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CONCURRENT ENGINEERING in BRAZILIAN CONSTRUCTION COMPANIES: MATURITY ASSESSMENT

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ABSTRACT

The purpose of this paper is to identify the maturity level of concurrent engineering in Brazilian construction companies in the Great Vitória region – Espírito Santo. This is a qualitative research study, which proposes a methodology based on semi-structured and structured interviews applied in Brazilian construction companies, using nine case studies in construction companies of Great Vitória (Espírito Santo, Brazil). The results confirm the appropriate methodology and confirm that the companies that were analyzed have, in general, a good and managed maturity level. The research also shows that the quality search initiated in the 1990s in Brazil is valid, since quality was concurrent engineering's most developed element in construction firms. However, there is still a lack of stakeholders' integration and understanding of what a multidisciplinary team is and how it should work, which suggests that companies need to work harder in training and coordinating their teams. As the results show, it is also noticeable that certain firms' characteristics, such as size, time in the market, centralization of decisions, among others, interfere in the level of maturity of concurrent engineering.

INTRODUCTION

Civil engineering has a great impact on Brazil's economy, accounting for 5.8% of Brazilian GDP and generating 2.7 million jobs in 2011 **[29]**. However, this industry also has negative impacts, because it is responsible for generating substantial waste and use of natural resources. One must bear in mind that products from the construction site, the buildings, are durable consumer goods, therefore, the impact of a building does not end after its completion, but perpetuates while the building endures and even after the end of its usable life.

For all these reasons, it is clear that even though construction drives the development of the country, it has many problems and challenges to overcome. In addition, the industry has undergone a series of transformations, due to external pressures and the need to overcome existing barriers, which are leading builders to incorporate numerous innovations. In today's competitive environment, where the profit of an enterprise derives from the market price less the costs of production **[24]**, systems and tools that promote cost reduction and ensure the inclusion of quality, creating an attractive product to consumers, are essential to a company's survival. While searching for answers to the needs of a company, many researchers seek to develop systems to assist in cost reduction and quality insertion, and an approach advocated by many is concurrent engineering - ES **[4, 18, 21, 31, 37, 40, 44, 48]**.

Concurrent Engineering *(CE)* is a work proposal that seeks to integrate all stakeholders of a construction project in the early stages, which attempts to anticipate problems and precipitates decision making, promoting time reduction and always taking into account the issues of life cycle, quality and responsiveness to customer demands *(internal or external)*. The main objectives of CE are time and cost reductions and increased product quality **[1, 2, 20, 32]**.

Despite the fact that this tool can be a key strategic advantage **[48]**, it is unclear whether Brazilian companies use it in their day-to-day, or if they are prepared to implement the modifications needed for CE to take place. If companies are not prepared to absorb this new knowledge, its hasty implementation can generate results contrary to the expectations. Therefore, it is important to know how the builders behave, if they have absorbed the new concepts and technologies, if they have enough maturity for concurrent engineering deployment, and what are the possible barriers to its effective use.

To determine the development of an enterprise with relation to a certain methodology, it is possible to use a maturity assessment. Although there are some maturity assessment models for concurrent engineering, such as RACE **[15]**, PMO-RACE **[16]**, PRODEVO **[3]**, the construction industry has a number of particularities that should be considered in a maturity assessment, requiring a specific model. Thus, the BEACON model, developed by Khalfan **[31]**, would be ideal, since it was created exclusively for the construction industry. However, this model was developed for the English/European reality, which is quite different from the reality of Brazilian construction, thereby the need for a model adapted to the local characteristics.

From this premise, a qualitative descriptive research is proposed whose general objective is to identify the level of maturity of the construction companies of Espírito Santo – Brazil, regarding the use of concurrent engineering. To fulfill this task, a new maturity assessment methodology for concurrent engineering is proposed based on the BEACON model, composed of structured and semi-structured interviews by means of a questionnaire. The case studies were conducted in nine client-builder enterprises, focusing on household developments in Vitória, Espírito Santo – Brazil.

To summarize, this article will discuss the elements of concurrent engineering, then present the maturity analyses available for CE, justifying the need for a new maturity assessment adapted to local reality. An overview of the proposed tool is then presented, followed by the research methodology adopted in this study. Finally, the results are exposed and discussed, and, the conclusions and recommendations are made.

