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The influence of technology on the development of partnership relationships in the Irish construction industry

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This paper investigates the potential for improvement in the construction supply chain management given the current crisis in the Irish construction industry. The research was undertaken because of the need to improve productivity and tackle historical problems between main subcontractors and specialist subcontractors in the construction industry. The goal of the research is to present and analyse a case study of the fit-out of Terminal 2 in Dublin Airport, Ireland. It seeks to establish if specialist subcontractors are active participants in construction collaborative technologies (CCT); contribute to the design process; are fully integrated into the supply chain; and have longer-term strategic partnership as opposed to project partnership as an objective. The research found that subcontractor involvement in design development using CCT was crucial to the success of the project and that investment in collaboration technology would be a determining factor in the future success of the industry.

Keywords: construction collaborative technology; partnership; specialist subcontractor; construction supply chain

1. Introduction

Employment in the Irish construction industry has almost halved since its peak level, now standing at 150,000, having reached 280,000 in 2006. With firms focusing on gaining

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competitive advantage over each other, and being quick to litigate rather than negotiate, a more constructive way to solve problems in the industry is required. While it is unrealistic to expect construction to make the same contribution to the country's GDP as it has done in the past, the industry is well placed to leverage the skills it accrued in the last decade and utilise them in the provision of building and infrastructure for the areas of the economy that retain potential for growth. The current decline in the industry could be seen as an opportunity to tackle low productivity and to remedy historic deficiencies in technological and business processes. Increased specialisation in the industry has led to sub contractors becoming responsible for the majority of construction works. As a result the construction supply chain has become ever more complex, presenting new challenges in terms of supply chain management. The importance of supply chain management has been recognised by those charged with policy-making and strategic planning within the industry: the 1998 UK Government-sponsored report "Rethinking Construction" envisaged "*a very different role for the construction supply chain…[it] is critical to driving innovation and to sustaining incremental and sustained improvement in performance*" (Egan 1998). The development of partnership between main contractors and specialist sub contractors, where specialists bring innovative practices to projects, is crucial to tackling problems in the supply chain. Partnership in the construction industry arose out of the failure of traditional procurement methods to satisfy client requirements (Mohamed 2002). It "*is driven by a clear understanding of mutual objectives and co-operative decision making by a number of firms who are all focused on using feedback to continuously improve their joint performance*" (Bennett and Jayes 1998). The increasing complexity of building projects requires advanced technology platforms to enable this level of cooperation between main contractors and specialists. Construction collaboration technology (CCT) is the means by which the industry can achieve effective supply chain management while adhering to the principles of partnership. In fact, collaboration through technology is the key to the evolution of partnering arrangements in construction (Wilkinson 2005)

This research involves a case study of the fit-out of Terminal 2 (T2) at Dublin Airport in Ireland, a complex commercial project where significant integration by members of the supply chain was required. A project of this nature by definition involves many specialties including: architecture, metalwork, steelwork, mechanical, electrical and structural engineering, flooring, cladding systems, networking and information technology (IT). The purpose of this research is to determine if:

- Specialist subcontractors are active participants in supply chain management through the use of construction collaboration technologies (CCT).
- Specialist subcontractors contribute to the design process at an early stage.
- Specialist subcontractors are fully integrated into the project supply chain.
- Strategic partnership between members of the supply team is realistic objective.

The research approach was qualitative, using unstructured interviews with designers, main contractors and specialist subcontractors. The research found that specialist subcontractors' use of CCT played an important role in the overall success of the project, specifically in relation to design timescales. Participation in the design process by specialist subcontractors was facilitated at an early stage through integration workshops that established a framework for essential coordination between specialist and main contractors. The research also indicated that while strategic relationships are desired, project partnerships are a more realistic objective with commercial realities being the determining factor in terms of future business. Government and industry initiatives have tended to focus on contractual issues between clients and main contractors without serious consideration of the role of specialist subcontractors in the supply chain. This study indicates that investment in collaboration technology and supply chain integration is crucial to tackling the current crisis in the industry.

