to the study and position data. Three very large organisations that are undertaking extensive constructions participated in the study. The findings from the organisations were discussed with a panel of project experts to clarify the rationale for industry practice and pinpoint areas that might be improved. The research is significant to both academia and practice as it directly addresses the manner of collaboration and marshals the contribution of other recent research. The findings are particularly relevant to practice as productivity improvement is the foundation of macroeconomic progress and Australia is heavily reliant upon the construction industry.

Since the 1990s there has been much interest in understanding the deficiencies and identifying solutions that enhance the coordination of both subcontractors and suppliers in the construction SC (Segerstedt and Olofsson, 2010) and considerable research has already been undertaken in this area (Zou, 2009). The research has been addressed from many perspectives: logistics, purchasing, transportation, operations management, marketing and R&D (Arlbjørn et al., 2011). There is however a lack of research concerning collaboration (Crespin-Mazet and Ghauri, 2007). This research addresses this shortfall by identifying areas of wasteful practice and the potential for improvements in collaboration.

A review of the extant literature determined a pre-scientific stage of research (Cresswell, 1994) and therefore the study is explorative. The research has two questions: (1.) Identify the factors inhibiting collaboration within the construction industry (2.) How can collaboration be improved in the construction industry? These research questions were further decomposed to interview questions related to the key issues found from the literature, in particular fragmentation, relationships and small and medium enterprise issues. A qualitative case study approach has been utilised as it is an appropriate instrument for exploratory research that seeks to answer 'how' and 'what' type questions (Yin, 2003). Supply chain theory is used to identify the nuances of construction collaboration and has been utilised in this study as a basis for an interview guide to understand organisations' collaborative practices and information requirements.

The following summarises the extant literature concerning construction supply chain management (SCM) and collaborative project management practices. The research design is described and the practices of three major construction organisations explained. An expert panel explication of construction project management process is also presented. Findings are discussed and conclusions drawn. The paper concludes with implications and the potential for future research.

2. Collaboration and construction project practices

There has been some increase in collaboration in the construction industry, but there are many challenges and complexities still to overcome (Dietrich et al., 2010). These can be grouped around 1) fragmentation in the construction industry (Dainty et al., 2001; Froese et al., 1997; Love et al., 2002), 2) the large number of small enterprises in the supply chain (Hadaya and Pellerin, 2010; Lönngren et al., 2010) 3) differences between manufacturing and construction supply chains and 4) the nature of relationships in the industry (Bankvall et al., 2010).

2.1. Fragmentation in the supply chain

Construction is defined by Eccles (1981) as the erection, maintenance, and repair of immobile structures, the demolition of existing structures, and land development. The market of the construction company is mostly local and highly volatile (Segerstedt and Olofsson, 2010) with subcontractors supplying 90% of labour and materials (Hartmann and Caerteling, 2010). Increasing complexity and competition in the industry mean that a construction company can no longer be managed as a separate entity (Zou, 2009). Bankvall et al,. (2010) advocate a holistic view that recognises the interdependence of the components in the supply chain (SC).

A SC is a collection of trading partners that are connected through financial, information, and product/service flows (Fugate et al., 2006). Improved management of the processes that underpin a SC such as demand, design, material requirements planning, product delivery and subcontractor management have significant potential for improvement in the industry (Zou, 2009). Mentzer et al. (2001) defines supply chain management (SCM) as a "systemic coordination of the traditional business functions and tactics across these business functions within a particular organisation and across businesses within the SC for the purposes of improving the long-term performance of the individual organisations and the SC as a whole" (p.22). Clearly, information technology is a key enabler of supply chain integration. Information sharing is a key benefit of IT use including strategic, tactical and operational information and data. This can lead to cost reductions due to more accurate inventory levels and logistical improvements (Nath and Standing, 2010).

2.2. Small enterprises

When a construction project commences available subcontractors with the requisite skills are assigned. Benjaoran (2009) found that the majority of these organisations are SMEs and that they often employ local subcontractors for trade skills and physical labour. Small businesses tend to lack collaboration capability, since they do not have the resources to invest in systems to support collaboration, nor do they evaluate effectively their collaboration practices (Love et al., 2002).

When an organisation embraces the collaboration concept the number of suppliers is significantly reduced. This is achieved by selecting suppliers to partner that are able to meet the criteria of long-term stability, quality of service, ability to deliver and price. This partnership concept has significantly reduced the cost of supply and improved products in many industries, but is yet to do so in the construction industry (Love, 2000). One reason is that the required investment in technology and innovation is not viable for the many SMEs in the industry (Benjaoran, 2009). This is because these organisations are often regional and they do not have the financial resources necessary to implement the required IT infrastructure (Lönngren et al., 2010). One consequence is delays in such things as approval of drawings and payments, this in turn slows cash-flow through the SC (Thomas and Tang, 2010). Other consequences include conflicts in work schedules of subcontractors, slow decision making, design errors and labour shortages (Thomas and Tang, 2010). These are elements of waste that have been eliminated in industries that have adopted SCM practices.

2.3. Construction supply chains

There are many types of SC: stable, uncertain; mature, developing; functional, innovative; push, pull. Indeed SCM is not a universal tool, and both SCM and lean procedures have been criticised for vague terminology and rhetoric (Bankvall et al., 2010). Nonetheless collaboration, standardisation of information and an element of trust are fundamental to successful SCM. IT is also a major contributor through capturing, analysing and presenting standardised information up and down the SC (Mehrjerdi, 2009).