1. Concurrent Engineering

Concurrent engineering is an approach that emerged in the manufacturing industry and then transported to construction with the objective to increase quality and reduce costs and time spent in project development **[1, 2, 22, 32]**.

Considering the large number of scientists involved in concurrent engineering research, it is understandable that some variations about its fundamental elements would occur. However, the literature review showed some unanimity considering certain elements that were displayed in most of the research analyzed, including:

- Anticipation of stages and decisions [19, 22, 26, 27, 32, 48]: it means to bring to the design stage all the doubts and uncertainties that could exist in the development of the project. Important decisions regarding the building process have to be taken during program and design development, minimizing possible problems and reworks that could arise in the future to suit the design and the building, ensuring higher quality and efficiency of the building and its processes;
- Concurrency of activities [6, 19, 22, 26, 27, 32, 48]: it is to conduct various stages/ activities of project development in parallel. The idea is to easily and quickly identify points of conflict between the steps and designs, to increase the integration between them and bring forward steps that would be relegated to a later development, to minimize design time. The parallelism also causes little loss of information, since changes occur all the time instead of exclusively at specific points;
- Multidisciplinary team [22, 26, 27, 32, 40, 48]: it corresponds to the establishment of a multidisciplinary team that operates in partnership from the beginning of product design. The collaboration between these agents, from all areas of knowledge, is what enables the development of a quality product which considers all the life-cycle stages of a building. In this scenario the coordinator has a great task, the one responsible for the articulation of the process and the actors;
- Stakeholders' integration [19, 22, 26, 27, 32, 48]: for the proper development of the process and of the multidisciplinary team, it is necessary to have efficient and effective communication between all stakeholders [38]. It is essential here that all disciplines and areas are connected, ensuring that the decisions made consider the various aspects and needs of those involved in the project, with exchange of information, from the early stages of development until feedback information regarding the use of the building; and
- Quality search and insertion [19, 22, 26, 27, 40, 48]: it seeks to ensure that decisions are always made in order to ensure the best performance and quality of the building for all individuals who will be part of its life cycle. Quality should be considered at all stages and by all stakeholders.

As structural elements, these items will be the backbone of the maturity assessment model proposed.

2. Methodology

The maturity assessment methodology was chosen to study the use of concurrent engineering in construction. Studies by Nightingale and Mize **[41]** and Santos and Martins **[46]** show that these analyses contribute to the development of enterprises because they can identify the gaps between what is desired and what is actually done. The maturity assessment examines whether and to what extent certain characteristics/circumstances – grouped in elements – occur, thus measuring the use of each element. From this result, they classify the level of maturity of a particular approach.

Good maturity assessment tools allow to not only measure the level of maturity of a particular approach, but also the company's performance, identification of critical elements, to analyze and identify areas for improvement, and also to develop the collective knowledge and experience **[14]**. In other words, from the results of a maturity assessment, it is possible to recognize the strengths and weaknesses of an institution and, therefore, to make a plan suitable to its reality, while creating strategies for its improvement and allowing it to develop and overcome its difficulties **[14, 15, 30, 34, 36, 42, 43, 46, 51]**.

Although there are models for concurrent engineering maturity assessment, as indicated in the introduction, the vast majority of them are not adapted to the construction industry. This may create an obstacle in obtaining the benefits of CE, since methods such as the ones developed by Shouke et al. **[48]** show that the adequacy of the analysis tool is essential to the objectivity and veracity of results. Under these circumstances, the BEACON model **[31]** would be the most appropriate because it was created exclusively for the construction industry. However, beyond the peculiarities of the sector, it is important that the maturity model also fit the characteristics of the place where it will be used; however, the reality of the English/European industry is very different from the Brazilian reality.

A review of the British construction industry shows that it is more developed and sophisticated than it is in Brazil. Haas' research **[28]** states that innovation in the construction industry in the UK is aimed toward management and that many universities have developed students with more skills related to leadership and management. This scenario is quite different in Brazil, where most of the civil engineering courses do not emphasize the development of managerial skills **[35]**. Another great difference between the British and Brazilian construction is the sector organization. While in Brazil a large number of firms tend to be the client organization and the builder/contractors at the same time; in England, this is an atypical scenario, where most projects are born in a client organization **[50]**, regardless of the enterprise that will be responsible for construction *(contractors)*.

