BARRIERS TO THE IMPLEMENTATION OF CONCURRENT ENGINEERING PRACTICES WITHIN THE UK CONSTRUCTION INDUSTRY

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ABSTRACT

Concurrent Engineering (CE) is considered as one of the emerging methods in the UK construction industry. The product and process optimisation through 'integration' is a key concern of CE. The integrative aspect is tri-fold, which comprises an integration of product(s), integration of process and most importantly the integration of supply chain. A correct adoption of the concepts and principles of CE into construction practice provides significant benefits to project stakeholders, such as reduced time and costs while improving the quality of products and process efficiency. However, its implementation is not optimised to its full potential within the construction industry. Therefore, this paper aims to identify the key factors that hinder the implementation of CE practices within the UK construction industry. Data were collected from an extensive literature review, observations and semi-structured interviews and thematic analysis was adopted to analyse the collected data. The findings indicate that the inability of parties within the construction project settings to communicate effectively is the most significant high level barrier for achieving a wider application of CE practices within the UK construction industry. In total 4 high level barriers, 13 medium level barriers and 38 low level barriers to the implementation of CE with the UK construction practices were identified. The findings of this study will benefit construction organisations, who wish to implement CE practices within their practice.

Keywords: *Barriers; Concurrent Engineering; Construction Industry; Integration; UK.*

1. INTRODUCTION

Construction is a complex, fast changing industry which requires its organisations to adapt for emerging technologies and new practices to survive in the competitive markets. Concurrent Engineering (CE) (also known as Simultaneous Engineering) is relatively a new ideology, which brings number of benefits to construction industry stakeholders, who have different levels of interest and influences towards the project. CE is a partial temporal overlaps of the activities involved in a design and construction of new product (Azzone and Bertele, 2014). The approach is identified as an attempt to optimise the design and construction processes to reduce lead times, improve quality and cost by maximising concurrency and collaboration in working practices (Evbuomwan and Anumba, 1998). The traditional procurement practice frequently follows 'silo' practices whilst CE looks for 'integration /collaborative' approaches through product, process and supply chain integration, which of course minimises the design variations, cost and time overruns. An effective implementation of CE practices within construction projects provides better value for client's investment. The approach is practical and robust. However its implementation process has proved somewhat difficult. Literature suggests that there are enormous

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benefits that can be expected from acorrect implementation of CE. However it is noticed that the application of CE practices is seemingly poor within the UK construction industry. Therefore, this paper aims to explore the key barriers to the implementation of CE with the UK construction practice.

2. CONCURRENT ENGINEERING

Construction is a major contributor to the United Kingdom (UK) Gross Domestic Product (directly 8.5% in 2008, rising to 10% overall when the entire value chain is considered) and a driver of historical GDP growth (National Construction Statistics, 2013). To survive in the future competitive markets, construction industry needs to recognise the complex adaptive nature of it, and be prepared for the future changes (technological innovation, new practices etc.). CE is a practical approach, which creates less chaotic environment while optimising time, cost, flexibilityand quality of construction product/process. The fragmentednature of the industry has a negative effect on its performance; therefore 'integration' and 'communication' areconsidered as two of criticalelements of CE towards a successful product / process delivery.

2.1. INTEGRATION

Integration is vital for the progression of construction projects operations. In specific to construction context, integrating can be identified within three domains, which are products, process and supply chain (team) integration. Product integration is to assemble the product from the product components, ensure that the product, as integrated, functions properly, and deliver the product (Carnegie Mellon University, 2008). Process integration seeks the possibilities for integrating the disconnected stages of product life cycle, which are design, procurement and construction (Thabet, 1999). Supply chain integration is a close alignment and coordination within a supply chain, often with the use of shared information systems. The supply chain integration covers both internal and external integration (Cao *et al*, 2015). Latham report (1994) strongly emphasised that there must be an integration of the work of designers and specialists and the more integrated the construction process can become the better the end result will be. In principal, successful projects are the product of well integrated teams (Ibrahim, Costello and Wilkinson, 2013). Integrated ICT systems are becoming a more popular tool to facilitate 'integration' (product – process – team) within the construction projects. For example, Building Information Modelling (BIM) is considered as one of innovative approaches to design, construction, and facility management in which a digital representation of the building process is used to facilitate the exchange and interoperability of information in digital format (Eastman, 2008). A successful application of BIM software increases productivity in building design, construction and in-use.