Early stages of SC transformation are concerned with productivity gains, inventory reduction and cycle time improvement, these leading to longer term benefits of increased market share and profit (Mehrjerdi, 2009). A key term in SCM is the 'push–pull boundary'. This is the point in the supply chain where products are pushed, generally from stock, to an organisation that is orientated to demand. Often the entity on the push–pull boundary in the construction industry is the main contractor. Being on the push–pull boundary is advantageous as the organisation has an opportunity to manage supply to demand. This allows an organisation to create value through adjusting to market conditions, innovating and creating cost efficiencies (Hilletofth, 2011).

There are major differences between construction and manufacturing SC, the main one being that the majority of manufacturing organisations have ongoing processes and relationships whilst construction organisations are project based with short-term relationships, one-of-a-kind products and onsite production (Segerstedt and Olofsson, 2010). The industries also differ in terms of value creation, level of complexity, degree of uncertainty and industry wide standards (Hellström, 2005). Vrijhoef and Koskela (2000) explain that construction SC has three distinctive characteristics:

1. convergence at the construction site of materials
2. one-off projects facilitated by repeated processes of project organisations
3. a make-to-order supply chain.

Collaboration is limited as contractors compete mainly on price (Benjaoran, 2009), which often results in adversarial relationships.

2.4. Types of relationships

Many relationships in the supply can be characterised as adversarial, short term and lacking in trust. The type of SC that supports discontinuous relationships and fluctuating demand are known as 'agile' (Mehrjerdi, 2009). Agile SC focuses on product demand and utilises a make-to-order approach. Agility is achieved by inventory buffers, over capacity and information systems (IS), these activities adding cost prior to providing benefits (Mehrjerdi, 2009). An agile approach requires collaborative planning, forecasting and replenishment (Attaran and Attaran, 2007) and is possible only with extensive diffusion of standardised information and IT. It requires organisations to pursue collaboration with the emphasis on increasing customer value and profit of SC partners (Fugate et al., 2006). There is some collaboration in the construction industry, these include strategic joint ventures and project level collaboration, however, according to Bourgault et al. (2008) project level collaboration is being hampered by distributed project teams that have nonaligned processes.

In summary, collaborative SCM is concerned with cost-effective management of products, information and financial flows from consumption to the point of origin (Kamath and Roy, 2007). The basis of SCM is the provision of information, usually by IT, to supplant inventory and waste. It appears that large-scale inventory reduction in the construction industry is difficult to achieve, but reduction of waste in other areas would seem practical. What appears to be a prerequisite to productivity improvement is what Turban et al. (2005) describes as a "total systems approach to managing the entire supply chain" (p. 242). Research has found that relationships in the supply chain do not improve unless the members of the supply chain are linked and closely connected (Nath and Standing, 2010). ICT has a pivotal role in improving relationships by sharing information and knowledge. Improved relationships in the supply chain reduce the risk of delays and other problems.

3. Research method

The research comprises three mini-cases and an expert review. The case organisations were selected as they are some of the foremost organisations within the Australian construction industry and as such have procedures developed over many years. The organisations are also the main contractor for works. The three companies operate differently: one provides construction projects to government or company tenders and manages all aspects of the construction project; another is undertaking an extensive infrastructure development and has a large number of major sub-projects that support the programme; the third organisation develops supply facilities for its energy product throughout Australia. Semi-structured interviews were conducted across the case organisations with senior managers.

The interview guide had key questions and prompts for areas of interest that may not be covered in the initial answer. The interview guide was derived from the literature review and focussed upon the process of managing large construction projects. The interviews are fundamentally a walkthrough of project practice. Areas of importance included information requirements, parties involved, timescales and positive and negative opinions about practice. All interviews were conducted by the same investigator. Other data sources such as project documents and public information have been used for triangulation purposes. The characteristics of the organisations are outlined in Table 1.

One of the organisations was selected as a pilot case to test the validity of the semi-structured interview guide. A total of 11 interviews were conducted with senior managers and project managers. The interviews were recorded and the recordings transcribed. The data being analysed with the Nvivo9 data indexing tool to the constructs derived from the literature and embedded in the interview guide. As proposed by Eisenhardt (1989) case analysis was undertaken both within and across cases.

To help clarify and crystallise findings, the inferences, but not the cases themselves, were discussed with a group of project managers from other organisations with an abundance of experience. One member of the group has worked in the industry for 25 years and is recognised worldwide as an expert in planning major projects (particularly those with short timeframes), recovering problem projects and advising at the concept stage about project practice. Another member has 45 years experience and is recognised in Australia as an expert in all levels of project controls. He oversees judicial reviews and manages arbitration processes. The third member has 40 year's experience and has managed numerous programmes and projects. He recovers problem projects and provides arbitrations between clients and contractors. The purpose of the panel was to explain the rationale of underlying practices of project management in the construction industry. The final step was, as proposed by Eisenhardt (1989), to compare the findings with the extant literature, so as to understand what are similar and what differ.

The research method is shown in Fig. 1.