Consequently, the BEACON questionnaire was proven inadequate to the Brazilian reality. At first, an attempt to use the BEACON questionnaire was conducted. The questionnaire was presented separately to architects, civil engineers and production engineers, who analyzed its questions and made some comments about it. What was concluded with this first trial was that the BEACON model questions were too complex and generated many questions, as it did not correspond to the Brazilian model of structuring a construction company and required knowledge that is not common to the professionals in Brazil. In addition, the length of the questionnaire proved to be excessive and would require much time for its application, and the use of self-applied questionnaires by mail or e-mail has been discouraged, since their response rate is very low.

Thus, the model proposed in this research has two phases. The initial one, called the approach phase, consists in gathering information that allows a documental analysis of the company and how the enterprise develops its initiation and planning process of a project. This works together with a semi-structured interview that supplements the information obtained through the documental analysis, characterizes the company and the respondent and evaluates, in a simplified way, the understanding of the interviewee concerning the five elements of concurrent engineering presented in section 2. The information gathered in this first step allows the results found in the maturity assessment to be analyzed, interpreted and understood according to the reality and characteristic of each company. The second stage

Statements	Always	Usually	Sometimes	Rarely	Never
Stakeholders participate in the project starting from the initiation phase, making comments and suggestions.	(5)	(4)	(3)	(2)	(1)
The accompaniment of the construction by the designers is an occasional activity that only happens when some change/modification needs to be made in the design.	(1)	(2)	(3)	(4)	(5)

(X) = Value assigned for each answer

TABLE 1. *Example of statements with its possible responses*

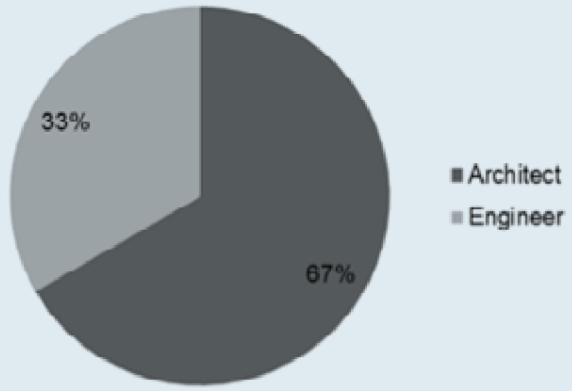

FIGURE 1. *Respondent's academic formation*

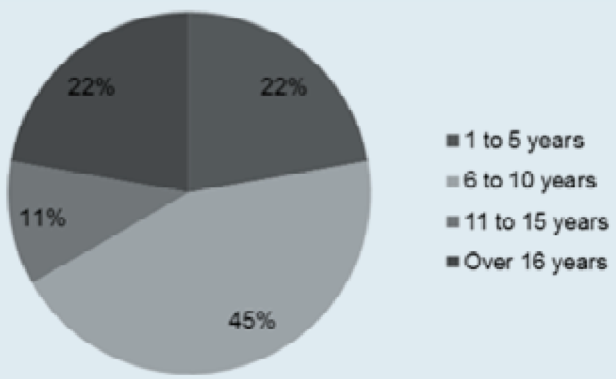

FIGURE 2. *Time of the interviewed in the Company*

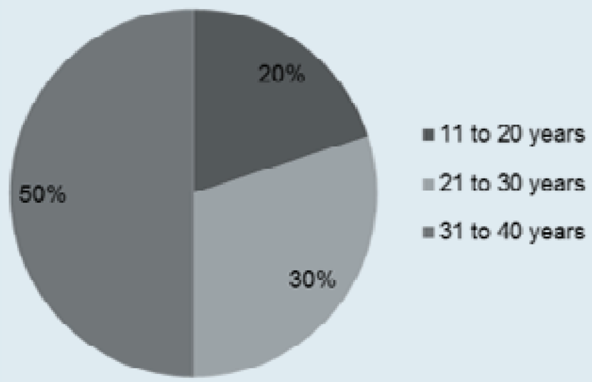

FIGURE 3. *Time in the Market*

consists of a more profound analysis of the company activities and elements related to the principles of concurrent engineering, representing the actual maturity assessment procedure. This second stage is based on an interview, done with the same respondent of the first phase, and uses a form based on the five basic elements of CE *(see item 2)*.

