CONCURRENT ENGINEERING READINESS ASSESSMENT OF SUB-CONTRACTORS WITHIN THE UK CONSTRUCTION INDUSTRY

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A vital part of the corporate strength of any organization is the ability to respond to changing market needs rapidly, and effectively. Time-to-market has become a crucial measure of an organization's business performance. Increasing demands for accelerated deliveries at a lower cost has put pressures on projects and processes within most industries. Therefore, with increasing competition, companies that want to survive in the market place have to improve in four key areas: product costs, product quality, time-to-market (from order to delivery), and customer satisfaction. One way to do this is to adopt a Concurrent Engineering (CE) approach to project delivery. CE is a way of working which enables the delivery of better, cheaper, faster products, using right-first-time methods and team working to enable concurrent consideration of all key lifecycle issues. It is evident that by adopting CE, the software and manufacturing industries have significantly improved their business processes. There is also increasing awareness of the benefits of adopting CE in the Construction Industry. CE has the potential to make construction projects less fragmented, improve project quality, reduce project duration and reduce total project cost. For a targeted and effective implementation, it is recommended to carry out a readiness assessment of an organization prior to the adoption of CE. Therefore, this paper discusses the adoption of CE within the construction industry, highlights the need of CE readiness assessment, and presents the details of the assessment of sub-contracting organizations within the UK construction industry using a new CE readiness assessment tool for the construction industry, the 'BEACON Model'.

Key words: concurrent engineering, , readiness assessment, sub-contractors

INTRODUCTION

Concurrent Engineering (CE), sometimes called simultaneous engineering or parallel engineering, has been defined in several ways by different authors. The most popular one is that by Winner *et al.* (1988), who state that concurrent engineering "…is 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 and Anumba (1998) define Concurrent Engineering as an "…attempt to optimize 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

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maximizing concurrency and collaboration in working practices." This is in sharp contrast with the traditional approach to construction project delivery.

In order to introduce aspects of CE in the construction project delivery process, various research efforts have been undertaken. A detailed account of these efforts is compiled and presented by Kamara *et al.* (2000). They have concluded that an important aspect of CE implementation in the construction industry, which is often overlooked, is the need to carry out readiness assessment of the construction supply-chain for CE implementation. Therefore, in order to carry out the assessment for CE implementation, the construction industry needs a specific readiness assessment model, which has been developed by Khalfan and Anumba (2000a). Therefore, this paper discusses the need for CE readiness assessment, presents a new CE readiness assessment model for the construction industry, the BEACON (Benchmarking and REadiness Assessment for the Implementation of Concurrent Engineering in CONstruction) model, and describes in detail the results of the model's use in the assessment of sub-contracting organizations within the UK construction industry.

CE READINESS ASSESSMENT

As discussed in the previous section one approach which has been successfully used to improve CE implementation planning is to conduct a readiness assessment of an organization prior to the introduction of CE. This helps to investigate the extent to which the organization is ready to adopt Concurrent Engineering (Componation and 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.

There are several tools and models, which are being used for readiness assessment of organizations for Concurrent Engineering. A comparison of these models and tools was presented by Khalfan and Anumba (2000c). 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 industry. 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 by the authors for assessing the construction industry. This includes both a 'People' and a 'Project' element – these are considered key aspects of CE. The new model named 'BEACON Model' is shown in Figure 1 and described briefly 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 organization. The second quadrant contains four critical people factors used to assess the team level issues within the organization 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 characterize the introduction and utilization of advanced tools and technology within the organization. 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 emphasized.