The research is bounded in two ways; firstly by the nature of case studies research and secondly through the extent and nature of the qualitative data. The case study approach has the inherent potential to create theories based on preconceptions as consciously or not, we listen and make sense of what we hear according to particular theoretical, ontological, personal, and cultural frameworks. "The worry always exists that the voices and perspectives of those we study will be lost or subsumed in our own views and interests" (Luttrell, 2000, p. 499). Mishler (1990, p.418) explains that "validity assessments are not assured by following procedures but by investigator's judgement". He has also pointed out that validation is often being applied to social science research in the same way as experimental research, with many studies being judged wrongly to lack academic rigour. He proposed that validation should be a theoretical rather than a technical problem. Mishler (p. 422) identifies the following six components that exemplify qualitative data research:

1) Focus on a piece of "interpretive discourse"
2) Take text as the basic datum
3) Reconceptualise as an instance of more abstract and general "type"
4) Provide a method of characterising and coding textual units
5) Specify the structure of the relationship among them
6) Interpret the meaning of the structure within a theoretical framework.

All of the above recommendations have been adopted in this study. Also, the discourse has been transcribed to text and coded in Nvivo. The text has been carefully analysed and conceptualised. The data has also been reconceptualised using cross case analysis.

The aim of explorative research is concerned with extending the research outside of the population considered. The population of three case organisations is a small sample and the organisations are all large corporations. One of the aims of the expert panel review was to mitigate the limitations of the data. The process adopted here is described by Lee and Baskerville (2003) as a description generalised to theory.

Triangulation of findings through documents and other data was adopted where possible. However, while interviewees appeared to be very open in their discussion of events, concerns about confidentiality were real, and in some cases, the intellectual property of documents was of concern. For these reasons, triangulation, from different data points in its full sense was not possible.

Table 1
Case study organisations.

Company identifier	Employees	Revenue	Product	Number of interviews
CO	13,000	\$M 10,200	Construction	4
IP	60,000	\$M 200,000	Resources	3
CP	6,000	\$M 700	Resources	4

4. Explanation of case practices

4.1. Mini-case construction organisation

The construction organisation (CO) has two primary methods of sourcing projects. One is through a business development manager who sources projects through relationships with key clients. The second is by responding to open tenders. The number and value of projects that the organisation can undertake at one time is restricted by the residual amount of bank guarantee that is used to assure or warrant projects. If the bank guarantee is to be utilised to assure other projects at the time of a proposed project, it is not possible to pursue the work.

The first stage of the tender process is a pretender or qualification meeting to determine if it is worthwhile to pursue the project. A parametric estimate of cost per square metre is produced using variables of floor area and anticipated level of build quality. If the project is deemed to be viable a more in-depth estimating process is initiated. This estimating activity was said to last approximately five weeks for a medium sized \$50M project, with two weeks being the minimum time for small projects. The

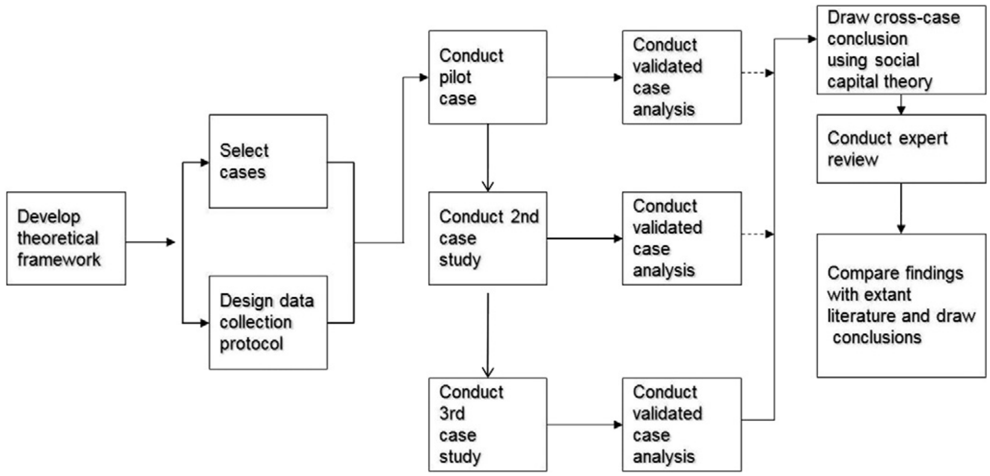

Fig. 1. Study method.

approach to estimating is dependent on the nature of the project. Some projects have detailed drawings that enable 'take offs' or bill of quantity to be identified. However, typically projects require the organisations that are bidding to produce a 'concept and price'. It was explained that sometimes a low cost design is proposed, only to subsequently find that the client wanted a more aesthetic and higher priced approach and vice-versa. This lack of knowledge of stakeholder requirements was identified as a major drawback in the tender process. Neither value engineering nor lifecycle cost management are undertaken pre-tender if the client does not specifically stipulate they are required and it was noted that they are rarely requested.

The first week of the estimating process is used to apportion the project into distinct work packages such as concrete, plumbing and form work. This enables bills of quantity for the works to be identified. The design team identifies contractors local to the proposed construction site and requests tenders for the works. A database of contractors that are prepared to travel to site is also used to identify subcontractors. The subcontractors' quotes may or may not include material supply. It takes approximately two weeks for contractors to quote for work.