2. The construction supply chain

Supply chain management (SCM) is a comprehensive approach to aligning all the organisations in a process that relate to each other through upstream and downstream linkages producing ultimate value to the customer (Slack *et al*. 2007). The construction supply chain is illustrated in Figure 1.

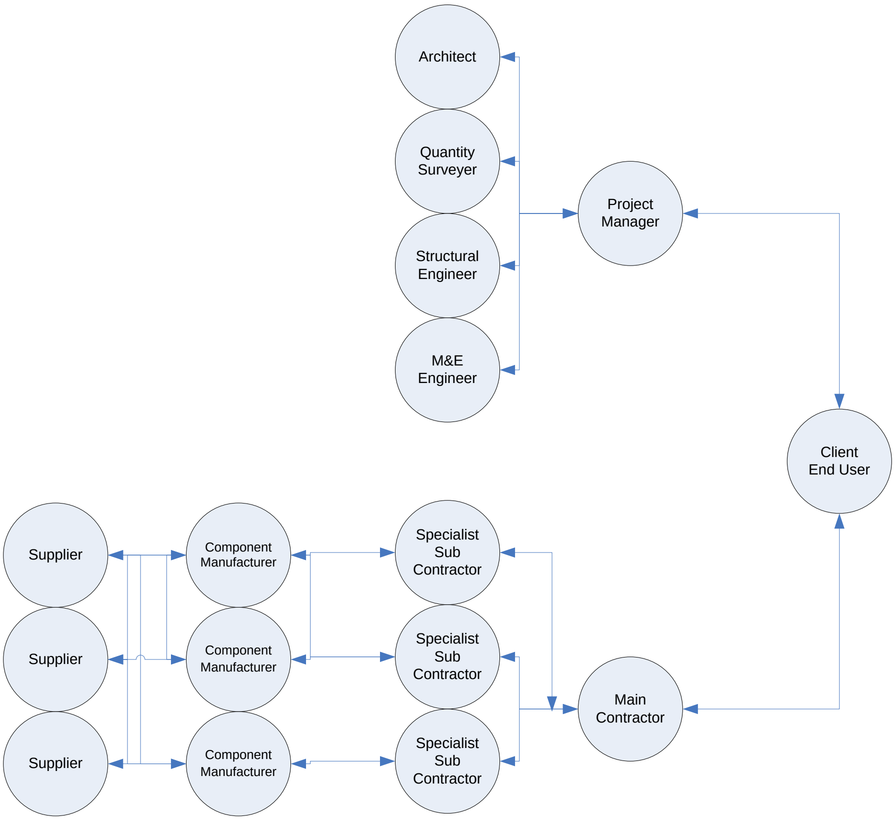


Figure 1. The construction supply chain

The construction industry has been slower than other industries to embrace the concept of SCM due to the circumstances in which collaboration takes place. Down-stream activities consist of the delivery of products and services by suppliers and subcontractors who traditionally are considered the weakest link in the chain (Akintoye *et al*. 2000, Saad *et al*. 2002). It is a converging supply chain directing all materials to the construction site where assembly takes place (Vrijhoef and Koskela 2000). It is most likely a temporary initiative producing one-off construction projects. As a result the supply chain is typified by instability, inefficiency and fragmentation. While the process from project to project can be similar, almost every project creates a new prototype (Vrijhoef and Koskela 2000). The construction supply chain also faces the challenge of overcoming traditional rivalries within the industry and needs to move away from a "*blame culture*" to a "*problem solving culture*" (Khalfan *et al*. 2007). Any cultural change in the industry needs to take place at all levels, especially middle management, supervisors and foremen who tend to be the people at the point of action tasked with implementation of policy.

