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ARTICLE

Evaluation of Implementation Preparation for CE based on BEACON Model —Taking Construction Enterprises in Yemen as a Case of Illustration

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ABSTRACT

After decades of civil war, Yemen is in a desperate situation, and the construction industry has been suffering from low productivity and poor performance. In order to improve the productivity for the Yemeni construction industry, Construction enterprises must adopt the best and new technologies, new management concepts and philosophies such as Total Quality Management (TQM) and concurrent engineering (CE) owing to achieve improvements in the process of product development. To ensure the successful implementation of CE in the Yemeni construction industry, it is necessary to assess the readiness of those companies to implement CE. In this paper, the BEACON model is used to assess the readiness of the Yemeni companies to implement the concept of CE, that assist in overcoming the construction industry's poor productivity and performance. A study assessing CE implementation readiness will help to promote successful CE implementation in the construction industry and enhance the efficiency of construction companies. The results show that most of the construction companies in the Yemen are not ready to implement CE. The main reason is that the enterprises rely heavily on traditional management methods, and need to improve the organization and management technology. The research results can provide theoretical support for construction companies, especially Yemen companies, to establish basis in implementing an appropriate CE approach for improving performance, and also help international construction companies entering the Yemen construction market to cooperate and implement CE.

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1. Introduction

CE approach is a kind of integrated design for new products. Proceeding from the perspective of the whole life cycle, it puts the key issues in the downstream stage of construction projects into the design stage [1-7]. The main objective of the CE concept is to reduce or avoid conflicts between different professions that may occur during construction and enhance professional synergy and work efficiency [8-10]. It is necessary to assess the preparation of the construction enterprises before the implementation of CE owing to further improve the construction efficiency [11-13].

The real expected benefits of CE implementation in the construction industry can only be achieved through practical evaluation, planning, and improvement based on procedures. The focus is on delivering the best performance throughout the supply chain, in terms of critical success factors. BEACON allows participants in this field to evaluate and benchmark their project deliveries and identify areas that require improvement or change and work together in an active business partner to achieve real, measurable success [13].

At present, some scholars have studied the related applications of CE in the construction industry. They believe that the preparation of the CE implementation and the corporate culture significantly affect the implementation results of the CE [14-19], and the construction enterprises need to have a sufficient level of expertise to ensure that CE is effectively implemented. In this regard, the University of Loughborough, Innovation Building Engineering Center (CICE) proposed a model to evaluate the preparation of parallel projects for construction companies, namely the BEACON model, which can be used to support the assessment of the preparation work in the construction industry, and can objectively measure the readiness of CE, and performance in the construction enterprises [20]. Khalfan and Anumba used British construction companies as an example to evaluate the implementation of CE using the BEACON model. However, the research object is relatively simple, the sample type is not comprehensive, and the research needs to be further improved [11].

The construction period of Yemen's construction projects is long, mostly using backward traditional cast-in-place production methods [21-25]. Because of the improvement in the quality and efficiency of construction projects by concurrent projects, many Yemeni construction companies have begun to implement parallel projects. However, to achieve the expected benefits through the implementation of CE, it is necessary first to assess the capacity and readiness of the construction enterprise to ensure that the corresponding capabilities of the construction enterprise have reached the level required for the implementation of CE. In this paper, the Yemeni construction enterprises are taken as an example to discuss the evaluation of CE implementation in the construction industry, and the preparation of enterprises to implement CE based on the BEACON model and its questionnaire. A novel application of BEACON model approach to evaluate the implementation preparation for CE and establish basis for improving Yemeni construction enterprises performance, and also help international construction companies entering the Yemen construction market to cooperate and implement CE is presented. Therefore, this paper takes some different Yemeni construction enterprises (as contractor; subcontractor; supplier; client; and consultants) as an example to discuss assess the implementation of CE in the construction industry. In this study, using the BEACON model and its questionnaire, the preparation ability of different types of construction enterprises (clients, consultants, contractors, sub-contractors and suppliers) is evaluated, according to the five levels of maturity.

The structure of this paper is as follows: Section 2 reviews the need for CE implementation preparation; Section 3 describes the overview of the BEACON model and performance metrics; Section 4 illustrates major results findings of this study; and the last section sets out the most relevant discussion and conclusions with future work of the study.