A focus on cost is maintained by ensuring that at least three quotes are obtained for each work package and contractors are directed that price is a major consideration. The estimates are entered into a software package that contains the bills of quantity. The software also utilises standard cost rates that have been previously established. These rates can sometimes be very inaccurate due to large fluctuations in exchange rates and changes in costs of some commodities.

The total cost of the project is identified from an amalgamation of subcontractor quotes and standard costs. It was explained that sometimes items are missed during the estimating process, but it was claimed that the organisation did not lose money on projects and had always at least met tender margin. The projects are conducted on a fixed price basis with tender margins of 6% to 8%. Budgets for contingencies have been eliminated in recent times due to increased price based competition. The organisation has however improved its sales conversion rate (sales achieved from qualified prospects) from 5% to 25%. In a more competitive environment, the CO has been increasingly successful due to margin controls and occupational health and safety (OH&S) record. It was noted that OH&S is very important and that there are less than 200 contractors in Australia with Federal OH&S accreditation. An exemplary OH&S record is seen as the major differentiator within the industry.

The client assesses the responses from the bidding construction organisations and awards the contract to the preferred vendor. When a project is awarded to the CO the design and estimating team formally hand over the project to the construction team. The process includes an identification of potential areas of losses and gains. All of the physical construction work is subcontracted to third parties with the main contribution to works of the CO being for project management and OH&S controls. The number of people required of the CO on-site is dependent upon the size of the project. A small project such as the construction of a school would require a site manager and contract administrator, with OH&S personnel visiting regularly. A larger project such as a mine would require between six and eight employees; these would include the site manager, OH&S representative, contract administrator, contract administrator's assistant and quality control personnel.

One of the early tasks is to create sub-components for the work packages. A template of cost codes is used to generate an initial high-level work breakdown structure (WBS). Each major element of the project is allocated a cost code; these codes are then broken down into sub-components for the lower level WBS items. These components become the basis of the budget, with both cost and margin identified. As far as possible the material demand is amalgamated across projects to gain volume discounts. However, this has limited value due to cost of transportation and therefore most materials are sourced locally to the construction site. Nonetheless, group discounts are available from some distributed suppliers.

The site manager will often employ the subcontractors that provided quotes during the estimating process, but they may also use alternative organisations at their discretion. Commitment costs are generated on purchase order approval, the commitment being reversed on subcontract invoice approval. Actual subcontractor costs are assigned to the cost codes on invoice approval. When variations occur between the costs and budget the reason is noted against the cost code. The budget and cost information is used to forecast the cost at completion on a monthly basis with provisions being made for potential foreseeable problems. The forecasts are seen as being very accurate and form part of the organisation's board reports. Subcontractors are paid on progress and this requires onsite verification of work completed. It was stated that subcontractors generally over-claim and site managers 'claw this back'. There is a five day hiatus between subcontractors submitting progress claims and progress being agreed. Once the progress has been agreed the subcontractor submits a sales invoice.

Progress payments for clients are identified from progress measured on a high-level spreadsheet rather than the costing and budgeting software. This progress is billed to the client on a weekly basis. The CO receives a lump sum payment upon mobilisation of the project and is therefore cashflow positive at all times. All contracts have a security component that acts as customer retention. This generally takes the form of a bank guarantee but may also be a bond or insurance contract. The cost of the guarantee is identified at the estimating stage and becomes a cost to the project. The guarantee is generally 5% to 10% of the project value for the duration of the project, and 50% of the original guarantee for a defects liability period.

At the end of the project there is a formal project close, where any losses, onsite issues and gains are clarified. This process includes a review of the estimating process. Particular focus is given to losses or gains over $50,000 and OH&S issues.

4.2. Mini-case infrastructure provider

The infrastructure provider (IP) constructs major facilities to support the sourcing and provision of the commodity product supplied by the other organisations within the corporation. The decision to commence a project is a strategic one that is based on macro economic factors. Projects may have a 20 to 30 year period between identification of opportunity and project initiation. When projects are commenced tenders are made for the acreage of land required. The process is supported by a gated approval process based on cost estimates and predicted value of product output. The project cost estimates fluctuate widely over time due to global economic factors such as exchange rates. Initial estimates have a rough order of magnitude of plus and minus 50%, reducing to plus and minus 10% after two further estimation processes.

A major project might comprise "hundreds of sub-projects all valued in many tens of millions of dollars". Subcontractors undertake the physical work and also specify the execution methodology. Subcontractors tender at "package level", a package being a discrete components of the overall programme. Packages subsequently become projects. The projects can be of fixed price or time and material basis. A major consideration for the selection of a subcontractor is OH&S record and technical expertise. It was explained that the proximity to Asia means that the market is competitive in terms of both price and capability. The margin that subcontractors apply is unknown, but it was explained that it is not in the main contractor's interest for a subcontractor to be unprofitable. Prior to awarding a contract, the subcontractor's financial accounts are scrutinised so that the viability of the organisation can be ascertained. When subcontractors are appointed their financial performance continues to be monitored.

Subcontractors are remunerated based on the value of work completed, and it is the subcontractor who, during the bidding process, identifies how progress will be measured. The progress for each package is monitored by a team of engineers and financial assistants. Percentage complete is assessed at the construction site. It was explained that subcontractors often overstated the percentage complete and this needed to be negotiated down by the main contractor. A senior manager stated "it is something of a game, they push up, we push down". On a monthly basis the many hundreds of large projects and the vast number of smaller projects report on progress. The data is amalgamated to establish the overall percentage complete of the programme.