2.2. Partnership

Construction projects rely on the combined efforts of several hierarchically linked organisations including clients, architects, engineers, quantity surveyors, main contractors, specialist subcontractors and suppliers all using their differentiated skills, knowledge and technology, with different structures, objectives, styles and operating procedures (Li *et al*. 2000). This complex structure presents unique challenges in relation to communication, coordination and trust. Partnership has been described as "*the key that will unlock the techniques and principles of total quality management*" or a "*concept of capturing within it a wide range of behavioural attitudes, values, practices, tools and techniques*" (Bresnen and Marshall 2000). Successful partnering reduces building costs while at the same time increasing the profit margins of participating companies. Table 1 demonstrates that as partnering agreements become more strategic, construction times can be cut by up to 80% and costs can be as much as halved.

	Construction Costs	Construction Times
Traditional approaches	100	100
Management approaches	85	70
Project partnering	70	60
Strategic partnering	60	50
Strategic collaborative working	50	20

Table 1. Traditional Vs partnership performance (Bennett and Peace 2006)

Previous research suggests that partnering in construction is divided into two approaches namely project partnering and strategic partnering (Bennett and Jayes 1995, Li *et al*. 2000, Mohamed 2002, Cheng *et al*. 2004, Kumaraswamy *et al*. 2004). Strategic partnering takes place when two or more members use partnership on more than one project. This alliance then focuses on developing procedures regarding performance improvement, work practices, improved quality and client satisfaction (Bennett and Jayes 1995, Li *et al*. 2000). Chan *et al*. (2004), lists ten critical success factors of partnering. These are:

- Establishment and communication of conflict resolution strategy.

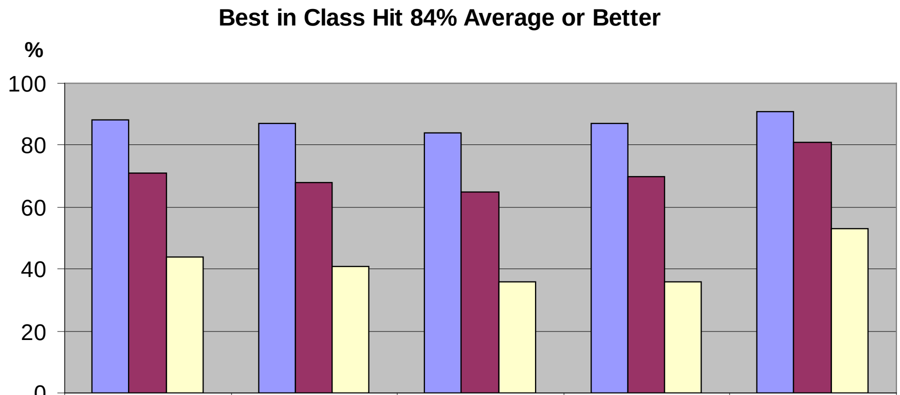
- Commitment to win-win attitude.
- Regular monitoring of the partnership process.
- Clear definition of responsibilities.
- Mutual trust.
- Willingness to eliminate non-value added activities.
- Early implementation of partnering process.
- Willingness to share resources among project participants.
- Ability to generate innovative ideas.
- Subcontractor involvement.

Other critical success factors determined from research in the UK and India indicate that the coordination of the site project manager with the client and the delegation of authority to the project manager by top management were essential in partnership (Mohamed 2002). There is also a need for informal communication lines amongst the project team (Jha and Iyer 2006). Barriers to partnership can be grouped under three categories: cultural, organisational and industrial. According to Eriksson (2009) cultural and organisational are the most critical as solving these generally resolves any industrial barriers.

A misunderstanding of the partnering concept can lead to a view that partnering relationships prevents firms from developing more profitable relationships. Relationship problems due to lack of commitment, breakdown of trust, lack of communication and cultural issues can result in the process not working. The partnering process is meant to accentuate the strengths of the members and therefore cannot compensate for the weaknesses of individual firms. Open communication can be difficult when a member of the process in involved with another member's competitor (Bennett and Peace 2006). Indeed some practitioners have noted that improved relationships between members had the potential to be abused by some contracting parties and lead to allegations of corruption (Chan *et al*. 2003). However for all these risks, research shows that inadequate staff training is the leading cause of failure of partnership arrangements (Wilkinson 2005).