For each element, a number of statements that characterize it were determined from the literature review. The statements are answered based on five alternatives. Each alternative was given a value *(1 to 5)*, where the highest value *(5)* corresponded to the most favorable response to the use of CE and the lowest one *(1)*, to the less favorable answer. Thus, the questions were designed so that the highest score option corresponds to the ideal situation for CE development *(see* **Table 1***)*.

The division of maturity assessment into five groups, each corresponding to one of the main elements of concurrent engineering, combined with the scores for each answer, allows to count the points for each element and to evaluate which are better or worse with regard to performance, thus enabling to diagnose the company's use of CE. The maturity assessment score per element is calculated based on Silva's **[49]** formula, where the maturity level of the element *(Me)* is equal to the sum of the points earned in that element *(pe)*, divided by the maximum points possible *(tp)*. Multiplying the result by 100, there is a maturity percentage value for each element, according to Formula 1:

$$Me = \frac{pe\, x100}{tp} \qquad (1)$$

where,
Me = element maturity *(%)*;
pe = points earned in the element;
tp = maximum points possible in the element.

To calculate the overall maturity, since each element has an essential role in the creation of a simultaneous process, they all received the same weight. The company's overall maturity *(Formula 2)* is found by combining the evaluation result of all five categories, therefore, it is the sum of the maturity of all elements divided by the number of elements *(five)*.

$$Mg = \frac{\Sigma_1^5 Me}{5} \qquad (2)$$

where,
Mg = company's overall maturity *(%)*;
Me = element maturity.

Score (%)	Maturity Level	Description
Up to 20	Ad-hoc	There is no understanding and no use of concurrent engineering in the company. Process and communications are almost all informal, modern tools & technology are not used consistently, there is no management and control of the project development process and there is disorganization among the stakeholders. It can have initiatives for improvement.
Score (%)	**Maturity Level**	**Description**
20 - 40	Repeatable	Standard methods and practices are used and the process is repeatable. There are barriers to communication within the project development team and interaction usually occurs at specific/ punctual moments. There is some use of management and control of the project development process.
40 - 60	Characterized	The project development process is characterized and known. The individuals involved in the process are well aware of clients' requirements, but not all stakeholders are involved in project design and planning. Moderate use of technological innovations.
60 - 80	Managed	The project development process is characterized, known, understood, measured, planned and controlled. Stakeholders are involved in almost all the process and there is good communication between them. Appropriate utilization of available technology and computer-based tools.
80 - 100	Optimized	A high degree of control is used over the project development process. Team performance is regularly measured, and optimizing performance measures are continuously validated. There is free and continuous communication and the decisions made are based on the enterprise database and consider the needs of all clients in the process. Represents a stage in which the company achieves a culture of continuous improvement of its practices.

TABLE 2. *Maturity Scale*

The score *(in percentage)* is analyzed based on a maturity scale divided into five levels, which is commonly used in maturity models *(CMM, BEACON, MMGP, PMMM, RACE, among others)*, adapted from the BEACON **[31]** and RACE **[15]** models. **Table 2** shows the proposed scale.

The respondents of the interviews are composed mainly of engineers or architects, exclusively, according to the percentage presented in **Figure 1**. Respondent's time in the company varies, although most have more than ten years in the enterprise, which ensures good knowledge of the construction processes *(***Figure 2***)*. The people selected to be interviewed were always directly related to the design process and had relative dominance and authority over this process to ensure that their answers reflected the reality experienced by the company. Thus, from the nine companies interviewed, in five of them, the people interviewed held manager/ coordinator positions.

The methodology was applied in nine case studies on Brazilian construction companies in the region of Vitória – Espírito Santo. Since it is a small sample group, this study is characterized as a descriptive, qualitative one, based on case studies and which sought to further describe the processes of each company.

3. Findings and discussions

The general characterization of the researched companies is illustrated in **Table 3**. All enterprises studied in this paper are, at the same time, client and contractor organizations and have focused on multifamily housing projects. These choices are justified by the fact that the client-contractor organization of construction companies is the most commonly used in Brazil, and because the urban housing demand in the country is very high, thereby making the construction of residential buildings very expressive **[8]**.