2.2. COMMUNICATION

Effective communication is a vital consideration in CE practices. Communication affects individuals, group and organisational performance. Literature identified levels of communication which includes 'intrapersonal', 'interpersonal', 'group', and 'mass' levels (Emmitt and Gorse 2003). Intrapersonal communication involves the cognitive process of an individual to understand information and interpersonal involves communication between two people enabling relationships to be formed involving the transmission of signals and messages between both parties. Small group communication means the communication between more than two people and multi group communication involves communication across different groups; this is now moving into organisational communication. Mass communication is the communication through mass media where there is little control on who or how many receive the message. New technology is radically changing patterns of organisational communication; the advances of integrated computer systems within organisations means information can be communicated faster. Some may be of the opinion that this aids the effectiveness of communication in that it provides all members with the same message however, the use of computer integrated systems and perhaps the use of email could put a hindrance on the social interaction aspect of a company and make the workplace very impersonal. Ochiengand Price (2009) emphasised the importance of high-quality communication between the main project offices and on-site are a must to reduce the complexity of the design implementation process. CE comprises the element of effective communication, which helps to form a well-informed

design. The advantage of a well-informed design means fewer errors at the construction phase,thereby producing cost savings. However, it should also be considered that if a design is detailed down to the lowest levels, then it leaves less room for error. Likewise, if the construction teams have all put together their needs and this has been incorporated into the programme, then it leaves less time spared. Therefore, CE encourages better communication to improve time, cost and quality.

The application of CE practices can be identified within few construction projects UK; however the technique is not that much popular within majority of construction projects. The extent to which CE is exploited to benefit processes and procedures is limited, and as such the reasons behind this need to be identified.

3. ADOPTED RESEARCH METHODS

An in-depth literature review was undertaken to identify the core principles of CE and a construction project was observed at three different time periods to understand the supply chain engagement in a typical construction project. In addition, eleven semi structured interviews were carried out among the industry professionals of leading construction companies in the UK to identify the barriers to implementation of CE. The selected interviewees were from architecture (1), engineering (1), project management (4) and quantity surveying (5) disciplines and their longevity of experience varied from less than 10 years to more than 30 years, thereby demonstrating a good spread of experience. Thematic analysis was used to cluster the data and to form high, medium and low level themes (barriers) that influence in implementation of CE practices within the UK construction industry.

4. DATA COLLECTION AND ANALYSIS

In addition to the literature review and three-point observation of the selected construction project, empirical data were collected to investigate the barriers. Interview questionnaire was developed and piloted among four postgraduate students from the built environment disciplines to check the clarity and readability of interview questions. All the interviews (11) were recorded and transcribed to generate the structured (high – medium – low level) themes. The Thematic analysis used to form 4 high level, 13 medium level and 38 low level barriers to implementation of CE within the UK construction industry (see Table 1).

Table 1: Thematic Analysis of Barriers to Implementation of CE Within the UK Construction Industry

High Level Themes	Medium Level Themes	Low Level Themes
Environment(e.g. organisational / project setting) (91)	Collaborative working (41)	Fragmentation and proximity (13)
		Breakdown/lost in communication (13)
		Meetings (12)
		Sharing space (3)
	Blame culture (22)	Fear of accountability (15)
		Cost implications (7)
	Roles and responsibilities (17)	Gap in roles/responsibilities (9)
		Competent professionals (4)
		Job specification (4)
	Integration and communication (11)	Commercial issues (11)
Personnel (88)	Project team (45)	Leadership (15)
		Effective communication (10)
		Resistance to change (7)
		Lack of experience (6)
		Lack of good working relationship (5)
		Proximity (2)
	Client involvement (32)	An engaged client (21)
		Detailed brief (11)
	Conflict (11)	Commercial issues (4)