2. Assessing the Need for CE Implementation Preparation

The use of CE by construction companies can shorten the development time and time-to-market of building products, reduce engineering changes, rework and costs, and thus improve the quality of building products and corporate profits [1-5]. The implementation of CE mainly needs to meet two essential elements: the first is personnel and management, including management system, team development, leadership, and organizational philosophy; the second is technical aspects, including design, communication, coordination, standard-setting, Technology, etc. [11-13]. At the same time, construction companies should be able to achieve a sufficient level of capability in these two aspects to better support the implementation of concurrent projects, an insufficient level of ability will make it challenging to achieve the expected results, which requires assessing the readiness to implement CE. Generally, the organizational implementation steps of CE as proposed by Karningsih et al. [13] (see Figure 1).

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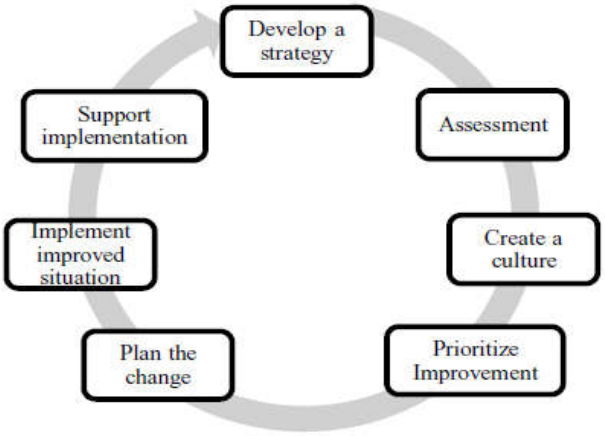

Figure 1. CE implementation steps

3. Overview of the BEACON Model

There are many tools and models, which are used to assess the readiness of enterprises in the manufacturing industry for CE. The most common are [24-27]:

(1) RACE: This tool was developed by Karandikar et al. Initially this tool was used in the US defense industry. RACE model essentially shows a snapshot of where a company is on the road to CE by asking questions about where the company presently is, as opposed to where it wants to be. The answers are mapped and a gap analysis is carried out. Now, this model often used in the fields of software engineering, automotive and electronic industries. It is possible to modify the characteristics of this model and make it reasonably suitable for use as a tool in both the construction industry and other industries. The RACE model consists in terms of two main components: organizational processes for product development, and information technology to support the product development process.

(2) PMO: the model is useful in the awareness and readiness stages of the improvement cycle of the product development process [13].

(3) PMO-RACE: PMO-RACE is the integration of both models (PMO and RACE).

Although there are many evaluation models for the implementation of CE, all these models mostly intended for manufacturing, automobile, programming, and electronic industries, where there is no special model suitable for the evaluation of CE in the construction industry. BEACON is the first model to assess the readiness of CE to implement CE [28,29].

BEACON in Construction methodology measures the readiness and subsequent performance of the participants in the infrastructure and construction supply chain. It is built on the principles of CE, used so successfully in major manufacturing and technology businesses [30]. The BEACON model icon is shown in Figure 2. The key to the BEACON model is that it includes technology and Process factors of other CE assessment tools with the extra essential elements of humans and Project present in significant infrastructure developments [31]. Measurement of those four factors targets are following (see table 1) [11, 13, 32]:

(1) Process: factors to assess the process maturity level of a construction organization - Management structures, Process Focus, Organizational Framework, Strategy Deployment, Agility.

(2) People: factors to assess the team level issues within the organization-Teams in an Organization, Discipline, Team Leadership, and Management, Team Formation, and Development.

(3) Project: factors to assess the client's requirements and design-related issues Facility Design, Quality Assurance, Client Focus.

(4) Technology: factors to characterize the introduction and utilization of advanced tools and technology within the organization - Communication Support, Coordination Support, Information Sharing, Integration Support, Task Support.

Table 1. Secondary elements of the BEACON model

Secondary Element	Description
Management system	Design the project management organization meeting the requirements of CE, establish and improve the management system.
Process Focus	Verify that the project development process has sufficient documentation and flexibility to accommodate changes in customer needs, personnel etc. Ensure that processes are regularly evaluated and improved by analyzing past decisions and reusing past processes.
Organizational Framework	Identify organized policies that help control and monitor the project development process and support teams in resource allocation, conflict resolution, and improve individual and team performance.
Strategy Deployment	Ensure that business strategies are clear and consistent, with a focus on improving the project development process. It also ensures that teams are set up to handle customer requests, and identify and prevent future problems.
Agility	Ensure that the project organization has the flexibility to respond to changes in the project development process.

