An Investigation of the Readiness of the Construction Industry for Concurrent Engineering.

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Abstract

The adoption of Concurrent Engineering (CE) within the manufacturing and other industries has led to notable improvements and resulted in improved time-to-market, reduced production cost, improved quality of the product, and active customer involvement. Therefore, it is expected that the implementation of CE within the construction industry would also bring about positive changes within the industry because CE has the potential to make construction projects less fragmented, improve project quality, reduce construction time, and reduce total project cost. It is considered essential within other industries to carry out a readiness assessment of an organisation before implementing CE. Therefore, to facilitate the adoption of CE within the construction industry, it is also necessary to assess the extent to which organisations in the industry are ready for it. This would result in identifying specific areas, which need attention and improvement. It would also help an organisation to see its current performance and areas in which it is weak so that corrective action could be taken. In order to assess the readiness of the industry, it is necessary to have an appropriate tool, which could be used within the industry. Tools and models available from other industries were evaluated and found inappropriate for the construction industry. This paper discusses CE implementation within the construction industry and highlights the need for CE readiness assessment. It presents a CE readiness assessment model for the construction industry – called the BEACON Model – and case studies, which were carried out in using the model to assess different sectors of the UK construction industry.

Keywords

Concurrent Engineering, CE Readiness Assessment, Case Studies, Construction Industry.

Introduction

Concurrent Engineering (CE), sometimes called simultaneous engineering or parallel engineering, has been defined by Winner et al. (1988), as "…a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements." In the context of the construction industry, Evbuomwan & Anumba (1998) define Concurrent Engineering as an "…attempt to optimise the design of the project and its construction process to achieve reduced lead times, and improved quality and cost by the integration of design, fabrication, construction and erection activities and by maximising concurrency and collaboration in working practices."

In order to introduce aspects of CE in the construction project delivery process for effective co-ordination and integration, various research efforts have been undertaken. A detailed account of these efforts is compiled and presented by Kamara et al. (2000) and Anumba et al. (2000). They have concluded that much more needs to be done if the reported benefits of CE in other industries such as manufacturing can be realised in the construction industry. It is also concluded that an important aspect of CE implementation in the construction industry is the need to carry out readiness assessment of the construction supply-chain for CE implementation. This is expected to establish the level of CE maturity of different sectors of the supply-chain with a view to informing implementation efforts. Therefore, in order to establish the level of maturity and improve planning for CE implementation, the readiness assessment of the construction supply-chain is imperative (Khalfan et al., 2001).

This paper discusses the need for CE readiness assessment, argues for a specific readiness assessment tool for the construction industry, and presents the BEACON (Benchmarking and REadiness Assessment for Concurrent Engineering in CONstruction) model. The later part of the paper presents the readiness assessment of sectors of the construction supply chain using the BEACON model.

CE Readiness Assessment of the Construction Industry

As discussed in the previous section one approach that has been successfully used to improve CE implementation planning is to conduct a readiness assessment of an organisation prior to the introduction of CE. This helps to investigate the extent to which the organisation is ready to adopt Concurrent Engineering (Componation & Byrd, 1996), and to identify the critical risks involved in its implementation within the company and its supply chain. CE Readiness Assessment has been successfully used for planning CE implementation in several industry sectors, notably manufacturing and software engineering. It is therefore imperative that, for CE implementation in the construction industry to deliver the expected benefits, readiness assessment of the construction industry should be undertaken. This will ensure that all sectors of the industry have reached an acceptable level of maturity with respect to the critical success factors for CE implementation, and may indicate the likelihood of the following benefits:

- Better and more effective CE implementation within the construction industry;
- Enabling the industry to evaluate and benchmark its project delivery processes;
- Development of more appropriate tools for CE implementation within the industry;
- Enabling the industry to identify areas which require improvements or changes; and
- Enabling the industry to realise the need for CE implementation in order to bring about improvements in the whole project delivery process.