Subcontractors are reporting at a detail many levels lower on the work breakdown structure than the main contractor. It was noted that the IP is relying on disparate subcontractors' project methodologies and that this created many complexities. It was also noted that project management skills of subcontractors varied widely and that this necessitates that the main contractor has close personal relationships with each subcontractor so that project information can be maintained.

The overall project contains a fully integrated schedule and a critical path. A monthly review process tracks each project against a 'very detailed baseline', the review includes 'commercial and schedule considerations'. Sometimes percentage complete estimates for a package reduce, particularly when an element fails during a test phase. This process was seen to be akin to "a game of snakes and ladders". The overall impact on the project of one of these setbacks was seen as "microscopic". However, a major concern was the possibility of delaying other or subsequent work-packages. When a project schedule slips the project is usually accelerated. There is a predetermined point in each project where rebaselining is considered.

Some of the more critical projects have penalties such as liquidated damages. It was noted that there is a very robust change management process, with "the scores" of out of scope activities identified at the construction site communicated through the layers of subcontractors and ultimately reviewed by a central change control team. A quarterly risk assessment is undertaken to establish programme status against target. When packages are finalised they become financial assets. There are many forms of project guarantees; the major ones are parent company guarantees, bank guarantees, and letters of credit.

4.3. Mini-case provider of commodity product

The commodity product (CP) provider constructs infrastructure for product supply or increases capacity of existing plant. The organisation is functionally organised and the project component of the business is seen to be outside of the major focus of the organisation. It was explained that this sometimes caused problems as project managers at times have to "beg or borrow" resources.

Projects are conceptualised within the commercial division of the organisation. The requirement can originate internally or from a client. In the early stages of the project an asset management and engineering team provides an estimate using what was seen as heuristics. A key element is the length of the facility required to carry the product. If the project is deemed feasible a concept stage is initiated that identifies at an indicative level how the infrastructure will operate. Further estimates are produced using a parameter driven spreadsheet. If the project is for an external client a sales and negotiation cycle is undertaken.

It was noted that many projects are not sanctioned as the organisation is often too busy to provide the project services. When a project is approved, there is a formal hand-over to the project management office (PMO). Projects have an internal mark-up above estimated cost and this becomes an internal transfer cost. A target estimate is agreed between the PMO and senior management with performance against that target being an element of the PMO incentive scheme.

Internal project personnel are restricted to project managers, financial managers and document controllers. Detailed project information is maintained in spreadsheets with summary cost information stored in an enterprise resource planning (ERP) application. The spreadsheets contain a target price, as well as granular budget and costs. The spreadsheet also contains purchase commitments; these are reported from the ERP application and are triggered at purchase order release and removed on purchase invoice receipt. Underlying inflation, particularly with regard to steel, was identified as a major cause for variance between budget and actual cost.

It was explained that subcontractors are often selected before the total scope is identified and that they are generally related to discipline; construction, piping, civil engineering being examples. The subcontractors plan the project in detail and develop the fine grain cost breakdown. The work breakdown structure is produced on a phase basis; design preliminaries, design, procurement, construction. It is the subcontractors that identify the major activities, along with labour hours and associated costs. The budgets are seen as very accurate. The budgeting process is often supported by internal engineers that are seconded from the engineering department.

The projects are monitored on a monthly basis, each subcontractor reporting against the work breakdown structure (WBS); these usually include earned value management calculations. An internal monthly report on project status is produced by amalgamating the non standardised vendor reports. The status report contains key performance metrics that identify progress. It was explained that in this way four project managers manage as many as 40 subcontract projects. There are two controlling groups: an advisory committee and a steering committee. The monthly reviews focus on budgeted capital expenditure and contingency, with project detail being seen as subordinate to these items. It was explained that "we should be accurate as we have done this before, but no matter how hard you try to get it right, you can't get it right".

Potential risks are identified for each element of the project. The risks are quantified in terms of probability of occurrence and consequence. Mitigation activities are identified, these may be insurance or contingency budgets. Contingency is held at both the highest and lowest level of the work breakdown structure; the low level contingency for risks specific to tasks, the higher, project level contingency for risks to the overall project. Expenditure of contingency is sanctioned by the steering committee and costed to the lowest level of the WBS. On a monthly basis total cost is calculated, the internal mark-up applied and an invoice for the activity produced for the client or internal cross charging. There is a strict hand-over procedure of completed assets at the end of the project.

5. Expert panel observations

The expert review took a critical stance of construction industry project practices. One major conclusion was that the contribution of the many organisations involved in projects between the main contractor and executor of the construction is opaque. It was noted that the layering adds costs, particularly for insurance, administration and contingencies. It also complicates logistics. It was further identified that the apparent low margin of main contractors is something of a misnomer as revenue is generated on limited investment and project execution activity due to the works being undertaken almost entirely by subcontractors. Main contractors therefore have high asset turns which results in significant return on capital employed in buoyant markets.

The group confirmed the findings from the case study that construction project tenders often require design to be undertaken by a number of main contractors, with main contractors in turn obtaining approximately three subcontractor quotes for each work package. They also confirmed that design rarely includes value engineering or life-cycle cost analysis. The lifecycle cost process was seen as particularly necessary as buildings are designed with insufficient regard to on cost or reliability. It was noted that if these processes were undertaken the total costs of ownership of a construction could be considerably reduced. It was also explained that cost of ownership was seldom used in net present value or internal rate of return projections.