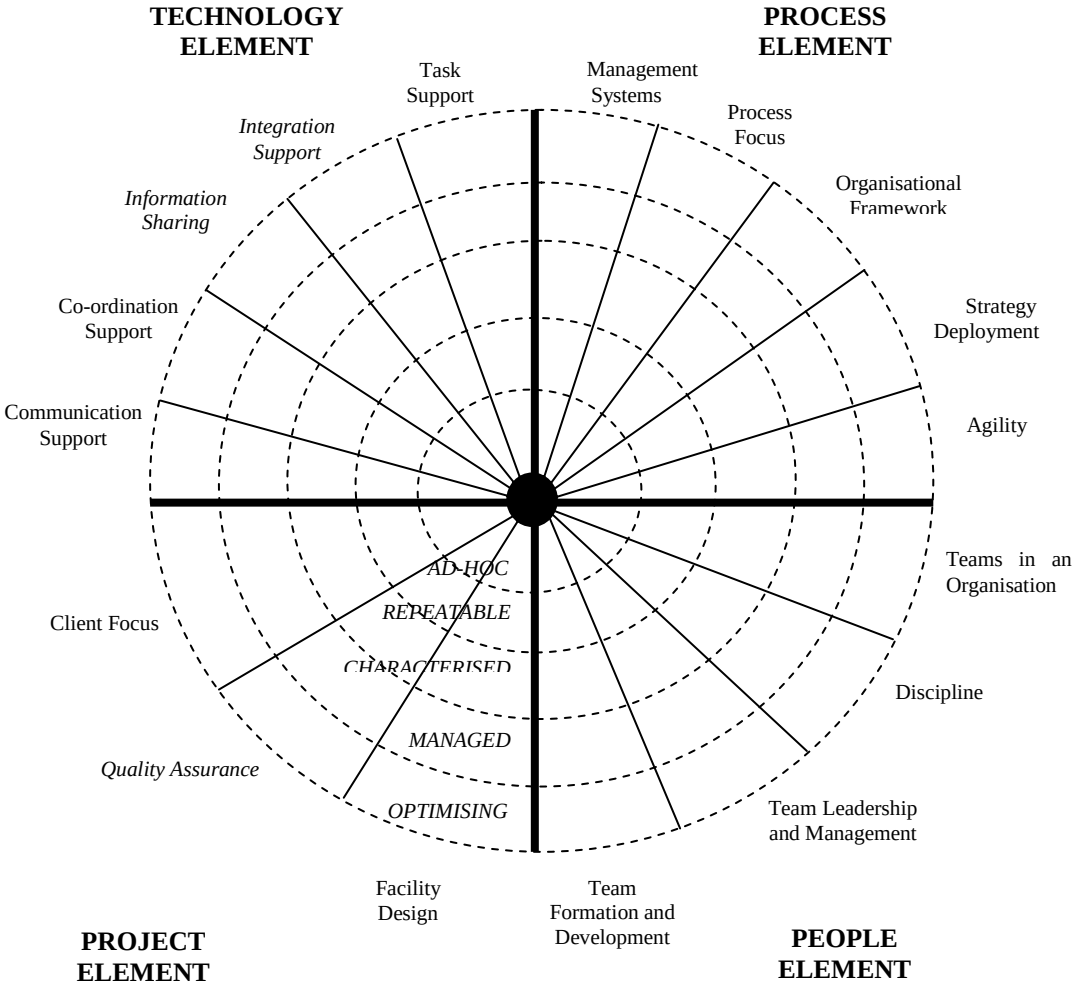

Figure 1: The BEACON Model

The rationale behind including the people and the project elements is that both of them are as critical to CE as the process and the technology elements and should be distinguished (Ainscough and Yazdani, 1999; Al-Ashaab and Molina, 1999; Brooks and Foster, 1997; Chen, 1996; Crow, 1994; Khalfan and Anumba, 2000b; Lee and Young, 1994; Love and Gunasekaran, 1997; Martin and Evans, 1992; Paul and 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 organization with respect to the quality of project development process, team-working, completed project itself, and technology employed within the organization. These five levels are Ad-hoc,

Repeatable, Characterized, Managed, and Optimizing and are described in Table 1. The Ad-hoc Level indicates that an organization is unfamiliar with CE practices or is not ready to adopt CE, whereas the Optimizing Level shows that the organization 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 organizations. The assessment scale has five possible options: "Always", "Most of the Time", "Sometimes", "Rarely", and "Never", corresponding roughly to five maturity levels (Note: Refer to Khalfan (2000) for a detailed description of the development of the BEACON model).

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

Maturity Level	Description
Ad-hoc	This level is characterized 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 and 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.
Characterized	The project development process is well characterized and reasonably well understood. A series of organizational and the 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 characterized 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 utilization of available technology and computer-based tools.
Optimizing	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 prioritized based on client's needs. Optimal utilization of appropriate plant and technology and technology-mediated group work is observed.

CE READINESS ASSESSMENT OF SUB-CONTRACTING ORGANIZATIONS

In order to assess the CE readiness assessment of the UK construction industry, sample case studies were carried out by using the BEACON Model. For the purpose of the case studies, the industry was divided into five categories: clients, consultants, contractors, sub-contractors, and material suppliers. This paper only focuses on the results of the case studies, which were carried out within sub-contracting organizations. Twelve sub-contracting organizations, ranging from small-sized to large, were sent the BEACON questionnaire and 25% of them responded and are

referred as 'Organizations A, B, and C' in this section. The assessment of sub-contracting organizations was important because they are doing most of the construction work on construction sites, and have multi-disciplinary and multi-skill teams for this purpose. Therefore, it was necessary to assess their readiness for collaborative and concurrent working practice. Most of the respondents commented that the people element is the most important and the technology element the least important element from their organizational point of view. A summary of the assessment results is also complied in tabular form and presented in Table 2, which shows percentages of all elements for each organization. The percentages for each factor within the elements were calculated after assessing the questionnaire responses for each organization. (Note: Refer to Khalfan (2000) for details on how the results were generated). A brief account of all the sample case studies is presented in the following sub-sections with the readiness assessment results, which are plotted on the BEACON Model diagram for each organization.