2.3. Innovation and technology

Progress in construction technology has been remarkable in recent years. Twenty years ago email was an emerging technology while today there is the possibility of viewing the actual construction of a virtual building in five dimensions, where 3D solid-modelling is combined with the 4th dimension of time and the 5th dimension of cost (Wilkinson 2005). Storing paper drawings on-site, as would traditionally have been done, allows a lot of scope for mismanagement and delays. Technology not only offers a means of tracking designs; it has also revolutionised design. Advances have been made with the availability of virtual project development involving the application of the building information model and the use of computer-aided evaluation and construction process simulation techniques throughout the product life cycle are proven techniques (Popov *et al*. 2010). To stay competitive manufacturers (end users) need to embrace the 3D model as a complete digital prototype for evaluating form, fit and function (Younis 2009). Emerging technology such as virtual reality enables interactive real-time viewing of 3D data (Whyte *et al*. 2002). Research carried out by the Aberdeen Group (2006) on behalf of the five main suppliers of 3D modelling software found that suppliers who invested in 3D technology hit an average of 84% on five performance indicators, where the average was 64%, see Table 2. Yet, clients and main contractors remain unsophisticated in their approach to dealing with subcontractors in relation to innovation (Whyte *et al*. 2002, Ivory 2005, Eriksson *et al*. 2007).



	Product Revenue Targets	Product Cost Targets	Development Cost Targets	Launch Dates	Quality Expectations
Best in Class	88	87	84	87	91
Average	71	68	65	70	81
Laggard	44	41	36	36	53

Table 2. Suppliers who invested in 3D technology (Aberdeen Group 2006)

2.4. Construction collaboration technology (CCT)

Online collaboration tools can facilitate easier management of construction projects and give improved access to information at any time and from any place. Wilkinson (2005) defines construction collaboration technology (CCT) as follows:

> a combination of technologies that together create a single shared interface between multiple interested individuals, enabling them to participate in creative processes in which they can openly share their collective skills, expertise, understanding and knowledge, and thereby jointly deliver the best solution that meets their common goal(s), while simultaneously creating an auditable electronic record of the people, processes and information employed in the delivery of the solution(s).

The common features of a CCT system are listed bellow in Table 3 and divided under collaboration and management features (adapted from Wilkinson 2005):

Collaboration features	**Management features**
Commenting and mark-up	Query management for request for information and technical queries
Measuring tools - allowing view to measure distances for cost estimation purposes	Document management (e.g. transmittals, submittals, instructions from construction manager / architect)
Commenting review - this allows viewing of past versions of a document / drawing	Change management
Status change - e.g. approval or authorisation	Approval management
Discussion forums / Bulletin Board	Print management
Sharing of CAD drawings, with user profiles defining access levels	Quality management e.g. snag lists

Table 3. Typical CCT system features

2.3.1. Benefits and limitations of CCT

CCT offers considerable benefits in terms of cost and time savings. It also enhances collaboration by providing an easily accessible forum for sharing information and increases transparency and lead times on requests for information and technical queries. However, the system does have limitations and can cause difficulties for those who are used to more traditional methods and processes. The benefits and limitations of the system in relation to promoting collaboration and therefore more successful partnership arrangements are outlined in the table below (adapted from Wilkinson 2005 and Chang 2009):

Benefits	**Limitations**
Earlier /more timely involvement in key decisions (concept, planning, surveying, design, specification, fabrication, construction, installation, maintenance, repair, replacement etc)	Slower mobilisation of initial team members as they must first agree to project protocols and get training on the system. Additional training needs of new-joiners can slow down the process when new contractors / suppliers come on board
Faster drawing revision cycles and other approval processes	Electronic communication makes it easier to revise a drawing and may result in the issue of more revisions than necessary – increased workload
Fewer claims for lost/out-of-date or incorrect information	Some system processes (printing/viewing etc) can seem tedious – users tend to have a preference for having physical a drawing ‘in front of them’
Better understanding of project an processes and greater transparency with audit trails	Too much transparency of commercial information can affect future tenders
Greater scope for creativity and innovation –sharing ideas	Allowing wider and easier access to information can allow more people to offer unhelpful comments or ideas lack of non-verbal cues can lead to misinterpretations