The panel particularly highlighted the overhead of managing and sanctioning out of scope activity. Changes are often identified at the lowest level of a project and may require communication through many parties to be sanctioned. The cost of these changes was seen to be reasonably more than the activity would have cost had it been included in the original scope of works, this being due to changes in project information, supply requirements and perhaps bespoke implementation. However, it was identified that the cost of these activities is arbitrary and therefore difficult to verify. This has significant impact on the project as it creates debate and disagreement which slows progress and significantly adds to the time required to manage a project.

The ongoing debate between subcontractors and higher level contractors about progress is seen to be a major cost to the industry. It also delays payments and creates an adversarial relationship between parties that should be working to a common goal. It was explained that payments were often made for undisputed completed work with disputed work requiring further reviews. This causes small organisations liquidity problems, particularly in times of low activity. It was further highlighted that whilst cash flow for main contractors is positive due to payments upon mobilisation, the flow of payments through the subcontractor network is haphazard and this has consequence for the viability of smaller organisations. To mitigate this a judicial review process has been established in Australia that allows subcontractors to quickly obtain arbitration for non-payment of work.

6. Cross case analysis

There are many apparent areas of waste and implications for improvements to practice and process. In particular the practice of having numerous competitors designing a construction, producing work packages, undertaking detailed estimates and creating bids is a practice that could be significantly more efficient. As many as 12 competitors undertake design, identify requirements and then obtain quotes from up to three subcontractors for each activity. When the project is awarded, 90% of the activity, the cost and the value, are lost to the industry. Importantly, it is the clients that are absorbing the cost recovery of this activity in the projects that are sanctioned. A change of practice whereby a design is fashioned to stakeholder specifications, bills of quantities are stipulated and contractors then bid for a known requirement would eliminate much of this waste. Importantly, it would also enable value engineering and life-cycle cost management to be incorporated in the design process.

Having the design as a competitive bid also slows the cycle time of projects. The shortcoming of the process is confirmed by much recent research: Hartmann and Caerteling (2010) found the competitive bid process created adversarial relations and mistrust — this being in direct conflict with the principles of SCM; Bankvall et al. (2010) determine that the process is the root cause of the lack of efficiencies in the industry; Segerstedt and Olofsson (2010) explain that the practice leads to technical difficulties that impede improvements in logistics. Improvements in this practice have been recommended by Arbulu et al. (2003) who advocate collaboration between partners and stakeholders in the design stage and for that process to be supported by standardised communication of information. Wikström et al. (2010) explain that involving the customers in the value creation process is a prerequisite to successful delivery. With regard to value engineering and life-cycle costing, Toor and Ogunlana (2010) suggest that projects should be evaluated on current needs, future demands and the expectations of stakeholders, and propose that design should increasingly focus on energy efficiencies and sustainability.

The lack of depth of main contractors' operations is also hampering productivity improvements. According to Segerstedt and Olofsson (2010) the reason construction companies' own personnel execute only a minor part of a project is to spread risk. Whatever the reasons, it creates wasteful communication and adds significantly to project management time. One of the project managers of the case organisation IP stated "we are analysing the project at too greater depth, we have teams of people looking into project details three levels below where we need to and it is costing millions".

The consequence of the layering of organisations is an increase in project management cost, proliferation of transactional documents and an almost exponential escalation of requirement to communicate. There are many characteristics that cause these problems, these include industry infrastructure, complexities of processes and mismatches between processes across organisations (Thomas and Tang, 2010). This layering is akin to a web that lacks the connection between the major strands, information is required to be passed along each strand by individuals who filter and collate the disparate information from the lowest level to the highest. The information is being processed centrally and then disseminated back to the lowest level through the chain of organisations. An increase in vertical integration would eliminate much of this waste and provide a basis for more robust control mechanisms.

There is a lack of maturity and integration of information systems (IS). The current practice of highly knowledgeable (and remunerated) project managers' manually parsing and collating data in spreadsheets is an enormous overhead to the industry. Many of the issues created by the tiered project delivery could be alleviated through standardisation of information and alignment of IT across organisations. According to Hadaya and Pellerin (2010) the construction industry does not only have numerous participants at different locations using assorted technologies, but also has different levels of detail and abstraction. The concept of SCM is concerned with organisational integration of processes, systems and actors (Bankvall et al., 2010). IT tools are central to this as they guarantee consistent and efficient information management across organisations (Lönngren et al., 2010). It was explained by Bankvall et al. (2010) that the arm's length relationships in the construction industry is a major impediment to integration.

It is, however, important to note that seamless computer-to-computer integration does not necessarily require standardisation of processes but codification standards for data. These standards might be types and sizes of cost fields or the fields required to transfer work breakdown information. Traditionally, it is the powerful organisations that dictate standardised practice in industries. In the construction industry the powerful entities appear to be the main contractor and as such they could specify standards for major projects for subcontractors to adhere to.