High Level Themes	Medium Level Themes	Low Level Themes
		Confusion and misunderstanding (4)
		Change (3)
Technology (77)	Good in theory (34)	Independent folders (12)
		Individual goals (8)
		Data input (6)
		Variance in workforce abilities (4)
		Need for verbal communication (4)
	Change management (24)	Time, cost and quality (9)
		Fast and easy visibility (9)
		Time consuming (6)
	Building Information Modelling (19)	BIM proactivity (9)
		Resistance to change (6)
		Time consuming and costly (4)
Practice (58)	Planning and past experience (29)	Modern methods/prefab (14)
		Learn from past projects/complex adaptive nature (8)
		Poor planning (7)
	Traditional vs Concurrent engineering (16)	Traditional approach (8)
		Good in theory (8)
	Individual goals/objectives (13)	Organisational priorities (13)

The frequency of each word appeared in the transcription was numbered and inserted within the bracket. The barriers to implementation of CE were categorised into the domains of 'environment' (both organisational and project), 'personnel', 'technology' and 'practice'. As a result of the above analysis, environment emerged as the most influential barrier toimplement CE practices within the UK construction industry. These high-level themes were further evaluated within their sub themes.

4.1. COLLABORATIVE WORKING

The problems associated with the fragmented nature of the industry were prominently discussed within the interviews. One interviewee emphasised*"fragmentation; that is the biggest sole destroyer of integration and communication"*. However, most of the construction teams / supply chain are reluctant to work together unless there is a special commitment on project goals. The nature of current construction team was also highlighted by one interviewee *"you put the team together and disperse them afterwards"*. Overall, the hindrances posed by geographical locations of the construction teams and the inevitability that construction teams are purpose built for a project and then dismantled once a project is completed means that communication and integration is difficult to build and/or maintain due to the attitudes and work commitments of construction professionals. The interviewees further noted positive and negative consequences of meetings. Majority of the interviewees referred to routine meetings which are scheduled on a weekly or fortnightly basis but one interviewee highlighted that often *"meetings can be badly planned in our industry which means they can be unnecessary and quite often go on far too long and not actually achieve any end goal"*. By contrary, another interviewee said in order to have effective communication, regular meetings are the key. Only one interviewee made reference to networking and said his organisation *"have a lot of inter-divisional events that enable networking and getting to know other people"*. Although networking and social events facilitate the integration and communication, no one else in the interview process encouraged this idea. However, the use of shared office space and its benefits to integration, communication and attitudes were highlighted.

4.2. BLAME CULTURE

The fear of accountability was the most significant issue identified under the theme 'blame culture'. This theme was supported by all interviewees, meaning it is commonly thought that there is a fear of accountability in the industry which affects people's attitudes and actions. One interviewee suggested

"people will generally try and hide if they have done something wrong". Another interviewee was more specific and pointed *"Health and Safety laws; obviously they have been brought in to try and reduce death and injuries which is a great thing but ultimately an individual can be responsible for something or held accountable"*. Blame culture may also be a result of the cost implications associated with responsibility. Blame culture is 100% present in the construction industry and *"when it comes down to a lot of damages as we are part of fit-out, a lot of the decision is whose responsibility is it to rectify it so everybody tries to pass the buck onto someone else because of the cost implications"*. This comment provides an insight into the link between the fears of accountability and potentially the reasons for this, namely cost implications, which leads to blame culture being a common attitude of construction professionals.