Table 4. CCT benefits and limitations

While most of the limitations can be overcome with prolonged use of a system it is critical that due consideration is given to these limitations at roll-out. A full understanding of the benefits of the system needs to be disseminated from the outset otherwise users will see training and use of the system as additional work. Substantial inputs from stakeholders are required from the outset and these requirements may be viewed as being outside normal contractual requirements (Chang 2005).

3. Research methodology

The purpose of the research is to determine if innovation and technology influences the development of partnership relationships between main contractors and specialist sub contractors. The T2 case was selected because it matched the following criteria:

- Commitment to the supply chain partnership.
- Use of CCT.
- Shared office space between main and subcontractors.
- Early involvement of specialists in the design process through workshops.
- Broad enough to allow data triangulation to take place.
- Broad enough to test the key principles of partnership as defined in the literature.
- Narrow enough to facilitate the collection of critical data.
- Contemporary to be appropriate to case study research.
- Access to the project and project personnel was possible.

The three companies involved in the design are members of Rethinking Construction Ltd; the project was large enough to select members from the client, main contractors and sub contractors and specialist subcontractors were involved at the design stage. Furthermore, the project was complex enough to test the characteristics of the partnership relationship; the members were easily identified; the case began in 2008 and ended in 2010 and the case used BIW which is a construction collaboration technology.

Data was collected using unstructured forty-five minute interviews. Interviews were conducted with the client, main contractors and specialist subcontractors, with a view to involving individuals who had worked on similar contracts overseas and who would be familiar with the partnership process. Interviewees were asked to relate the facts as well as their views and opinions of the fit out process and subjects that arose in initial interviews were followed up. A formal questionnaire was not used but an interview guide was generated. The interviews were then transcribed verbatim and interview scripts were read several times to get a feel for interesting issues that emerged from the data. A list of themes was compiled as they emerged and the data was sorted a number of times to identify and eliminate repetition. Each interview text was repeatedly checked to ensure that the themes accurately reflected what the interviewees had said. A list of fifty line items resulted. At this stage certain themes were eliminated if they were not well represented in the text. The data was then grouped into four general categories. These are (a) construction collaborative technology; (b) design development; (c) partnership and (d) technology and twelve sub categories. The interview transcripts were read again with each occurrence of a sub category noted in the margins. Data triangulation involves the careful reviewing of data collected through using multiple sources of information (Oliver-Hoyo and Allen 2006, Yin 2009). There are four types of triangulation: methodological triangulation, data triangulation, theoretical triangulation and investigator triangulation (Farmer *et al*. 2006). This research uses data triangulation involving multiple data sources.

4. Case study

4.1. Company profile

T2 Dublin Airport is owned and operated by the Dublin Airport Authority (DAA), which operates airports in Dublin, Shannon and Cork in Ireland. This case study arises out of the DAA’s €2 billion investment at Dublin airport, which involves the construction of a second terminal and significant improvements to the existing airport. The building with an annual capacity for 15 million is projected to cost €395 million and opened in November 2010. The T2 construction project was broken into seventeen sub packages with a “main contractor” appointed to each. Each specialist subcontractor maintained a management structure on site including a contracts director; contracts manager; designers; site engineering; finance; supervision and installation fitters. In the fit-out contract the number of site fitters exceeded 900 personnel at peak time (i.e. February and March 2010) or 36% of all site personnel.

