Maturity analysis of small companies AEC for the implementation of management by simultaneous engineering

https://doi.org/10.56238/sevened2024.010-031

Paulo Henrique Ferrarini Gevaerd[1] and Cezar Augusto Romano[2]

ABSTRACT

The work presents an analysis of maturity in architecture, engineering and construction companies, in relation to the objectives of Simultaneous Engineering. The main objective was to understand the impact on the maturity of small companies in the architecture, engineering and construction industry when using collaborative computational tools in the implementation of Simultaneous Engineering concepts. To develop the research, bibliometric analyses were made to characterize the main authors involved with the themes of Simultaneous Engineering. These authors formed the theoretical basis for the development of the interview protocol in multiple case studies. After the elaboration of the research protocol and its improvement based on a pilot study, interviews were conducted with representatives of nine companies in the sector and from their answers maturity analyses were developed. As a result of the analyses, the following conclusions were obtained: small companies need greater self-knowledge to balance their business maturity; Architecture firms have a different maturity profile from engineering and construction firms, and architecture firms are positively influenced by their tools, engineering and construction firms still have low levels of maturity in these relationships; The tools currently used by companies do not help in the integration of business and intercompany processes, which hinders the implementation of Simultaneous Engineering concepts.

Keywords: Simultaneous Engineering, AEC Industry, Colabotarious Computer Systems.

[1] MSc - Federal Technological University of Paraná
[2] Doctor - Federal Technological University of Paraná

INTRODUCTION

Planning in civil construction is a systemic process where the existing concepts for the determination of this structure for works and the constraints between activities are not addressed such as the process of elaboration of a Project, where the existing concepts that structure the calculation memorials and the criteria of constraints in the development of the design are strictly followed. Therefore, there is a need for studies that deal with the planning process (CHIBINSKI, 2012).

Civil construction, in its current structure, uses a sequential practice for the development of activities within its production cycle. This traditional practice results in the evident separation between the design phase and its respective execution. This segmentation has resulted in non-conformities, such as: schedule delays, budget failures and low construction quality (SILVA, 2013).

According to Chen (2008), because of the intensity and diversity of information, efficiency in information management is crucial for the construction industry. Therefore, tools and technologies must be increasingly applied with a focus on improving the quality of data management.

Concurrent Engineering (CE) incorporates two key principles: integration and concurrency. Integration is the relationship of processes and the content of information and knowledge, between and within stages of the project, and all the technologies and tools used in the development of the project. Simultaneity is determined by the way tasks are planned and the interaction between the different actors (people and tools) and the product development process (ANUMBA et al., 2007).

What is the impact on the technological maturity of small companies in the architecture, engineering and construction industry when using collaborative computational tools in the implementation of Simultaneous Engineering concepts?

The delimitation of the research comprises a multiple case study regarding the technological maturity of small companies in the architecture, engineering and construction industry, which operate in the city of Curitiba, in the State of Paraná.

The objective of this article is to present the results of the maturity analysis of the small companies interviewed, thus initiating a set of theoretical reference articles for the application of business maturity studies that allow the development of the management methods of companies for the future of the construction industry, based on collaboration between all those involved in the supply chain.

BIBLIOMETRIC ANALYSIS

SCOPUS ANALYSIS

According to Gil (2016), the privileged place for the location of bibliographic sources has been the library. However, due to the wide dissemination of bibliographic materials in electronic format, research through databases and search systems is of great importance.

Scopus is the largest database of citations and abstracts of peer-reviewed literature: scientific journals, books, and conferences. Presenting a comprehensive overview of the world's research output in the fields of science, technology, medicine, social sciences, arts, and humanities, as well as presenting intelligent tools for tracking, analyzing, and visualizing research. (ELSEVIER, 2017)

To use the Scopus search system, it is important to define the keywords that actually cover the search. Therefore, initially, a spreadsheet is prepared with all the potential words that refer to the work and then a selection is made of those that will really support the research. The table of keywords for the research related to this study is presented in Chart 1.