By analyzing **Table 3**, it can be seen that the sample has a similar origin, coverage area, standardization, design process and organizational structure. As for time in the market, there is a variation, which enables creating three classes: 11-20, 21-30, and 31-40 years, with the concentration of companies in each of these classes varying according to what is presented in **Figure 3**. Here, it is interesting to note that the youngest construction enterprise interviewed has 13 years in the market, which indicates a sample of companies consolidated in the market. Regarding size, firms were characterized according to the classification of the Brazilian Service of Support for Micro and Small Enterprises **[47]**, where only one company was identified as small *(up to 99 employees)*, being on the outskirts of this classification with 98 employees; five were categorized as medium *(100-499 employees)*; and three as large *(over 500 employees)*. These characteristics are important because they allow creating groups from which it is possible to compare the influence of certain characteristics on the level of CE maturity.

Concerning the maturity achieved, the analyses reveal that the vast majority of the companies studied showed a good level; about 55.5% have a "Managed" level of maturity, needing some intervention to achieve the "Optimized" level *(see* **Table 2***)*. Only one enterprise *(E)* is featured on the "Characterized" level, requiring greater efforts to raise levels. Three companies, 33.3% of the sample, have their maturity level classified as "Optimized", which means that they need to maintain their good results through the continuous improvement cycle. However, among those in the optimized level, only in company F do the elements have the same baseline, which shows that the other enterprises in the "Optimized" group require improvements in order to even out the development of its elements.

In **Table 4** it is also possible to see the percentages obtained in each element and, below, its performance compared to other elements in the same company, the element numbered one showing best performance and so on until it arrives at the fifth position. Analyzing the classification, it can be noticed that the element "Quality search and insertion" appears as the most developed in the sample, with an average of 80.94%. This result may be related to the ISO 9001 standardization, present in almost all companies sampled, with the exception of E, which had the lowest result for this element. Considering a decreasing scale of development, after "Quality search and insertion", the best results are in "Concurrency of activities", followed by "Anticipation of stages and decisions". The elements "Multidisciplinary team" and "Stakeholders' integration" were the less developed, with very close results in terms of placement and average, which can be understood by the great relationship and interdependence between them. Nevertheless, even with a slight difference, the worse results are in the element "Stakeholders' integration".

To better understand the results and the possible factors that influence them, comparisons were drawn between companies based on the characteristics chosen, and as a result, some groups were created. The maturity average of CE for these clusters was calculated according to Formula 3 and the following conclusions were made:

$$Ma = \frac{\sum_1^x Mg}{N} \qquad (3)$$

where,

- Ma = group maturity (%);
- Mg = company's overall maturity;
- X = companies in the group;
- N = number of companies included in the group.

Time in the market

By grouping firms according to time in the market, it is possible to divide them into three groups: those with less than 20 years of operation *(C and D)*, 21-30 years *(B and H)* and those with more than 31 years A, E, F, G and I). Plotting the maturity average of CE for each of these groups *(Ma)*, the following values were obtained: companies with 11-20 years got Ma = 74.23% *(Level: Managed)*; those with 21-30 years got Ma = 80.51% *(Level: Optimized)*; and those with 31-40 years got Ma = 73% *(Level: Managed)*. Comparing the results of these three groups, it was seen that in the sample studied, firms with 21 to 30 years are more prepared to use CE. This may be the consequence of different factors, the first one due to the fact that maturity is an evolutionary process **[5]**, causing the younger companies to not have such a good result; and, at the same time, older firms tend to be more conservative, which may hinder assimilating new technologies **[9]**.

Size

In terms of size, there is only one company *(B)* classified as small, the others can be divided into large *(A, F and I)* and medium *(C, D, E, G and H)* enterprises. Considering these groups and making the maturity average for concurrent engineering in each *(Ma)*, it can be determined that the large size group has a better maturity level than the midsized one, with Ma = 77.76% and Ma = 72.46%, respectively. This result is in agreement with others found in the literature review, which states that large companies have greater ease to reach maturity in the CE, since they have more resources available **[13, 23, 31]**. Considering company B as the whole small group, it would be the group with the best result, with a Ma = 78.90%. Even if this result seems to diverge from the literature studied, it can be understood, if we consider that despite being classified as small sized, company B is the boundary of the small size class, with a small difference in the number of employees separating it from the midsized companies. This could mean that many of the resources available to the midsized companies could already be available and that it should be more prone to be included in the medium size group. Following the reasoning proposed above, the maturity level of concurrent engineering for medium sized companies, with the addition of company B, would be raised to 73.54%, which still does not guarantee a better outcome of the group when compared to the result of the larger ones.