There are several tools and models, which are being used for readiness assessment of organisations for concurrent engineering. A comparison and brief description of these models and tools were presented by Khalfan & Anumba (2000b). After analysing the comparison matrix, it was concluded that the RACE model would be the most appropriate for use as the Readiness Assessment Tool for Concurrent Engineering in the construction industry. However, the RACE model requires adaptation and modification for this purpose because, essentially, it was developed for other industries such as manufacturing and software engineering. Thus, it needs to be tailored to the requirements of the construction industry and the people working within the industry. Therefore, a CE readiness assessment model has been developed for assessing the construction industry. This includes both a 'People' and a 'Project' element – these are considered key aspects of CE, which were not adequately covered in the RACE model. The new model, named 'BEACON Model', is shown in Figure 1 and briefly described in the next section.

The BEACON Model

The BEACON Model (see Figure 1) is divided into four quadrants or sections to represent four elements or aspects of the model, which are Process, People, Project, and Technology. The first quadrant contains five critical process factors used to assess the process maturity level of a construction organisation. The second quadrant contains four critical people factors used to assess the team level issues within the organisation, while the third quadrant is comprised of three critical project factors used to assess the client's requirements and design related issues. The fourth quadrant presents five technology-related critical factors used to characterise the introduction and utilisation of advanced tools and technology within the organisation. The key advantage of the model is that it does not only include the process and the technology aspects as covered in other models but also introduces two new dimensions, people and project elements. These elements were covered to a limited extent in existing readiness assessment models and tools but were not adequately emphasised. The rationale behind including the people and the project elements is that both of them are as critical to CE as the process and technology elements and should be distinguished (Ainscough & Yazdani, 1999; Al-Ashaab & Molina, 1999; Brooks & Foster, 1997; Chen, 1996; Crow, 1994; Khalfan & Anumba, 2000a; Lee & Young, 1994; Love & Gunasekaran, 1997; Martin & Evans, 1992; Paul & Burns, 1997). This is one of the novel features in the BEACON model.

For all of the elements, five levels have been adopted from the RACE model (CERC, 1992), which indicate the level of maturity of an organisation with respect to the quality of the project development process, team-working, completed project itself, and technology employed within the organisation. These five levels are Ad-hoc, Repeatable, Characterised, Managed, and Optimising, and are described in Table 1. The Ad-hoc Level indicates that an organisation is unfamiliar with CE practices or is not ready to adopt CE, whereas the Optimising Level shows that the organisation is ready to adopt CE or is already practising CE within its project delivery process. A model-based questionnaire (called the BEACON Questionnaire) has been developed for use in assessing construction organisations. The assessment scale has five possible options: “Always”, “Most of the Time”, “Sometimes”, “Rarely”, and “Never”, corresponding roughly to the five maturity levels (Note: Refer to Khalfan (2000) for a detailed description of the development of the BEACON model).

CE Readiness Assessment Case Studies

In order to assess the CE readiness of the UK construction industry, case studies were carried out by using the BEACON Model. One of the reasons for carrying out case studies is the fact that they help to solve current problems through an examination of what has happened in the past and what is happening now, and thus save a lot of time (Yin, 1989). For the purpose of the case studies, the industry was divided into five categories: clients, consultants, contractors, sub-contractors, and material suppliers. This paper presents the results of the case studies, which were carried out within organisations from all these categories.