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Secondary Element	Description
Team Formation and Development	Identify whether the organization has a strategy for team formation and development. Evaluate the sense of responsibility, cooperation and ability of members of the team and sub-teams.
Team Leadership and Management	Ensuring the selection and appointment of team leaders is based on technical and managerial capabilities.
Discipline	Team members can work together to achieve the team's goals, and members of different architectural disciplines can make the most of their roles and work together efficiently.
Teams in an Organization	Ensure that the team has the right to work and communicate smoothly; develop policies that measure team performance, planning, and peer review within the team.
Client Focus	Ensuring that the customer is part of the project development team. That also can prioritize all project decisions based on the customer's needs, and all members of the team understand the customer's needs.
Quality Assurance	Confirm that project standards management and quality assurance activities have been adopted and continued during the process from design to construction.
Facility Design	That verify that the preliminary design of the facility has been prepared and discussed prior to entering the final design and construction phase.
Communication Support	Ensure that team members communicate with each other over the network and use the Internet to exchange data and virtual meetings.
Coordination Support	Coordinate the work of team members to support project tracking, conflict identification and resolution, negotiation, etc.
Information Sharing	The information required for project development can be accessed electronically and managed by an appropriate database management system.
Integration Support	That confirm that all team members are integrated through a shared, integrated information model, and that all team members use a common operating system.
Task Support	Ensure that CAD, simulation tools, and past design information are effectively used for facility design and to assess the impact of management tools on the project.

For these four factors and their relevant critical elements, five different levels of performance indicators assess the level of project planning and performance within the project team and supply chain, from ad-hoc at the most basic level to optimizing at the best level. BEACON objectively measures CE readiness and performance in the construction enterprises. This research work is undertaken in five segments of the construction industry: clients, consultants, contractors, sub-contractors and suppliers as presented in Table 2.

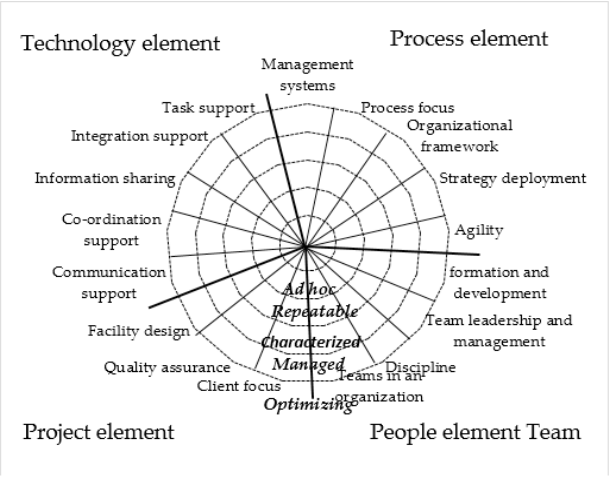

Figure 2. BEACON model icon

The BEACON model needs to evaluate the level of preparation of the various capabilities (elements) included in the model through questionnaires. Respondents need to judge the performance of the corresponding ability level in the relevant textual situation. The assessment scale has five choices and represents different scores (expressed as

Table 2. BEACON model maturity

Maturity level	Description
Ad hoc	This level is characterized by unclear procedures and controls, team confusion and disorder, team members do not understand their tasks, and do not know how to operate effectively; project management techniques are not fully applied, modern construction tools and information technology useless.
Repeatable	Standardization methods are applied in the monitoring of project development processes, the prediction of demand changes, and the estimation of costs; however, communication barriers exist within the project development team, and information technology and tools are less used.
Characterized	In the process of project development, it shows good characteristics. The company implements a part of the organization and process improvement and uses the proven technology to improve team efficiency. Most people know the customer's requirements very well, but the customer is not involved in the project construction process.
Managed	Not only does the project development process show good features, but they can also be quantified and controlled; information technology and tools are used to control and improve the project process, reducing the uncertainty of the project process; the project development team does most of the work and resolves conflicts. The customer participated in the project construction process.
Optimizing	Adopt better management techniques in the project development process, pay attention to the continuous improvement of the project; measure team performance regularly; customers become part of the project development team from the beginning, and all project decisions are prioritized according to customer needs.