Standardization

Concerning standardization, the companies studied presented three different standards: OHSAS 18001, ISO 14001 and ISO 9001, that deal with health and safety procedures in the work environment, environmental management, and quality management, respectively. The one that most affects concurrent engineering is ISO 9001. Due to this, companies were grouped according to those with or without ISO 9001. Even though there is only one company in the sample that does not have ISO 9001 certification *(E)*, a fact which limits generalizations, the disparity between its maturity assessment result and the other companies' results cannot pass unnoticed. E company was the one with the lowest level of maturity *(55.55%)*, the only one in the sample to be ranked as characterized *(see* **Table 4***)*. This result emphasizes the importance of this standardization *(ISO 9001)* for quality development, which is directly represented in the assessment by the element "Quality search and insertion". It also indicates that ISO 9001 is a strong inducer for the deployment of CE.

Company	Time in the market (years)	Size (# employees)	Origin	Coverage area	Standardi-zation	Line of business I	Line of business C	Line of business IC	Design development IN	Design development E	Design analysis IN	Design analysis E	Organizational structure	Centralized decision making
A	32	Large (1 100)	Vitória	Espírito Santo	ISO 9001			X	X	X	X		functional	high
B	24	Small (98)	Vitória	Espírito Santo, Rio de Janeiro e Goiás	ISO 9001		X	X	X	X	X		functional	low
C	13	Medium (430)	Vila-Velha	Vitória e Vila Velha	ISO 9001		X	X	X	X	X		functional	low
D	18	Medium (104)	Vitória	Vitória	ISO 9001			X		X	X	X	functional	moderate
E	31	Medium (145)	Vitória	Vitória	-			X		X	X		functional	high
F	32	Large (820)	Vitória	Vitória e Serra	ISO 9001	X		X	X	X	X		functional	low
G	38	Medium (250)	Vitória	Espírito Santo	ISO 9001 OHSAS 18001		X	X		X	X	X	functional	moderate
H	29	Medium (128)	Vitória	Vitória	ISO 9001			X	X	X	X		functional	high
I	39	Large (450 just in Espírito Santo)	Outside Espírito Santo	Espírito Santo, Rio de Janeiro, São Paulo, Maranhão, Piauí e Pará	ISO 9001			X	X	X	X		functional	high

Legend:
I = Work as client organization for other companies
C = Work as contractor for other companies
IC = Work as client-contractor (together),
IN = Internal
E = External

TABLE 3. *Sample characteristics*

Company	Anticipation of stages and decisions	Concurrency of activities	Multidisciplinary team	Stakeholders' integration	Quality search and insertion	Overall maturity	Level
A	77.65% (3º)	77.77% (2º)	60% (5º)	65% (4º)	87.69% (1º)	73.62%	managed
B	75.29% (4º)	80% (2º)	87.27% (1º)	75% (5º)	76.92% (3º)	78.90%	managed
C	82.35% (3º)	77.78% (4º)	85.45% (2º)	73.75% (5º)	90% (1º)	81.87%	optimized
D	62.35% (3º)	71.11% (2º)	58.18% (4º)	57.5% (5º)	83.85% (1º)	66.60%	managed
E	54.12% (3º)	66.67% (1º)	49.09% (5º)	52.5% (4º)	55.38% (2º)	55.55%	characterized
F	84.71% (4º)	88.89% (1º)	83.64% (5º)	88.75% (2º)	86.92% (3º)	86.58%	optimized
G	80% (2º)	77.78% (3º)	72.73% (4º)	65% (5º)	85.38% (1º)	76.18%,	managed
H	90.59% (1º)	82.13% (2º)	72.73% (5º)	80% (3º)	78.46% (4º)	82.13%,	optimized
I	77.65% (2º)	71.11% (3º)	69.10% (4º)	63.75% (5º)	83.85% (1º)	73.09%	managed
Average	76.08% (3º)	77.03% (2º)	70.91% (4º)	69.03% (5º)	80.94% (1º)	74.95%	managed