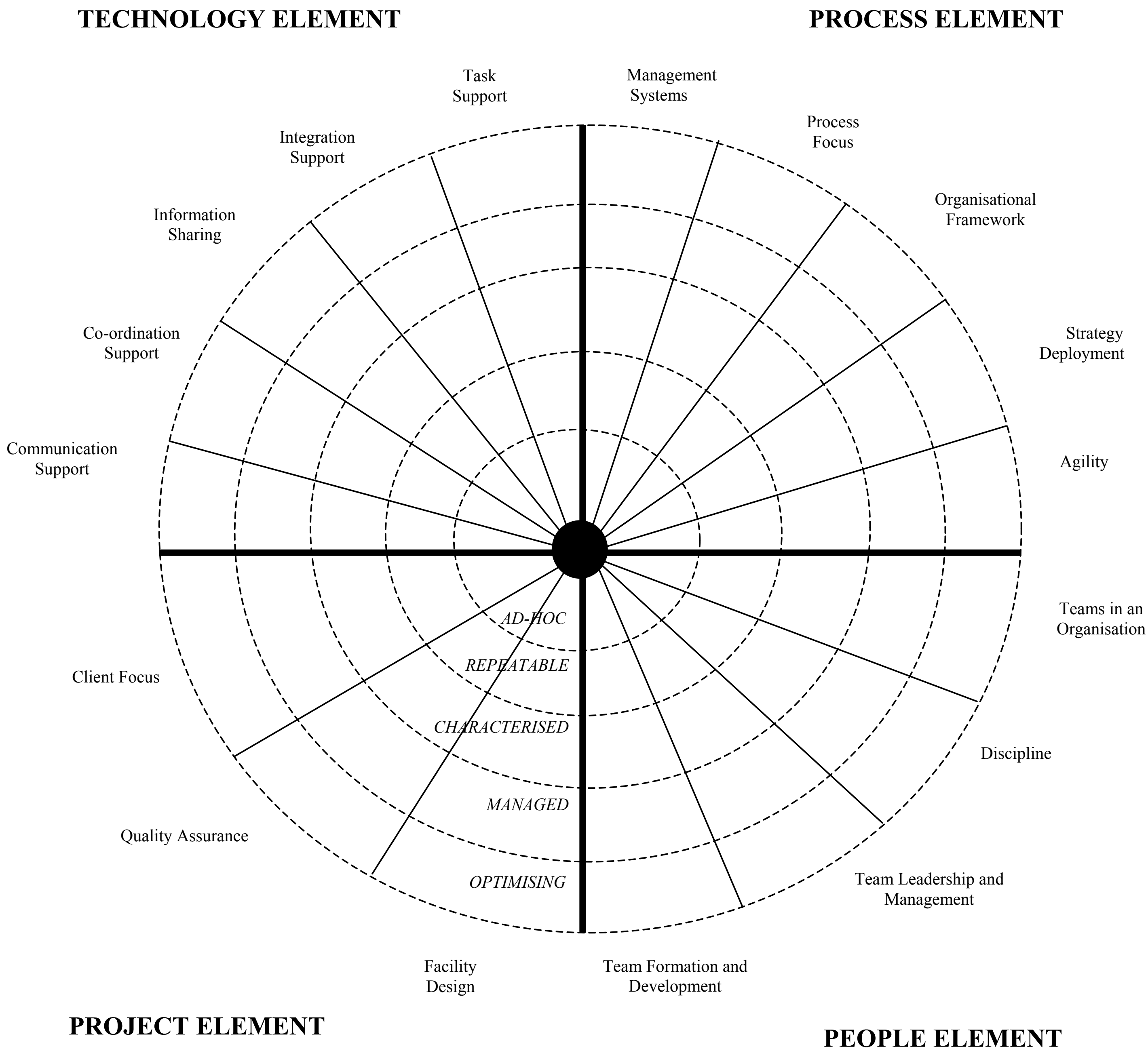

Figure 1: The BEACON Model

Table 1: BEACON Model Maturity Levels (adapted from RACE model)