4.3. ROLES AND RESPONSIBILITIES

The gap in roles and responsibilities was the most influential issue under the theme of roles and responsibilities. It was mostly identified that some people understand what is required of them and some do not, with one interviewee noted, *"things often fall under 'the too difficult to handle' or, 'I don't fancy that aspect', so then it falls into a grey area so there is a gap"*. This topic was evenly prominent across the different construction professionals. The idea that some areas of work offer*"poor job specification"* is linked with the gap in roles and responsibilities. Interviewees felt that professionals often feel that something is not their job and with someone else also dismissing it, creates a gap. Specialisation was raised as an issue. Construction professionals are often too specialised in their field and do not want to move away from that, but construction requires that. For instance, a quantity surveyor needs to have sufficient technical knowledge to understand and fulfil their role effectively in the same way a construction manager also needs to understand the commercial implications of works to fulfil their job role successfully. On the other hand, required competencies of professionals were highlighted by two interviewees. This low level theme is in contrast to the gap in roles and responsibilities as it enforces that people do understand their roles and responsibilities in the industry.

4.4. INTEGRATION AND COMMUNICATION

Commercial issues were identified as a major barrier to effective integration and communication. Many interviewees believed that maintaining a competitive edge involves holding back commercial information which goes against integration and many could not identify a way forward, and that organisations need to make profits so this issue would always be present. One interviewee stated *"it is a very competitive industry so everyone wants to make money"*. Though this is necessary, full integration of construction parties seems difficult to achieve.

4.5. PROJECT TEAM

The resistance to change was perceived to be a barrier to CE. It was identified that the industry employees a variety of people in terms of age, background and culture. The bringing together of construction professionals with tradesmen and so on means that some are ready to embrace new technologies, whereas others wouldn't even consider the idea, leading to very different approaches. Proximity of people is another barrier to CE. The geographical location of the construction parties would influence the ability to work concurrently. Two interviewees within the sample identified proximity as a barrier to CE is that many interviewees work in joint client/contractor offices and so did not encounter this as a difficulty in their own experiences. Lack of leadership was identified as the most significant barrier to implementation of CE. One interviewee highlighted that *"the barriers in most cases are not the concepts of CE but how things are set up to run it and the leadership"*. It was highlighted that for CE to be effective, all must know what is required of them and need to be brought on board to a concurrent way of working. The way in which to do this is through leadership. The effect of a lack of experience/know-how is another barrier to CE. In this data set, interviewees felt that designers lacked experience of pressures on site, many construction professionals were *"too specialised"* and did not have a good enough general technical knowledge to perform their roles effectively and work towards a project goal concurrently.

Communication was seen to not have been strong enough within the industry for CE to work effectively, with some suggesting implementing communication systems to overcome this barrier. With so many tasks being conducted at once in construction, being able to manage these effectively using CE, coordination was seen to be the key and this requires effective communication. Lack of good working relationships were viewed as a barrier to CE as concurrency could not take place without established working relationships. The industry's inability to form good working relationships could be due to the longevity of the industry and teams being dispersed after a specified period of time.

4.6. CLIENT INVOLVEMENT

The need for an engaged client was discussed by all interviewees and was brought to attention in many different perspectives. *"Client involvement usually brings success to a project if you have somebody who can communicate exactly what it is they want"* was the viewpoint of one interviewee. Throughout the interviews it was recognised that client involvement is significant. However, it can lead to frustrating situations when decisions cannot be verified within the time constraints. The importance of a detailed brief and its clarity was something which is scarce in the industry and in particular, the need for a client to communicate their requirements effectively was emphasised.

4.7. CONFLICTS

Confusion and misunderstandings lead to conflicts. For example one interviewee noted that instructions which say *"make good floor in a particular room. Now what the contractors impressions of making good a floor and the clients impression of making good a floor might be two completely different things"*. The interviewees felt there is a lot of confusion and misunderstandings in the industry and this leads to conflict when people are not clear on what is required. The continual design change involved in construction projects was also thought to lead to conflict. It should be noted, by construction professionals, that CE aims to reduce change. Commercial issues seem to have a strong connection with conflicts. Four interviewees stated that they believed CE could never be 100% successful due to the commercial aspect of all businesses: Profits come first.