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Table 3. BEACON model questionnaire example

D41: Communication support	always	most of the time	sometimes	rarely	never
1. When working in the same project, all members of the team are connected to each other in the network					
2. Everyone uses email to communicate					
3. All members and sub-teams of the project development team exchange project data over the network					
4. Team members can share project-related applications over the network					
……					

a percentage): always =4, most of the time =3, sometimes =2, rarely =1, never =0. The form of the questionnaire used in the study shown in Table 3. After summarizing the valid questionnaire results, the average of the evaluation scores of each secondary element took as the final evaluation result.

As far as aggregating all scores is concerned, in order to calculate the percentage of each critical factor and to plot it on the BEACON model chart, the actual result for each question was taken from the critical factors. For example, the results of integration support are summarized in 8 questions to receive a total score of 21 using the result for each question. If all the answers are "always" for each question or data, then the overall score will be 32. Therefore, for integration support, this will result in a 65.625% (21/32 x 100) percentage out of 100% possible. This percentage is then drawn to the model inside the "Managed Level". Most results were developed manually [11].

The assessment score needs to be translated into the corresponding level of maturity to determine the specific situation of the current capacity level of the construction enterprise. Generally, when the element score is in the range of 0-20%, the Ad hoc level corresponding to the maturity level, the score is in the field of 20%-40% corresponding to the repeatable level, the score is in the field of 40%-60% corresponding to the characterized level, and the score is in the 60%-80% interval corresponding to the managed level, and the score is in the 80%-100% interval corresponding to the optimizing level.

4. Results

Twenty companies in each category were randomly chosen, with at least five expected to respond. The questionnaires were sent with a cover letter to all the selected companies. Prior to submitting the questionnaires, each company was contacted and the most appropriate person was identified, either from the upper or middle management level, who have knowledge of the company and who can complete the questionnaire appropriately. A summary of the evaluation findings is compiled and presented in Table 4, which shows the average percentages of all elements within each category. Average percentages for each factor within the elements were calculated after assessing the questionnaire answers for each category. A brief narration of all case studies within each category is presented in the following sub-sections, with the results defined in the BEACON Model Diagram for each industry sector.

4.1 Questionnaire Analysis

Because of the absolute difference between the construction industry and other industries, especially the construction and construction process of construction products involves multiple participants in different parts of the supply chain. The resources required for production and construction will eventually be concentrated on the construction site, while the construction products are single-piece, The characteristics of fixedness and large volume, the implementation of CE in the construction industry requires the joint efforts of all enterprises in the supply chain to ensure that the enterprises in different links have sufficient implementation capacity, so the enterprise departments of each link should conduct a questionnaire survey together.

The typical construction supply chain includes five types of organizations: customers, consultants, contractors, subcontractors, and suppliers [32]. This paper combines relevant literature research and engineering practice to further select different types of customers, consultants, contractors, subcontractors and supplier organizations for the construction industry in Yemen. The questionnaire was issued from November 2017 to April 2018. A total of 100 questionnaires were distributed to the construction industry supply chain participants in Yemen, with an effective collection of 35. Respondents are mostly high-level or middle-level managers of organizations, who have an overall understanding and grasp of the preparations for the implementation of concurrent projects.

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Table 4. Preparation results of the CE of Yemeni construction enterprise

Elements	Serial number	Secondary element	Construction supply chain participants (%)				
			Contractor	Subcontractor	Supplier	Client	Consultants
Process element	D11	Management Systems	69.23	73.08	38.93	43	59.62
	D12	Process Focus	51.92	60.13	60	58.14	30.6
	D13	Organizational Framework	75	65	55	48.13	42.5
	D14	Strategy Deployment	57.5	52.5	58.14	60.25	85.5
	D15	Agility	40	50	67.05	56.6	45
People element Team	D21	Formation and Development	65	75	75	61.67	63
	D22	Team Leadership and Management	75	68.75	63.13	70.54	75
	D23	Discipline	75	75	82.25	60.73	87.5
	D24	Teams in an Organization	65.14	55.08	49.5	68.08	60.58
Project element	D31	Client Focus	50	61.38	86.36	45.65	31.82
	D32	Quality Assurance	36.36	75	75	35.76	50
	D33	Facility Design	90.14	61.11	85.65	75.25	35.11
Technology element	D41	Communication Support	41.67	75	95	30.15	10.5
	D42	Co-ordination Support	70	25	51.66	25	25
	D43	Information Sharing	41.67	40	77.37	25	22.73
	D44	Integration Support	54.63	70	65.75	44.8	25
	D45	Task Support	38.46	45	50	45.1	46.15

4.2 Contractor Organization

After the evaluation scores of the implementation preparations matched with the maturity, the level of readiness of contractors' organizations in the Yemeni construction industry to implement CE obtained, and the results were summarized as shown in Figure 3. The survey results of the contracting organizations show that most of the respondents considered that the preparation of people element is the most important. They also believe that team leadership, management, and professional interface are the most important elements within people's elements. At the same time, most of them ranking the people element in the construction field is the most important, and the technology element is the least important.