Maturity Level	Description
Ad-hoc	This level is characterised by ill-defined procedures and controls, and by confused and disordered teams that do not understand their assignment nor how to operate effectively. Informal interaction with the client is observed, management of the project development process is not applied consistently in projects, and modern tools & technology are not used consistently.
Repeatable	Standard methods and practices are used for monitoring the project development process, requirements changes, cost estimation etc. The process is repeatable. There are barriers to communicate within the project development team. Interaction with the client is structured but it is only at the inception of the project. Minimal use of computer and computer-based tools.
Characterised	The project development process is well characterised and reasonably well understood. A series of organisational and process improvements have been implemented. Teams may struggle and fall apart as conflicts are addressed but a team begins to respect individual differences. Most individuals are well aware of client's requirements but client is not involved in the process. Moderate use of proven technology for increasing group effectiveness.
Managed	The project development process is not only characterised and understood but is also quantified, measured, and reasonably well controlled. Tools are used to control and manage the process. The uncertainty concerning the process outcome is reduced. Work is accomplished by the project development team and conflicts are addressed. Client is involved throughout the process. Appropriate utilisation of available technology and computer-based tools.
Optimising	A high degree of control is used over the project development process and there is a major focus on significantly and continually improving development operations. Team performance is regularly measured, and performance measures are continuously validated. Client is a part of project development team from inception and all project decisions are prioritised based on client's needs. Optimal utilisation of appropriate plant and technology & technology-mediated group work is observed.

Methodology

Ten companies within each category were selected randomly with the expectation that at least five of them would respond. Questionnaires were sent out with a covering letter to all the selected companies. Before sending out the questionnaires, each company was contacted and the most appropriate person was identified, either from senior or middle management, who had knowledge about the company and could adequately complete the questionnaire. A summary of the assessment results is complied and presented in Table 2, which shows average percentages for all the elements within each category. The average percentages for each factor within the elements were calculated after assessing the questionnaire responses for each category. A brief account of all case studies within each category is presented in the following sub-sections, with the results plotted on the BEACON Model diagram for each industry sector.

Readiness of Clients

33% of client organisations responded to the questionnaire, ranging from large to small in size and representing different client sectors such as hospitals, academic institutions etc. All respondents identified the people element as the most important and the technology element as the least important element from their point of view. The average assessment result is plotted on the BEACON Model diagram shown in Figure 2. The clients are doing best in the project element, need the most improvements in the technology element, and have average performance under the process and people elements. The overall result of client organisations shows that some of the critical factors are at the ‘managed level’ while the rest are at the

Table 2: Summary of the Readiness Assessment Results

	Construction Supply Chain Participants				
Elements	***Clients (%)***	***Consultants (%)***	***Contractors (%)***	***Sub-contractors (%)***	***Material Suppliers & Manufacturers (%)***
Process Element	***Avg.: 68.13***	***Avg.: 71.69***	***Avg.: 73.94***	***Avg.: 80.04***	***Avg.: 63.15***
Management Systems	66.13	71.64	77.31	83.33	54.98
Process Focus	70.36	66.83	70.38	82.69	63.26
Organisational Framework	68.33	68.75	78.00	81.67	58.75
Strategy Deployment	73.75	77.50	74.50	76.67	67.50
Agility	62.08	73.75	69.50	75.83	71.25
People Element	***Avg.: 68.56***	***Avg.: 75.39***	***Avg.: 78.81***	***Avg.: 81.13***	***Avg.: 71.88***
Team Formation and Development	70.42	71.88	76.50	86.67	81.25
Team Leadership and Management	81.25	75.78	81.88	84.38	67.71
Discipline	66.67	80.47	85.63	87.50	80.21
Teams in an Organisation	55.91	73.44	71.25	65.97	58.33
Project Element	***Avg.: 76.92***	***Avg.: 73.59***	***Avg.: 76.60***	***Avg.: 85.51***	***Avg.: 73.08***
Client Focus	80.89	65.91	69.09	82.58	72.73
Quality Assurance	69.79	81.26	86.26	90.63	72.92
Facility Design	80.09	73.61	74.44	83.33	73.61
Technology Element	***Avg.: 55.01***	***Avg.: 52.81***	***Avg.: 67.56***	***Avg.: 76.11***	***Avg.: 42.32***
Communication Support	57.92	60.63	64.50	83.33	55.83
Co-ordination Support	49.30	39.58	62.78	72.22	35.18
Information Sharing	55.69	50.00	70.00	65.15	44.04
Integration Support	55.76	48.44	69.38	82.30	40.63
Task Support	56.40	65.39	71.15	77.56	35.90

‘characterised level’ of CE readiness. This confirms that the client organisations are not ready to adopt CE and the areas, which need attention are: all the critical factors within the technology element, agility within the process element, quality assurance within the project element, and teams in an organisation within the people element.