The three companies appointed by the DAA to design and project manage the T2 project are members of Rethinking Construction. The UK based structural steel main contractor is also a member of the Rethinking Construction Ltd Alliance, whose members adhere to the principles of partnership in construction. In terms of CCT, the T2 development used BIW Technologies as the web based communication system. In total 38,000 documents were issued onto BIW during the T2 and Pier E design phase. Specialist contractors shared office space with main contractors in an open plan environment meaning that competitors shared office space with each other. 3D modelling, virtual prototype and analysis software was used in the design of T2 Development and Pier E. The software created a full digital prototype prior to manufacturing taking place.

4.2. T2 Fit-out case study

The fit-out contract covering the new terminal and Pier E was awarded to the main contractor PJH on the 15th September 2008; it included the floors, walls, ceilings and all other internal fittings for the new terminal. PJH appointed ten specialist subcontractors to key areas such as specialist ventilation products, glazed screens, glazed balustrades and stairs and internal signing. Tender price and previous experience were critical elements in the selection of specialist subcontractors. Furthermore, PJH had previously worked with most of the selected specialist subcontractors. PJH appointed project managers to specific areas of the fit-out who arranged design workshops, the building and benchmarking of samples and finished goods, the program of works and visits to manufacturing facilities or specialist equipment manufacturers. All documentation issued onto the BIW collaboration site by fit-out specialist subcontractors was issued on headed paper using a numbering system and a single document format which was understood by the wider site team. A disused warehouse close to the site within the airport complex was converted into a sample presentation location known as the ‘sample shed’. Architects and other members of the design team and the client would review full scale samples of proposed products or finishes where sign off would be given prior to full scale manufacturing.

The 866 authorised users of the CCT system, BIW were broken down as follows:

- 7% client
- 33% main contractors
- 42% design team
- 18% specialist subcontractors.

All design output documentation including drawings, models, analysis and submittals were loaded on to the system. Authorised users made comments and approvals online and the status of the document was changed from “for review” to status A (approved), status B (approved with comment) or status C (rejected). The documents and all associated comments and approvals were available for all registered users to see. Design workshops were held weekly at the early stages in the design development. The meetings, chaired by a member of the design team, brought representatives of all the relevant parties together to discuss design requirements and coordination of works. Here specialist subcontractors were given the opportunity to influence design direction while maintaining the overall architectural or structural requirements.

Preliminary design documentation was prepared and issued on the BIW collaborative system for formal comment. 3D modelling, virtual prototype and analysis software was used in the design of T2 Development and Pier E. The software created a full digital prototype prior to manufacturing taking place. The software was also used to carry out structural analysis (i.e. finite element method) on the structure to ensure compliance with the relevant codes of practice and design intent. An example of the need for collaboration on one element of the project was the design of the service boom. Design workshops for the development of this structure would have had input from six main contractors. Having created the digital prototype it was possible to manufacture and install the structure within budget and programme, without design clashes. The case “T2 fit-out” was a 20 month element of a 60 month project.

5. Findings and discussion

5.1. Construction collaboration technology

The construction collaboration technology (CCT) used in T2 was provided by BIW Technologies and on site was known simply as BIW. Training in the system was provided by means of a user handbook and telephone support given by the document controller employed by main contractors to their specialist subcontractors. All documentation loaded onto the system was held in a virtual holding area until screened by document controllers prior to being made available to all users on the CCT. The majority of interviewees were satisfied that the system was useful as a repository for electronic data, including those who believed that the system did not function as intended. However, less than half the people interviewed stated that the CCT system was critical to the delivery of T2. Some of the key challenges experienced are listed below.

- Users expressed frustration at the length of time (often several days) between loading a document onto BIW and it actually being available to other users or the design team for comment.
- Delays were also experienced (beyond the contracted 10 days) in the time it took the client to respond and the main contractors used these delays to build a case for design delays due to client response times.
- Specialist subcontractors frequently experienced difficulties with documentation being rejected by the document controllers for non-compliance with coding, layout and presentation, indicating that that they did not have adequate training.
- Some interviewees stated that BIW did not work as a collaboration tool. The reasons for this ranged from difficulty in locating documents on the system to delays in getting feedback from the client. Also noted was that when comments were actually made, several documents were returned by the client at the same time. This frustrated the specialist subcontractors as the sequence of design work was interrupted. Specialist subcontractors would have expected documents to be returned in the sequence that they were loaded onto BIW and not in batches.
- One interviewee stated that it was "*very hard to beat having a drawing in front of people when discussing integration*" and another interviewee stated that in order to overcome client delays workshops were resorted to where drawings were marked-up by hand, and that it was in these workshops that collaboration actually took place.
- The traditional divide between client and main contractor that has existed in construction for decades was evident in interviews with the client stating that the