The survey results show that most of the critical factors (mainly processes, projects, and technical elements) are at the characterized level, and only some of the factors are at the managed level, indicating that the Yemeni contracting organizations are not ready to adopt CE. The main reason as: (1) the contracting organizations do not know much about the customer's needs. (2) The contracting organization is not involved in the design phase is likely to lead to design change or rework during the construction phase. (3) There is a lack of effective communication between the different departments. The contracting organizations should adopt a more efficient way of information communication, actively participate in the whole process of the project, open up contacts with customers and design, and strengthen the communication between different departments.

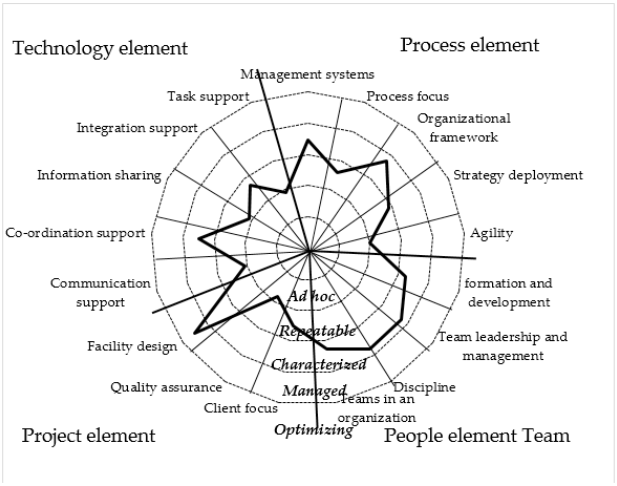

Figure 3. Evaluation of the readiness maturity of contractor's organization to implement CE

4.3 Sub-contractor Organization

After the evaluation scores of the implementation preparations matched with the maturity, the level of readiness of subcontracting organizations in the Yemeni construction industry to implement CE obtained, and the results were summarized as shown in Figure 4.

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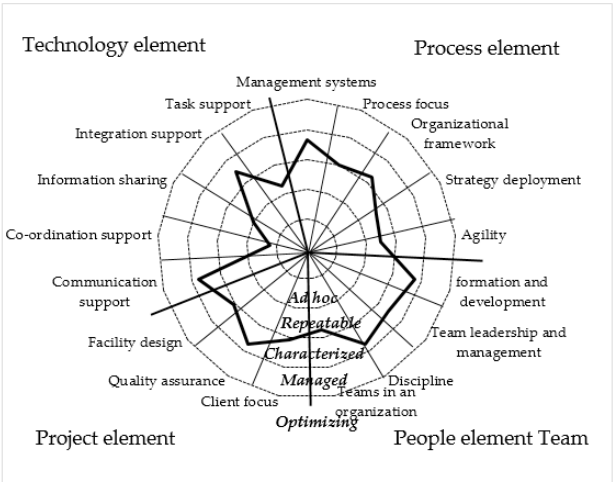

Figure 4. Evaluation of the readiness maturity of subcontractor's organization to implement CE.

The survey of subcontracting organizations in this paper shows that the majority of respondents indicated that the preparation of people element is better, and the technical elements are the worst. Also, most of the respondents commented that the people element is the most important in the construction field, and the technology element is the least important in this field. Most of the critical factors are at the managed level and do not require significant improvements. However, some of the factors (strategic deployment, flexibility, team organization, information sharing, and work support) are not at this level, but at the levels of repeatable and characterized, and these factors need to be improved. In general, Yemen's subcontracting organizations are not ready to adopt CE.

In response to the assessment of critical factors, the subcontracting organization needs to improve the workflow and content of its participation in the project process to ensure a clear business strategy. In terms of people elements, an efficient team is established to identify better and prevent future problems. At the same time, it is necessary to enhance the ability of the team to organize in different professional fields, strengthen professional coordination, and effectively deal with the contradictions between professions. Concerning technology can be summarized as follows:

1) Developing communication between different disciplines within the organization as well as with other organizations (client, supporters, etc.).