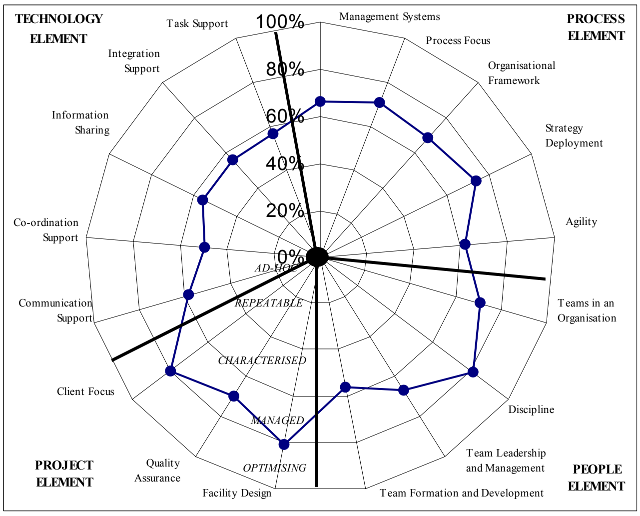

Figure 2: CE Readiness of Clients

Readiness of Consultants

The response rate for consultants was the same as for clients, that is four consulting organisations out of twelve architecture and engineering consultants responded to the questionnaire. Most of the respondents stated that the people element is the most important and the technology element the least important element for them. The average readiness assessment result for consultants is shown in Figure 3. This shows that consulting organisations are at the ‘managed level’ except for some of the critical factors, which indicate the ‘characterised level’ of the CE readiness for the organisations. Most of the critical factors in the process, people, and project elements are at the ‘managed level’, whereas almost all of the critical factors under the technology element are below the ‘managed level’. This result concludes that the consulting organisations need significant improvements before they are ready to adopt CE. The areas which need attention and consideration are: all the critical factors within the technology element, client focus within the project element, and process focus and organisational framework within the process element.

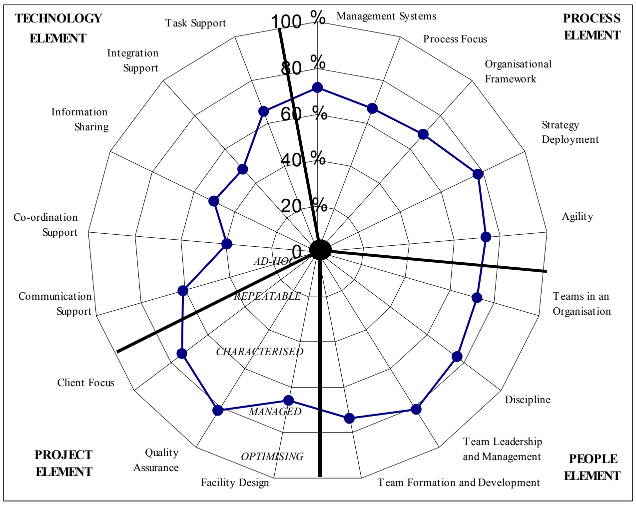

Figure 3: CE Readiness of Consultants

Readiness of Contractors

Five contracting organisations, ranging from medium-size to large, responded to the questionnaire; this represents around 40% of the total number of questionnaires sent. Most of the respondents considered the people element the most important and the technology element the least important element, which is the same as for clients and consultants. The average assessment result for the contractors is plotted on the BEACON Model diagram shown in Figure 4. All the critical factors under the process and technology elements are at the 'managed level' of CE readiness whereas for the project and people elements, some of the critical factors are even at the 'optimising level'. This concludes that the contracting organisations are ready to adopt CE and have already adopted aspects of CE in some of the critical factors within the elements. The areas which need attention are communication support, and co-ordination support within the technology element, client focus within the project element, agility within the process element, and teams in an organisation within the people element.