system was used in a "*cute [read cynical] way as opposed to using it under the terms of partnership*", while the main contractor stated that it took too long for documents to be viewed and commented on by the client.

- This divide between the client and main contractor impacted negatively on the partnership process and led to the view held by some that the technology was used was a means to apportion blame rather than to improve processes.

5.2. Specialist sub-contractors and design

Workshops were arranged by main contractors and/or client representatives, bringing together the specialist subcontractors' design teams to discuss aspects of the project in great detail. Design responsibility moved down the line where specialists were increasingly taking responsibility for the design of their own work. Following the workshops, specialist subcontractors completed detailed designs and loaded the resulting drawings and specifications on to BIW.

- The majority of people interviewed agreed that specialist subcontractor involvement in design was of a much greater significance than that of a traditional subcontractor where they would work from an established design, rather than be involved in its creation.
- However, benchmark samples in the "sample shed" were considered inadequate by many specialist subcontractors as they were constructed from drawings with little or no integration, and the opportunity was lost to anticipate problems that were encountered on site during the actual build. When the works commenced on site it became obvious that site conditions and several sets of building tolerances (from other specialists) presented challenges that the specialists were not prepared for.
- The client argued that insufficient design resources were put in place by the specialist subcontractors at the initial stages in the design process and that had more resources been employed, then problems would have been identified earlier. The client also argued that benchmarks were only useful as a sign-off for quality and finish, and not to check that the integration process had worked.
- Despite reservations about the resources used by the specialists, the client found that the design development process was shorter than projects undertaken elsewhere of

similar scale. While this strikes a positive note for the companies involved, significant additional costs may have been incurred that could have been avoided.

Here we see that the client and specialist subcontractors had different understandings of the purpose of the benchmark samples. The client having been involved in the conceptual design was familiar with how the job was going to come together. The client's design process did not factor in that several specialists were going to be involved in the construction and that they were liable only to understand their specific scope of works. This situation would have been avoided if the project had been designed using a single model environment (3D environment), which was continued through the project as a live process (4D environment).

5.3. Partnership

All the main contractors agreed that effective relationships between members of the supply chain were critical to achieving the goals of total quality management (TQM). Teams who worked well together produced better quality work in a more cost-efficient manner whereas teams who did not work well together struggled to achieve the same levels.

However, specialist subcontractors did not share this view, perhaps suggesting that specialist subcontractors do not trust other members of the supply chain. One of the main contractors stated, "*[…] relationships are the key ingredient to giving the client what they require…in the current climate commercial considerations determine everything*". While it is understood that good working relationships between teams are important to satisfying client requirements, commercial pressures influence the commitment by main contractors to maintaining these relationships. It would appear that the main contractors' obligation to both the client and to staying within budget meant that the 'relationship' to specialist subcontractors felt the resulting pressure, and perhaps this explains why specialist subcontractors were less positive in interviews about working relationships.

5.3.1. Project versus strategic partnering

There was universal agreement that commercial considerations would determine if repeat business took place between the members of the T2 supply chain. Commercial considerations principally relate to achieving the required tendering targets on any new project. Specialist subcontractors stated that irrespective of the relationships established on T2 or the desire of particular contracts managers or members of the design team to use a particular contractor, contracts would be awarded on a cost basis. One main contractor hit a cautionary note when he stated that until all final accounts were agreed it was not possible to determine the true commercial position of T2. The majority of specialist subcontractors awarded contracts on T2 by the main contractor had worked together on previous contracts. Less than half of the interviewees considered that it was possible to establish strategic partnership relationships as a result of T2. We also found that repeat business on project partnerships was more likely than the establishment of strategic partnerships into the future.