Table 2: A summary of the Assessment Results of Sub-Contracting Organizations

	Organizations		
Elements	Organization A (%)	Organization B (%)	Organization C (%)
Process Element	63.69	93.96	82.46
Management Systems	73.08	96.15	80.77
Process Focus	65.38	96.15	86.54
Organizational Framework	70	87.5	87.5
Strategy Deployment	52.5	95	82.5
Agility	57.5	95	75
People Element	66.93	91.2	85.26
Team Formation and Development	75	95	90
Team Leadership and Management	68.75	90.63	93.75
Discipline	71.88	100	90.63
Teams in an Organization	52.08	79.17	66.67
Project Element	65.83	98.32	92.40
Client Focus	61.38	97.73	88.64
Quality Assurance	75	100	96.88
Facility Design	61.11	97.22	91.67
Technology Element	50.71	91.55	86.08
Communication Support	75	90	85
Co-ordination Support	27.78	97.22	91.67
Information Sharing	40.91	81.82	72.73
Integration Support	65.63	90.63	90.63
Task Support	44.23	98.08	90.38

Case Study 1: Organization A

Organization A is a medium-size sub-contracting company with over 200 employees and over £16m annual turnover. The respondents commented in the questionnaire that the people element is the most important and the technology element is the least important element from the organization's point of view. The assessment result is plotted on the BEACON Model diagram shown in Figure 2. This shows that Organization A is in the managed level except for some of the critical factors, which indicates the characterized level for the organization. This concludes that the organization A is not ready to adopt CE. The areas, which need attention, are task support, co-ordination support, and information sharing within technology element, strategy deployment and agility within process element, and teams in an organization within people element.