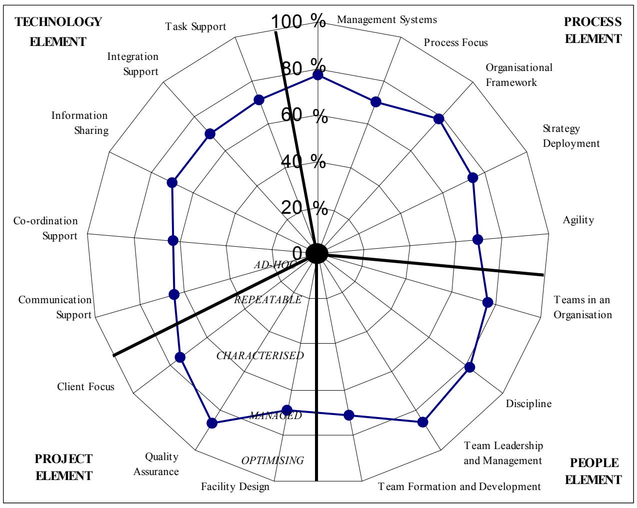

Figure 4: CE Readiness of Contractors

Readiness of Sub-contractors

Twelve sub-contracting organisations, ranging from small-sized to large, were sent the BEACON questionnaire and 25% of them responded. Most of the respondents commented, as did the previous groups, that the people element is the most important and the technology element the least important element from their organisational point of view. The average assessment result for sub-contractors is plotted in Figure 5. This shows that subcontractors are at the 'optimising level' of CE readiness except for some of the critical factors under the process, people, and technology elements, which are at the 'managed level'. This concludes that the sub-contracting organisations are ready to adopt CE and have already adopted aspects of CE in some areas. The areas which need to be improved are co-ordination support and information sharing within the technology element, agility within the process element, and teams in an organisation within the people element.

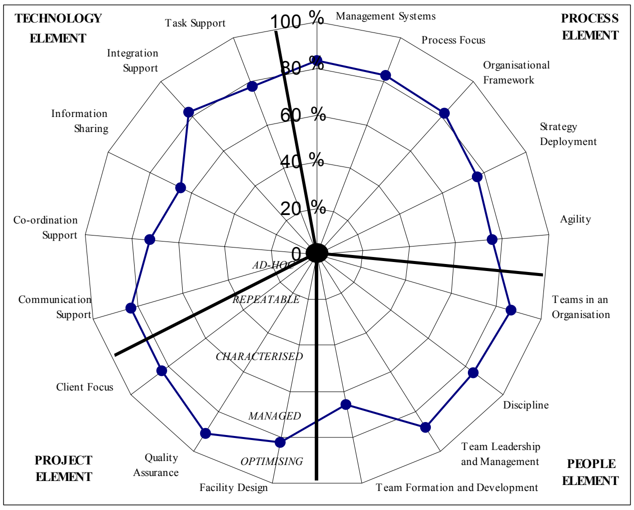

Figure 5: CE Readiness of Sub-contractors

Readiness of Material Suppliers and Manufacturers

Three material suppliers and manufacturing organisations, ranging from medium to small-sized, responded to the questionnaire, which was 25% of the total number of questionnaires sent. Here again, most of the organisations considered the people element as the most important and the technology element as the least important element. The readiness assessment result of the material suppliers and manufacturers is plotted on the BEACON Model diagram shown in Figure 6. It could be seen that almost all the critical factors under the process, people, and project elements are at the 'managed level' whereas all the critical factors under the technology element are below the 'managed level'; and co-ordination support and task support are particularly poor under the technology element. This shows that the material suppliers and manufacturers still have a long way to go before they are ready to adopt CE. Significant improvements are needed in all the critical factors within the technology element, management systems and organisational framework within the process element, and teams in an organisation within the people element.