TABLE 1 Keywords used in the Scopus survey

Referenciais Teóricos	Em inglês	Palavras similares ou sinônimas
Engenharia Simultânea	*Concurrent Engineering*	*Collaborative Engineering*
Sistemas Colaborativos Computacionais	*Computer Suported Collaborative Work*	*CSCW*
Engenharia de Requisitos	*Requirements Engineering*	*RE*
Ambientes Computacionais Integrados na Construção	*Computer Integrated Environments in Construction*	*CIE*
Indústria da Construção Civil	*Construction Industry*	*AEC and Real Estate*
Gerenciamento, Planejamento e Controle de Obras	*Construction Management*	*Building management and construction planning*

ANÁLISE BIBEXCEL PAJEK

The 153 authors who have publications related to the research theme form a citation network, which is represented in Figure 1 due to the number of citations per author.

FIGURE 1 Author Clusters and Their Interaction Networks

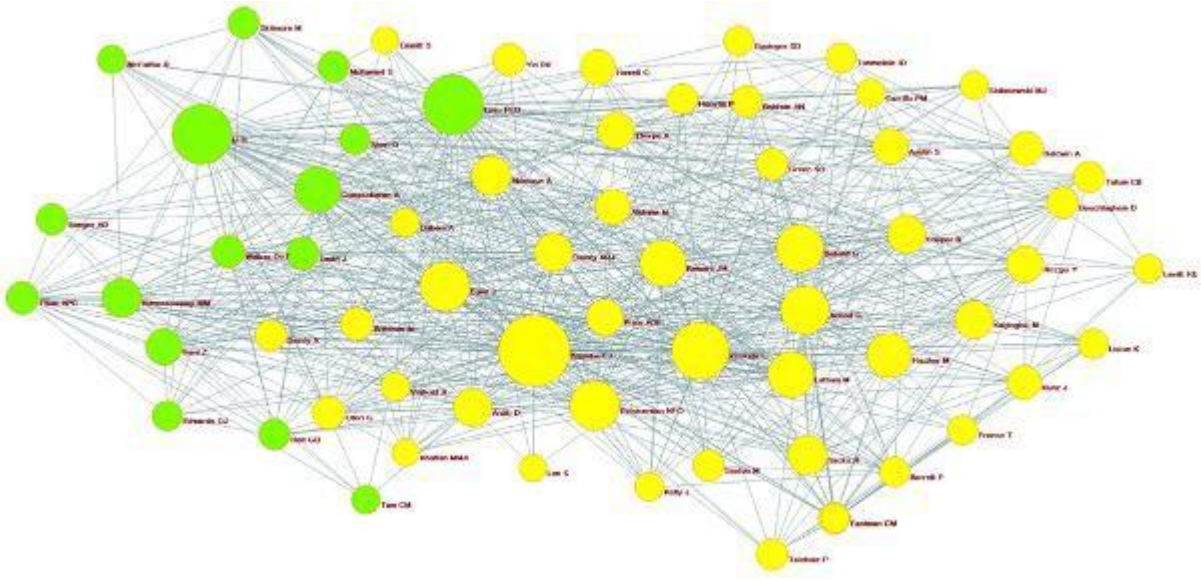


Figure 1 shows 2 groups (or clusters) of authors that have a higher degree of co-citations, i.e., authors who, when producing their work, tend to cite other authors more often than from the other

groups.

The yellow group is made up of researchers who are related, mainly by the strand produced by the author Anumba C.J., whose works are related to Simultaneous Engineering, but also to the use of computerized systems and techniques that enable the integration of those involved, as well as the fulfillment of customer requirements.

The other cluster of researchers, the green group, is directly related to the research authored by Love, P.E.D., whose work has the strand of research production in relation to the reduction of rework on construction sites due to the principles of Simultaneous Engineering.

CONCURRENT ENGINEERING

According to Winner et al. (1988), Simultaneous Engineering is a systematic approach to the integrated and concurrent design of products and their related processes, including production and support. This approach aims to have designers, from the outset, consider all elements of the product life cycle from conception to disposal, including quality, cost, timeline, and user requirements.

For Khalfan (2001), there is an urgent need to improve the construction supply chain, and for this it is necessary to understand the entire life cycle of the project from its beginning, taking into account all the requirements raised for the operation and maintenance of the structure.

According to Anumba et al (2007), another justification for adopting Simultaneous Engineering in construction is the fact that its objectives and strategies (principles) are directly related to the problems encountered in the construction industry, as shown in Chart 2.