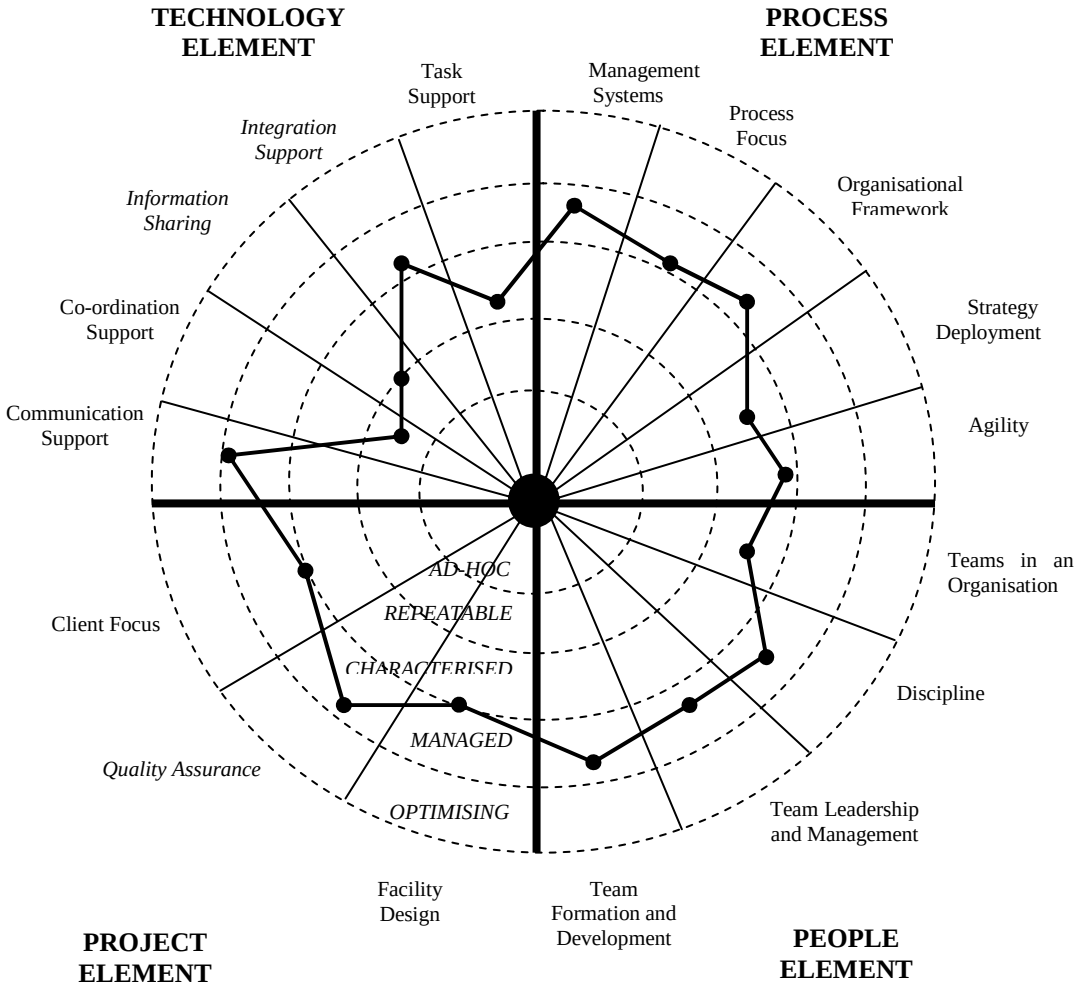

Figure 2: CE Readiness of Organization A

Case Study 2: Organization B

Organization B is another medium-sized sub-contracting company with over 450 employees and with over £60m annual turnover. Responses to the questionnaire indicate that the process element is the most important and the technology element is the least important element from the organization's point of view. The assessment result is plotted on the BEACON Model diagram shown in Figure 3. The results show that the organization B is in the optimizing level except for a few critical factors, which are in the managed level. This concludes that Organization B is ready to adopt CE and has already adopted CE approach in almost all of the critical factors within all elements. Areas require improvements are teams in an organization within people element, and information sharing within technology element.