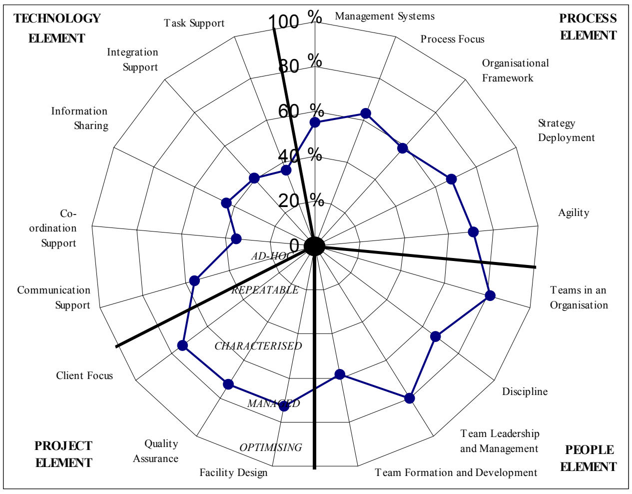

Figure 6: CE Readiness of Material Suppliers and Manufacturers

Discussion

After analysing the results of the readiness assessment case studies of the participating organisations within each category, it could be seen that the people element is considered the most important element and the technology element the least important element from most of the organisations' point of view in all categories. Most of the contracting organisations are almost ready for concurrent engineering (CE) in general and most of the critical factors in each elements are within the 'managed level' of CE readiness whereas consulting organisations are not ready, although some of the critical factors are within the 'managed level' while the rest are below the 'managed level' and need improvements. The same is true of client organisations, which need improvements in more than half of the critical factors within each element. The assessment results for suppliers and manufacturers portray them as the least ready for the adoption of CE. On the other hand, the results for sub-contractors show them to be the most ready for CE implementation, compared to all other sectors, with most of the critical factors at the 'optimised level'.

As far as critical factors under the process element are concerned, sub-contractors are the best and are at the 'optimising level', whereas all other sectors are at the 'managed level'. Agility is the weakest area for clients, contractors and sub-contractors, whereas process focus and management systems are the weakest areas for consultants and suppliers respectively. Material suppliers and manufacturers need the most improvements to the critical factors under the process element.

Client organisations need the most improvements within areas covered under the people element whereas sub-contracting organisations are performing well except for one factor, that is teams in an organisation, which is also the weakest critical factor in all the other sectors. Overall, for the people element, sub-contractors are at the 'optimising level' and the rest are at the 'managed level' of CE readiness.

All sectors seem to be performing well in the areas under the project element, specially sub-contractors, who are at the 'optimising level' of the CE readiness while the rest are at the 'managed level'. Client focus seems to be the weakest area for all sectors except for the client organisations, which need the most improvements within the quality assurance factor.

Critical areas covered under the technology element need the most attention and consideration by all sectors, although contractors and sub-contractors are marginally better than others, being at the 'managed level'. Clients, consultants, and suppliers are all at the 'characterised level' and need considerable improvements in all areas under this element. The weakest critical factor for all sectors is co-ordination support.

The overall results show that the construction industry, as a whole still needs improvements in most of the critical areas in order to adopt CE effectively. Sectors, which seem to be ready for CE adoption are those, which are client-focused, have greater focus on monitoring and controlling of their project development process, and are continually improving their development processes and operations.

Conclusions

The assessment results show that the people element and technology element are respectively the most and least important elements for most of the organisations in all categories. Contractors and sub-contractors, in general, are ready to adopt aspects of CE within their organisations whereas clients, consultants, and suppliers & manufacturers are not ready to adopt CE. The most important conclusion is that, overall, the construction industry is not yet ready to adopt CE and needs significant improvements in a number of critical areas before CE adoption. The industry also needs appropriate guidelines for improvements in the weaker areas as well as guidelines for the implementation of CE within the industry. Another important conclusion, which could be drawn, is that the BEACON model can be successfully used as a CE readiness assessment tool for the construction industry. It can also be used as a useful tool for self-assessment on the four key elements: process, people, project, and technology even for organisations (in any category) not necessarily considering the implementation of CE. The readiness assessment of the construction supply chain, using the model, will enable the development of guidelines for the effective and more appropriate implementation of CE in construction.

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