The many discussions of construction industry SCM are based on a level of maturity of collaboration that does not exist. Importantly, mature supply chains that are found in other industries such as supermarket retailers, were not implemented holistically but evolved over time. These were facilitated by and in turn, standardisation through bar-coding of product codes, developments in IT to enable seamless transfer of information and changes in culture. There were agreed inter-organisational transaction standards such as EDIFACT and ANSIx12. Industry ratifications of the components of the EDI messages were identified and implemented almost universally in industry sectors during the late 1980s and 1990s. This activity was a major cost to the organisations that collaborated at that time, however, they now demonstrate the benefits in productivity improvements. Importantly, it is today much less challenging and costly to collaborate due to widely accepted standards such as the World Wide Web (WWW) and extensible mark-up language (XML).

Wikström et al. (2010) explain that research into the complex project transactions that exist in the construction industry is necessary for productivity to improve and those sentiments are supported by this research. It may be that the obvious fragmentation in the industry prevents widespread standardisation being implemented by the actors. However, there are some major IS organisations that have large scale applications that are utilised in the construction industry; these include applications from CSSP, Intergraph, Microsoft, Oracle, and SAP. If these organisations were to promote standards for data, particularly budget, commitment and cost information within multi-level work breakdown structures, this would have the potential for major productivity improvements. London and Kenley (2001) concur, explaining that there is great potential for an industrial organisational methodology for the construction industry.

The time lag between an activity taking place and knowledge of that event at the highest level is also restricting management decision making. The current wait at the end of each month for reports to pass through the project management chain is similar to the financial closing practices that became defunct in most organisations with the implementation of Enterprise Resource Planning (ERP) applications in the 1990s. The provision of timely financial information in other industries has enabled managers to be increasingly proactive and a similar improvement is available to the construction industry.

Recent research has also confirmed that there is much room for improvement in the area of information management: Benjaoran (2009) found that the systems utilised in project management offices were cumbersome and that there was a proliferation of spreadsheets; Bankvall et al. (2010) found that dissemination of IT is critical for improvements to occur and this needs to be supported by the use of data standards. Lönngren et al. (2010) also identified information standardisation as potentially the biggest driver of productivity in the industry with Zou (2009) finding that construction supply chains are as strong as their weakest link and that a lack of standards is creating a chain reaction of delays. Hadaya and Pellerin (2010) believe that the organisational structures do not support integrated IT and that many implementations are undertaken with insufficient forethought, concluding that the potential benefits of IT are not being recognised.

The process of the lowest level of subcontractors claiming for work, having the work reviewed and the amount of work then generally disputed, seems archaic compared to collaborative practices in other industries. This is a stark contrast with operations in the retail sector where vendor managed inventory (VMI) allows suppliers to replenish client's stock, update clients' inventory quantities, invoice for those products and automatically receive payments. Green and May (2005) believe operational initiatives and workflows need to be scrutinised in detail for practices to improve, and that an aspect must be the elimination of adversarial relationships. Hartmann and Caerteling (2010) agree, explaining that the relationship between contractors and subcontractors must be more collaborative for improvements in productivity to occur.

To sum up, the method of design, tiering of contractors and verification process in the industry adds cost, but does not appear to add value. Perhaps the most significant finding of this research is the limited focus on value adding activities in project management practices within the industry.

7. Discussion

There are a number of wasteful practices and great potential for productivity improvements in the construction industry. A greater emphasis on the use of appropriate software systems, standardisation of contracts, and collaboration can reduce some of the waste and significantly improve productivity. Relationships with project suppliers or subcontractors that are characterised by informal communication with an absence of formal practice are likely to be problematic with firms. These types of relationships can be termed under-designed relationships (Bensaou, 1999) and can be improved by moving to electronic management of practice and communication. Those relationships that are over-designed in the sense of involving more communication and management than is warranted can also be improved by standardisation of practices and reporting by use of electronic project software. Strategic relationships require some additional investment in time and communication and often require bespoke practices, although these too can be managed electronically. The task for firms is to classify their inter-firm relationships and use appropriate electronic systems to standardise interaction where possible. Fig. 2 shows how collaboration might be facilitated.

Fig. 3 explains the key factors impacting on collaborative working that are particularly important in strategic relationships. It also examines the organisational benefits resulting from improved collaboration.

a) Productivity improvements could be achieved by improving project related financial management. Project scope and cost estimation is an area where many problems arise and this frequently leads to project cost overruns. The bid process sets up a competitive arena and changing the competitive bid process to one of stakeholder led design, with this including value engineering and lifecycle costing would be a way of reducing cost. Better communication and integration with supplier IT systems would also improve cost estimations.
b) IT enabled communication between suppliers should lead to improved vertical and horizontal communication flows within the supply chain. This would reduce errors, and cost and time overruns in projects. The added benefit would be the increase in knowledge within the supplier base that could also carry over to future projects.
c) The development of stronger relationship ties with suppliers and subcontractors would increase the sense of obligation and accountability that again should improve the quality of work and improve project outcomes.
d) Although improved ICT integration and alignment should impact on all of the factors in this list, a greater use of ICT within the supply chain develops the general level of ICT sophistication within a firm and the supplier base. This can lead to dynamic improvements since the more sophisticated a firm is in their use of ICT then the more they are aware of the potential of future ICT led improvements. There is also