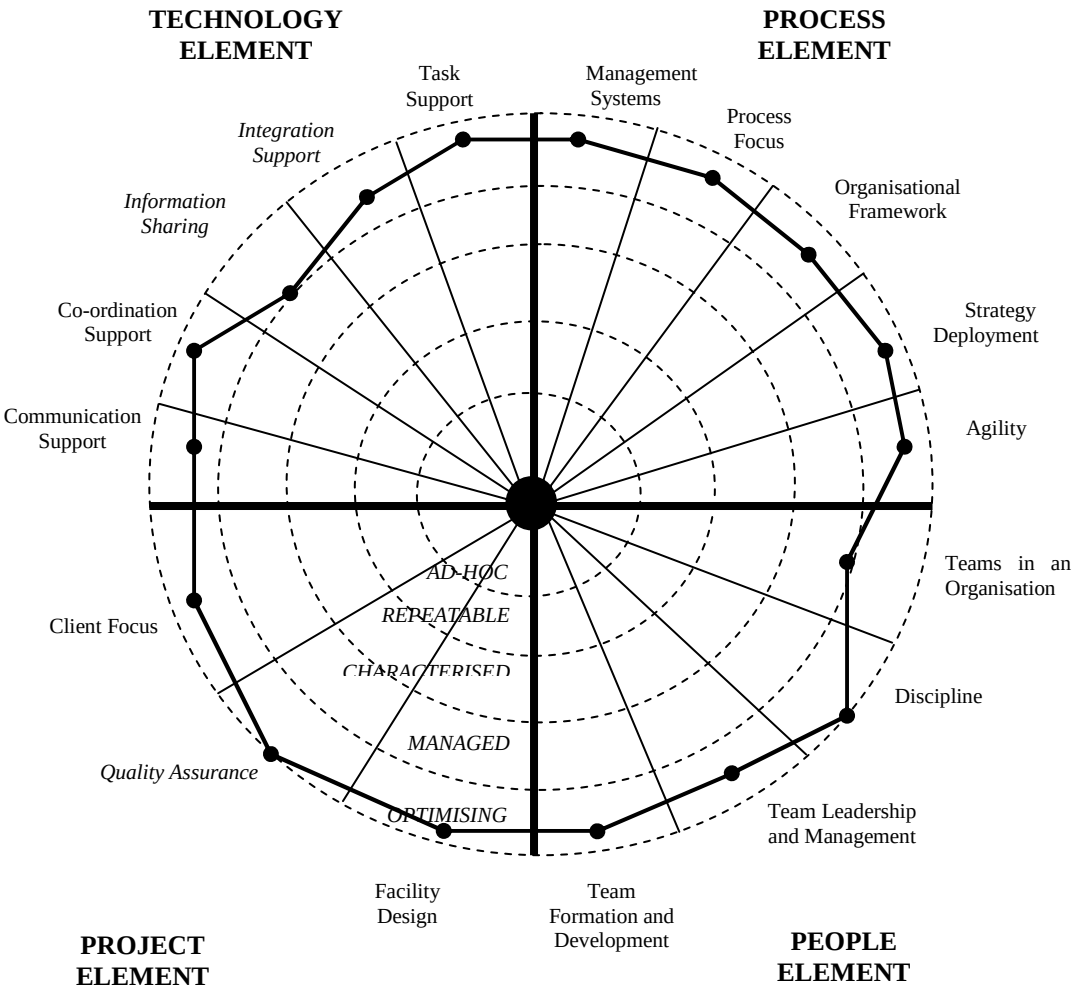

Figure 3: CE Readiness of Organization B

Case Study 3: Organization C

Organization C is a large contracting organization with sub-contracting activities with over 3,500 employees and with over £1.4b annual turnover. According to the background information in the questionnaire, the people element is the most important and the technology element is the least important element from the organization's point of view. The readiness assessment result is plotted on the BEACON Model diagram shown in Figure 4. The assessment result shows that some critical factors are at the optimizing level while the rest are at the managed level. This concludes that the Organization C is also ready to adopt CE and has already adopted CE approach in some of the critical factors within the elements. The areas, which need improvements, are information sharing within the technology element, client focus within the project element, agility within the process element, and teams in an organization within the people element.

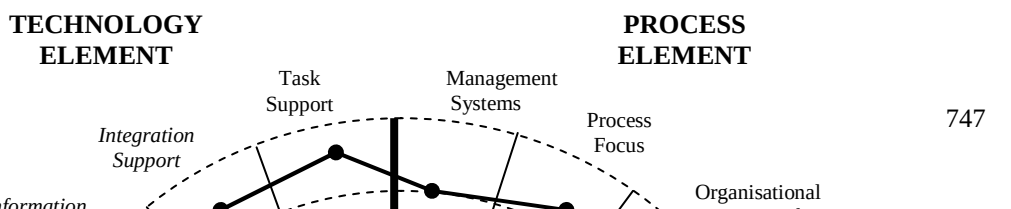

Figure 4: CE Readiness of Organization C

DISCUSSION

After analysing the results of the readiness assessment case studies of the participating sub-contracting organizations, it could be seen that the larger sub-contracting companies are better prepared to adopt CE than medium-sized firms, which need improvements in most of the critical areas. It is evident from the case studies that the technology element is the weakest element in all sub-contracting organizations and needs attention in order to improve communication, co-ordination, integration, and information sharing among the employees, and between the organization and other members of the construction supply chain. Above all, the average assessment result for sub-contractors shows that subcontractors are at the 'optimizing 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 organizations 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 organization within the people element. The conduct of the assessment of sub-contracting organizations met with a number of difficulties: securing senior management input to the survey/assessment; targeting key/appropriate personnel to respond; and ensuring that the responses reflect the true picture within each organization and are not designed to paint a better picture than what actually happens in an organization. Another issue, which must be taken into account, is if a

manager at the middle level filled in questionnaire, there is a possibility that he would not have an idea of the whole organizational structure and systems with respect to the questionnaire and would not be able to respond confidently. It has also been noticed that responses given may be biased in order to give a better image of the organization even they knew that the name of their organization would not be mentioned and kept confidential.

SUMMARY AND CONCLUSIONS

This paper has discussed the importance of CE readiness assessment and presented the BEACON Model, which has been developed for use as a CE readiness assessment tool for the construction industry. It has also presented the results of sample CE readiness assessment of three sub-contracting organizations within the UK construction industry. The following conclusions can be drawn from the case studies:

The BEACON Model can be successfully used as a CE readiness assessment tool for the construction industry;

There is also a need to carry out similar sample case studies in other sectors within the construction industry such as clients, consultants, contractor, etc., to get a complete picture of the industry;

The model can act as a useful tool for self-assessment on the four key elements: process, people, project, and technology even for contracting organizations not considering the implementation of CE;

From the results of the assessment, it can be stated that the large participating sub-contracting companies are better prepared to implement CE than medium-sized participating companies, which need improvements to get ready;

The technology element is the weakest element and requires attention and improvement in all participating sub-contracting organizations; and

The assessment of the sub-contracting organizations, using the model, will enable the development of guidelines for the effective and more appropriate implementation of CE in construction.

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