4.8. GOOD IN THEORY

The significance of independent folders within integrated ICT systems was emphasised during the eleven interviews. One interviewee stated "we have a site and project wise for CAD, obviously not everything can be open to everyone so we have different areas". Supportively, another interviewee stated that "limited integrated systems enables things of a personal nature to be kept private" demonstrating the need for organisations to keep certain aspects of the business operations private, meaning integrated IT systems will never be fully integrated.

Individual goals proved to be a key player of what stands in the way of integrated IT systems. One interviewee noted that*"people a lot of the time have their own singular objectives rather than one joint goal. It should be that the aim is to build the job and everybody works towards that. But that's not always the case"*. The overall theme established was that integrated IT systems do not have the ability to overcome the fact that each party has their own individual goals and are most of the time working towards these rather than as a joint effort to get the job done. The importance of the data input into integrated IT systems was seen to dictate how useful they are by interviewees. It was maintained that the system was only as good as the data put into it in determining its effectiveness. One interviewee described some systems as *"slow and sluggish"* whereas another interviewee says their integrated system helps their organisation to *"monitor and manage everything centrally"*.

On the other hand a need for verbal communication and variance in workforce abilities were noted as of equal important. It was maintained that integrated IT systems will never document everything and verbal communication is a core to the progression of projects. In regards to variance in workforce abilities, one interviewee addressed the financial capabilities of the subcontractor in terms of integrated IT systems. In contrast to this, another interviewee identified variance in workforce abilities as the different levels of

skills of people of varying ages, background and the lack of training provided for the ever-evolving IT system.

4.9. CHANGE MANAGEMENT

Time, cost and quality, and fast and easy visibility in relation to integrated IT systems were the most discussed facts by the interviewees. The benefits of integrated IT systems were noted by a number of interviewees by highlighting *"speed, efficiency and maybe even cost"* which contradicts previously quoted interviewee describing the IT systems as *"slow and sluggish"*. From this it can be derived that professional opinions on integrated IT systems largely vary and this could be down to the different systems employed within organisation and their performance. In terms of fast and easy visibility, designers were most forthcoming with this theme and *"swiftness of visibility"* was linked to the ability to *"see problems before they occur and being in the position to do something about them"* with early warnings and contractual communications being issued on integrated IT systems. The time consuming element of change management felt that updating information on integrated IT systems and so on took too long with one interviewee even describing it as *"counter productive"* and another calling it *"frustrating"*. It appears that there are mixed feelings on IT systems, proving there is room for improvement for many.

4.10. BUILDING INFORMATION MODELLING

The awareness of the benefits of BIM seems to have made its way to industry and is continually increasing. However, the resistance to change still appear within the use of BIM and this is an identified obstacle which needs to be overcome. The reasons for BIM resistance is *"because people are still used to working in an old style methodology"*, and *"there are such extremes within the industry in terms of technology and how things are actually done still so there is a long time before we are fully there"*. The transition from old style methods to BIM will be an ongoing concern and the flow of development to all parties needs to be addressed. Another issue highlighted was the time consuming and costly element (training, licence, ownership of model etc.) of BIM. The commercial professionals were most concerned with this issue with one interviewee stating that in one of the projects they had produced *"six or seven estimates before even seeing the BIM model because people weren't as quick as necessary in getting the information across"*. It was also raised that the BIM model is only as good as the information input into it, therefore, this research highlights that this is something which needs to be managed; time on data input.

The introduction of BIM for construction projects seems as a positive driver for integration and CE. A few benefits of BIM include clash detection and mitigation, faster drafting without loss of cost and quality and most importantly to the movement of CE; co-ordination and collaboration. BIM and CE work hand in hand in the progression they aim to achieve in terms of reduced design time, effective management, and improved quality and reduced costs. For the implementation of BIM to be as successful as possible, the identification of challenges is imperative. It should be recognised that the merging of BIM into the construction industry will not be without its challenges, but the professions cannot afford to be outside of the BIM loop (Martin, 2012).