5.4. Technology

The technology brought to the project by specialist subcontractors consisted of 2D CAD and some 3D CAD and finite element analysis. There were contrasting views on the adequacy of the technology used: it was described by the client as "*not ground-breaking*" and typical of such a project. Yet in interviews none of the construction main contractors expressed a view that specialist subcontractors should be bringing more innovation and technology to the project. It was in fact the specialist subcontractors themselves, and the non-construction main contractors that held this view. Some interviewees stated that a single model environment should have been used on the project as a whole or in particular areas where a considerable amount of integration between parties was required. A single model environment requires that a building or particular elements of a building be developed on a single platform using 3D. One main contractor who had worked on several airport developments around the world considered single model environment CAD systems to be common in projects similar in scale to T2. This contrast in opinions relating to technology could be explained by the fact that main contractors are essentially management companies with limited site skill and they view technology as being the responsibility of the specialist subcontractors.

6. Conclusion

The Irish construction industry has experienced significant job losses with just over half the numbers employed now than at the height of the boom in 2006. The most critical issue facing the industry today is to increase efficiency in order to improve customer service. The construction supply chain must develop creative solutions to complex construction problems while tackling the low productivity and the litigious and adversarial environment that has existed for decades. A crucial element in this process is the development of partnership relationships between main contractors and specialist subcontractors where the focus is on facilitating innovative practices by specialist subcontractors. Specialist subcontractors must be active participants in supply chain management through the use of construction collaboration technologies. Their input to the design process must come at the early stages of a project and for this to happen they need to be fully integrated into the supply chain. Strategic partnerships between members of the supply chain should be a realistic objective if the industry is to see continuous improvement in efficiencies.

This study clearly demonstrated that specialist subcontractors were active participants in the use of CCT. Issues encountered in the use of CCT were representative of traditional client / main contractor rivalries and impeded the partnership process. In order to overcome some of the issues identified in this study the following recommendations should be considered:

- The rules of engagement with the system must be defined from the outset and agreed by all. For example, realistic time schedules must be defined and agreed. Furthermore, all parties involved in the process must agree to be mutually accountable for these schedules.

- Face to face meetings and participative workshops should be scheduled in conjunction with CCT use in order to generate requirements; establish priorities; engage people; develop ownership and ultimately build trust among the supply chain partners.

- All parties must have some formal training in the use of the CCT. Potential benefits of the system should also be communicated to all.

- A 'technology' champion should be assigned for the three key areas: client, main contractor and subcontractor.

We found that specialist subcontractors had a key role to play in the design process. However their contribution was more significant when they were engaged earlier in the process and actively contributed to the creation of the final design. In light of this, specialists should be involved at the initial project briefing stage, and should be facilitated with a complete overview of the project, rather than being confined exclusively to their specific area of expertise. This will allow them to identify problems in advance and generate a better awareness of the impact and implications of their decisions. Active involvement in participative workshops with other actors in the supply chain will help to develop mutual understanding, better integration and possibly greater respect and trust over time. The research also indicated that strategic relationships were possible in theory but that a continuation of project partnerships was a more realistic objective. The research also found that commercial demands in relation to tendered values would determine if future business would be possible between the members of the partnership process.

Government initiatives have yet to recognise the need to make partnership a key element in overhauling the industry. The focus to date has been on solving contractual issues between client and main-contractors without little regard to the need resolve issues in the entire supply chain which is increasingly made up of specialists. Partnership relationships must be included in discussions regarding the future of the Irish construction industry. Emerging technologies that would revolutionise supply chain management should be investigated by clients and included in project set-ups from the outset. Moving forward, this requires main contractors and specialist subcontractors to invest in innovation and technology thereby enabling the industry to sustain demand through increased efficiency and reduced costs.

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