2) Integrate information, facilitate its sharing, and access by all stakeholders.

4.4 Supplier Organization

After the evaluation scores of the implementation preparations matched with the maturity, the level of readiness of supplier organizations in the Yemeni construction industry to implement CE obtained, and the results were summarized as shown in Figure 5.

A survey of supplier organizations (including material suppliers and manufacturers) in this paper shows that the respondents indicated that people and technology elements are better prepared and that the process elements are the worst. Also, most of the respondents commented that the people element is the most important in the construction field, and the technology element is the least important in this field. Process focus and agility factors in the supplier's process elements are at the managed level, organization framework and strategic deployment are at the characterized level, and management systems are only at the repeatable level. For the people element, the two factors of team leadership and management, and formation and development are at the managed level, and the remaining elements are at the level of optimizing and characterized. For project elements, the overall level is at the optimizing level, and only the quality assurance factor is at the managed level. For technical elements, most of the factors are at the managed and characterized levels, and only communication support is at the optimizing level.

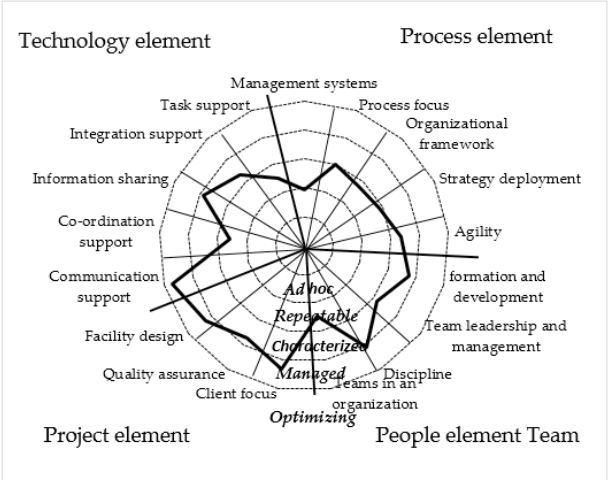

Figure 5. Evaluation of the readiness maturity of supplier organization to implement CE.

The evaluation results show that the current Yemeni supplier organizations have not adequately prepared for the implementation of concurrent projects, and needs to focus on the improvement of process and technology elements.

4.5 Customer Organization

After the evaluation scores of the implementation preparations matched with the maturity, the level of readiness of customer organizations in the Yemeni construction industry to implement CE obtained, and the results were

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summarized as shown in Figure 6.

This study received valid responses from eight different types of customer organizations (including hospitals, universities, hotels, etc.). Respondents in customer organizations indicated that the preparation of people element was the best, and the technology element was the worst. Also, most of the respondents commented that the people element is the most important in the construction field, and the technology element is the least important in this field. From the evaluation results, most of the factors except the facility design, team in an organization, and team leadership and management reach the managed level, and most of the other factors fluctuate around the characterized level. This indicates that the level of competence of Yemeni customer organizations is at the characterized level of CE preparation, and it is far from the implementation conditions of CE. Relevant enterprises should strengthen the emphasis on technology elements and other elements with lower evaluation levels and make better preparations for the adoption of CE.

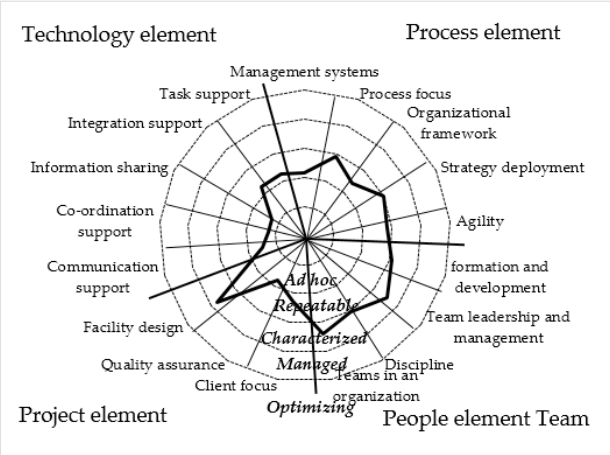

Figure 6. Evaluation of the readiness maturity of customer organization to implement CE.

4.6 Consulting Organization

After the evaluation scores of the implementation preparations matched with the maturity, the level of readiness of consulting organizations in the Yemeni construction industry to implement CE obtained, and the results were summarized as shown in Figure 7. Most of the respondents also commented that the people element is the most important in the construction field, and the technology element is the least important in this field.