TABLE 4. *Maturity assessment result with the position obtained by each element*

Design development

By splitting the sample between those companies that deal exclusively with outsourced design *(D, E and G)* and those that, at the same time, hire outside professionals and elaborate some of the designs internally *(A, B, C, F, H and I)*, two groups are created. Comparing the maturity average *(Ma)* of the two groups, the companies that work exclusively with outsourced design underperformed, 66.11% versus 79.36%, those that hire and internally develop the designs. A possible explanation for this result is that increasing the outsourced professionals involved in project development may intensify communication difficulties, a problem which, according to Conde **[11]** and Bruel **[7]**, tends to be minimized when those involved are part of the same company.

Design analysis

All of the companies interviewed analyzed the projects in search for errors and compatibility problems, which shows progress in comparison to other studies, such as the one developed by Corrêa **[13]**, in which only some of the companies interviewed performed this analysis. Dividing the enterprise by how this analysis is performed, they can be separated into those that perform it internally *(A, B, C, E, F, H and I)* and those that, in addition to doing it internally, hire design companies to do it *(D and G)*. The difference in the maturity assessment of the two groups is small, with the one that has dual analysis presenting Ma = 71.39% and the group with internal analysis exhibiting Ma = 75.96%. Fontenelle **[25]** observes in one of his case studies that the division of analysis and supervision activities in the design process between construction and design companies generates areas in which the process is not well defined. This means that, similarly to what happens in item 4.4, the increase in the number of stakeholders outside the organization may be responsible for the lower maturity assessment performance of the group with external and internal analysis.

Level of centralization in decision making

The organizational structure of all companies in the sample follows the same orientation: functional. What varies between them is the issue of power centralization. According to Robbins **[45]**, in decentralized enterprises, actions to solve problems can be faster and more people participate in decisions. Therefore, decentralized companies tend to have a more favorable environment for the development of CE, since decentralization stimulates concurrency of activities, anticipation of stages and decisions and, especially, multidisciplinarity. The maturity average of the groups *(Ma)* are 71.10%, 71.39% and 82.45% for companies with high *(A, E, H and I)*, moderate *(D and G)* and low centralization *(B, C and F)*, respectively, pointing to what was observed by Kruglianskas **[33]**, that an evolution of maturity occurs as the enterprises decentralize.

4. Conclusions

Considering the transformation and pressure for improvements that have been taking place in the construction industry, one possible solution for this scenario is the use of concurrent engineering. Despite the potential gains that this technique can bring to companies, it is important that CE implementation is done in a conscious and appropriate fashion. Hence, it is important to conduct a CE maturity assessment to identify obstacles hindering the development of the company, allowing, based on this diagnosis, for actions to be taken to correct them.

Therefore, the objective of this paper is to analyze the maturity level for CE in construction companies in Grande Vitória – ES, Brazil, through a new assessment methodology suited to the Brazilian reality. The research done in nine case studies shows that the maturity for concurrent engineering is at a managed level, with an average of 75.72% *(see* **Table 4***)*, indicating a high use of concurrent engineering elements and a known and characterized process. However, variations in the results may occur due to enterprise characteristics, where it can be concluded, for the studied sample, that:

- Usually, growth in the company size implies improvements in the maturity of CE;
- The larger the number of third parties involved, the lower the maturity; and
- The presence of ISO 9001 standard raises CE maturity.

It is interesting to note that the most developed element usually corresponds to "Quality search and insertion", which can be related to the large presence of the ISO 9001 standard in the sample. Nevertheless, there are difficulties to overcome, especially in "Multidisciplinary team" and "Stakeholders' integration" elements, which were those with the lowest results. This means that there is little interaction, bad communication and cooperation problems among the participants of the process, corroborating the findings presented by Eriksson et al. **[17]** and Mitchell et al. **[39]**, which show that improvements are still needed for companies to fully employ CE.

The strong relationship between "Stakeholders' integration" and "Multidisciplinary team", as well as the effect of ISO 9001 on the results obtained, should be further investigated. Future studies should also focus on conducting quantitative research in construction companies, as well as reproducing this study in other Brazilian states in order to generalize the results.

authors

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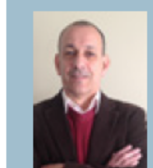

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