4.11. PLANNING AND PAST EXPERIENCE

The importance of prefabrication and its impact on time, cost and quality was highlighted by interviewees as using forward planning to get ahead on a project. One interviewee noted *"getting the design resolved a lot earlier in the process so we can manufacture as much of our building off site as possible"* with another interviewee enforcing the time saved using prefabrication, *"we are building 30% quicker than anyone has ever built a hospital before and have taken 30 weeks off the programme which gives us massive savings prelims wise."* It can be inferred from the interview process that prefabrication is a key associate of CE for interviewees, and has the support of the industry. The lessons learnt from past projects taking into account constructions complex nature are not reflected in new projects. Three interviewees noted that the construction industry is unique and complex with others stating that these projects have been built before, and the barriers posed by past projects are still present on current projects. Interestingly

one interviewee explained that *"CE is developed as a result of poor planning; works have to start on site with an incomplete design due to time restraints, however this is never the intention"*.

4.12. TRADITIONAL VS CONCURRENT ENGINEERING

Interviewees urged that a design should be completed before construction commence and that this is the way construction should work and it would eliminate many problems. However, this is never the case. One interviewee stated *"it would be much simpler if it was traditional that client gave us a design and we built it but we are developing the design whilst we are building it and proposing solutions"* at the same time. The idea of a concept being good in theory but not practical, which was raised as part of another theme earlier in this paper, has proved to be relevant again within the theme of traditional vs concurrent engineering. When describing CE in practice, interviewees often used phrases such as *"it's nice in theory"* or *"it doesn't work like that"*.

4.13. INDIVIDUAL GOALS/OBJECTIVES

It was identified that internal goals took preference over all parties working in unison towards one goal on a project. One example given by an interviewee of a hospital project summed up this theme accurately, *"the problem we have here on a hospital is that the client doesn't want to make a decision on equipment till the last minute in case any new equipment comes out but us as the contractor needs the decision really early on equipment so we can get hold of it and get it installed into the building and that might have an effect on some of the other systems we put in for example, the routes of cables or installation of walls"*. It was also identified that to satisfying everyone's requirements with so many parties involved can be challenging.

5. CONCLUSIONS

The aim of this research was to explore the barriers for implementing concurrent engineering within the UK construction industry. The research revealed that CE practices within construction projects seem to be employed to a certain degree. However, many construction professionals are not familiar with the term. The findings explain the understanding of fundamental principles of CE; integration and communication, are weak in the industry both in building and infrastructure and therefore many felt CE's application was not at its best. The key advantages of CE are immense. Time savings, once design and construction activities are coordinated effectively, thus leading to cost savings and quality assurance, improved working relations and making the industry a more productive place. The limitations identified that in order to coordinate design and construction, integration and communication is vital and this is one of the construction industry's major weaknesses. Amongst other limitations, individual goals and objectives of organisations, particularly commercial goals, stood in the way of integration, preventing the successful implementation of CE. The most critical finding of this investigation was the identification of four high level barriers, 13 medium level barriers and 38 low level barriers for implementing CE with the UK construction industry. The similarity could be identified with Ibrahim, Costello and Wilkinson (2013) studies which was based in New Zealand as their studies also identified 'focusing on goals and objectives', 'trust and respect', 'free flow communication', 'no blame culture', 'commitment from top management', 'team flexibility and responsiveness to change', 'collective understanding', 'seamless operation with no organisational boundaries', 'sharing information' and 'encouraging initiative' as relationship oriented indicators, and 'creation of single team location', 'innovation and improvement', 'integrated ICT system', 'effective management of health and safety' and 'client care team' as non-relationship oriented indicators that influence in team integration. As such, it appears that further research is necessary to explore how to overcome the barriers for implementing CE in order to harness its full potential.

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