The evaluation results of consulting organizations (including architects, structural designers, cost consulting, project management consulting, construction services consulting, etc.) show that most of the factors are at the repeatable level except that the communication support in the technology element is at the Ad hoc level. Also, strategic deployment and discipline factors have reached an optimizing level. Overall, Yemen's consulting organizations are not yet ready to adopt CE and need to make large-scale improvements to most of the competency factors.

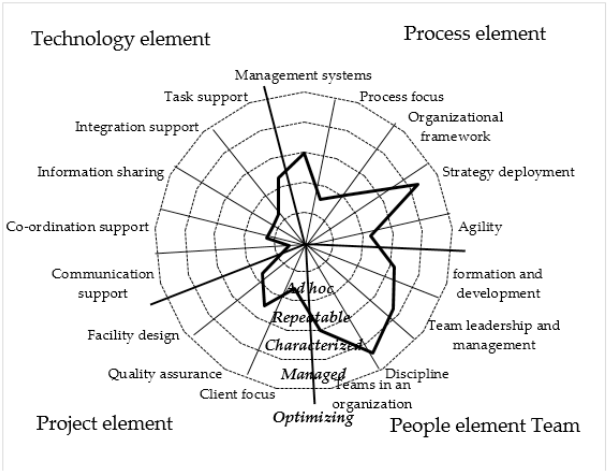

Figure 7. Evaluation of the readiness maturity of consulting organization to implement CE.

5. Discussion and Conclusions

After analyzing the results of the readiness assessment case study of the participating companies 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 company's point of view in all categories. Most Yemeni construction companies are not ready to implement CE and most of the critical factors in each element are within the "characterized level" of CE readiness and need improvement. The critical areas covered under the technology element need more attention and consideration by all sectors. All construction companies in Yemen are in need of major improvements in all areas under this element. The weakest determinant of all sectors is coordination support and Information Sharing.

The results interpret that the most construction enterprises in Yemen are not ready to implement CE mainly because of their dependence on traditional management methods. More improvements required in fields such as corporate culture, employee organization, and technological base. The research results can provide references for construction enterprises to implement CE and promote efficiency in the construction industry. 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

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CE adoption, are those, which are client-focused, have a greater focus on monitoring and controlling of their project development process, and are continually improving their development processes and operations. In general, the outcomes show that the construction enterprise still wishes to supply: improvement in most of the critical areas, higher group-working and business integration. Segments that appear prepared for CE adoption are the ones which: are client-targeted, monitor and control the project development process and continual target improvement of their processes and operations. It is indicated that the better performers are likely to be major contractors and specialist sub-contractors, whereas clients, consultants, suppliers and manufacturers needed to improve their position.

This paper takes some different type of construction enterprises (as a contractor; subcontractor; supplier; client; and consultants) in Yemen as an example to discuss the implementation of CE in the construction industry, and evaluates the preparation capabilities of different links and different types of construction enterprises through the BEACON model. Based on the results of the implementation preparation assessment of different construction companies in Yemen, the level of preparation of Technology factors is generally low; most construction companies are not prepared to implement concurrent projects (CE), although some of the capacity factors have reached the level of management and optimization, but some factors also only reach the characterization level, and even some factors are below the repeatability level. The main problem lies in the fact that the management of Yemeni construction enterprises still relies on traditional management methods, and the management level lags behind. They do not understand the importance of advanced management tools and information technology in modern management. Yemeni construction companies need to pay attention to advanced management tools, introduce and apply new information technologies such as BIM technology, and strengthen information communication, sharing and collaboration.

The research results are conducive to the management improvement of Yemeni construction enterprises, and also help International construction enterprises to understand the corresponding capabilities of Yemeni construction enterprises. International construction companies entering the Yemen market usually have greater strength. They can give guidance and advice to Yemen construction companies in terms of personnel organization and management, and help local powerful cooperative enterprises to carry out training on building information management personnel, improves corporate management capabilities and help.

Author Contributions

Conceptualization, S.D. and Z.L.; Formal analysis, S.D. and M.A.; Funding acquisition, Z.L.; Investigation, S.D. Z.L, and M.A.; Methodology, S.D.; Software, S.D.; Validation, S.D. and M.A.; Writing – original draft, S.D.; Writing – review & editing, M.A.

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