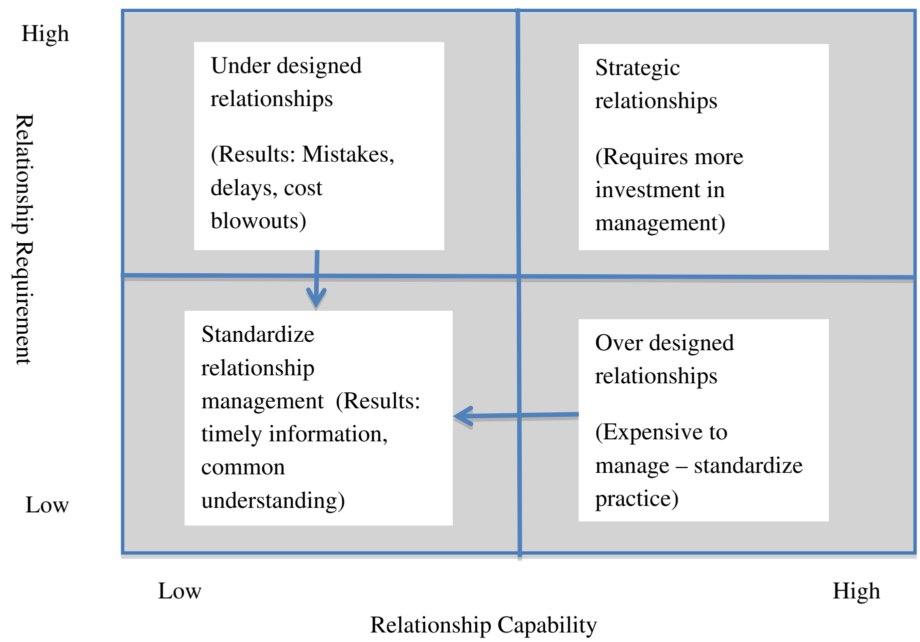

Fig. 2. Classifying and managing relationships with ICT in projects.

the phenomenon of mimetic pressure, a form of legitimation, where firms follow the lead taken by other firms because there is a pressure to avoid being a laggard or the "odd one out" (Standing et al., 2009).

e) A change to a more collaborative and open culture is required. A collaborative culture can be defined as an emphasis on team-work and group effort rather than individual effort and reward. For ICT to be fully leveraged a collaborative culture is required (Standing and Kiniti, 2011). Although organisational culture is usually slow to change, management must put in place the directives and rewards to foster collaboration and then monitor improvements.

Focussing on these issues will increase the level of collaboration that should result in:

a) Improved project efficiency in relation to quality of deliverables, time and cost.
b) Organisational performance in terms of profit, market share and brand perception in the market place.
c) The collaborations should develop stronger ties for the more strategic partnerships and manage weaker ties more effectively through standardised practice management systems. There should also be consideration given to the development of shared visions for the partnerships/relationships and disclosure of values, attitudes and beliefs. Expectations of work practices can be reduced to rules and procedures but there also needs to be a values and attitudes statement as a framework for collaboration since not every work practice or task can be reduced to a policy or procedure. These suggestions can play a role in developing levels of trust and confidence and build up goodwill in the supply chain. Although these recommendations may appear time consuming, the extensive use of ICT can enable the development of better collaboration without excessive overheads.

8. Conclusions

Until processes are viewed holistically across the many organisations in the supply chain there will continue to be negligible productivity gains. The major issue is how this will

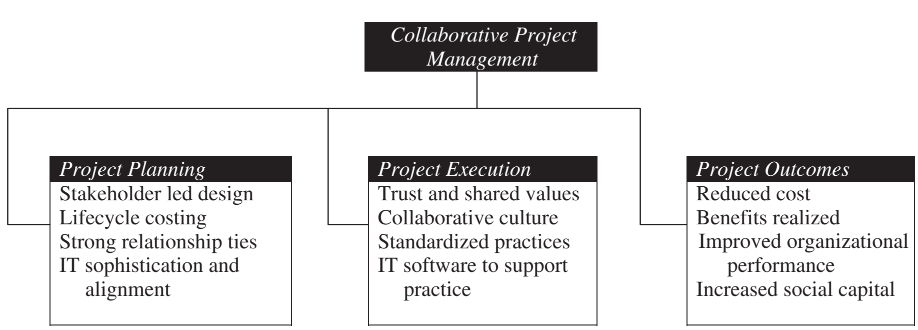

Fig. 3. A model to facilitate collaboration in the construction sector.

be achieved, particularly as project management offices seem to be viewed as both direct and indirect functions. Managers of construction organisations should decide how, or in what way, the project management function adds value.

The construction industry has not taken full advantage of the evolutions in IT practices that have been applied to other industries. An investigation of the merits of IT and business strategy alignment, EDI initiatives and business process re-engineering is appropriate. A review of these principles has the potential for significant productivity gains. These could form the basis of a research study or industry review. There are also other opportunities for research, particularly an in-depth review of relationships and processes using perhaps actor-network theory or activity theory. Further clarification of project management activities, inter-organisational information requirements and their consequence upon organisational and industry productivity are also required.

There are many implications for practice: they can be summarised as excessive fragmentation, a lack of standardisation of project management practices, poor information standards, a lack of investment in IT and insufficient focus on efficiency improvements. Research over many years has identified the construction industry as a laggard in terms of productivity improvements. This research and other recent research have highlighted wasteful practices as well as how productivity improvements might be achieved. Perhaps the next stage is to identify who, or perhaps what in the case of IT, will be the agent of change.

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