TABLE 2 The reasons for adopting Simultaneous Engineering in Construction

Necessidade de Mudança na Construção	Objetivos e Princípios da ES
A necessidade de mudança na construção vem à tona no que diz respeito à falta de competitividade natural dessa indústria, e também na inabilidade de satisfazer seus clientes em relação aos custos, tempo e qualidade.	Os objetivos e princípios da ES incluem: satisfação do cliente, competitividade para o negócio, redução no tempo e custos de desenvolvimento do produto, melhoria na qualidade e valor.
A integração dos processos da construção são vistos como uma das mais importantes estratégias para aprimorar a fragmentação tão notória na indústria da construção.	O uso da ES facilita a integração dos membros das equipes de desenvolvimento e produção, dessa maneira aprimorando os processos de desenvolvimento dos produtos.
Estratégias emergentes para aprimorar os processos da indústria da construção são inadequados; elas apenas levam em conta um aspecto do problema, resultando em "ilhas de automação", como é o caso das estratégias da construção relacionadas à sistemas computacionais integrados	Como é uma fusão de outras metodologias, ferramentas e técnicas, a ES prevê não apenas um framework para a integração dos processos da construção, mas também várias outras ferramentas e tecnologias usadas no processo.

Source: Anumba et al, 2007, pp 6 (translated by the author)

In Love (1998), it is possible to understand that in order to be successful in the implementation of HE in any organization, the objectives to be achieved are:

a) Improve understanding of customer and end-user requirements;

b) Improve collaboration between project participants;

c) Improve the effectiveness of teams and projects;

d) Reduce rework and variations (in redesign and non-conformities);

e) Reduce project time and cost.

For Lakka et al. (2001), there are several tools that can assist in the implementation of Simultaneous Engineering in companies, each with its advantages and disadvantages. Therefore, it is necessary to understand and evaluate a tool that achieves the objectives of the research and, consequently, helps companies to identify their technological maturity in relation to Simultaneous Engineering.

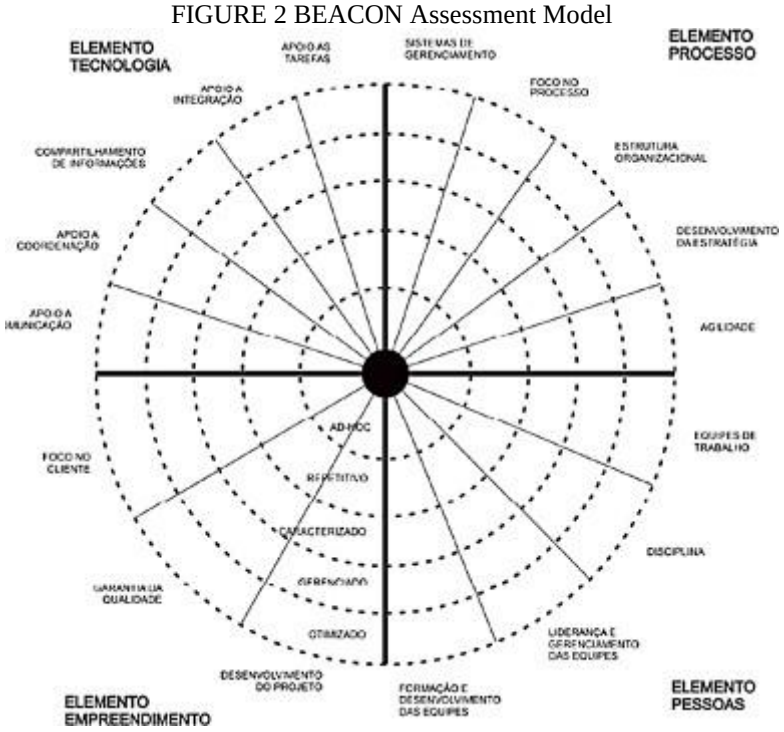
According to Khalfan (2001), the process of implementing the concepts of Simultaneous Engineering should go through four stages. The first is part of the company's knowledge of the benefits of CE. The second is related to the analysis of the measures of the company's potential, in this case the assessment of business maturity. The other two stages are application and then process improvement.

Among the various models used for validation, the RACE (Readiness Assessment in Concurrent Engineering), which according to Pretti (2013), is an evaluation model created by WVU's Concurrent Engineering Research Center and aims to be a more general tool, which can be used for various types of industries, underpins the analysis structure of another model, the BEACON (Benchmarking and Readness Assessment for Concurrent Engineering).

BEACON is divided into four key elements: processes, people, project and technology, which in turn are divided into critical factors, with a series of questions for each factor. (PRETTI, 2013).

In Khalfman (2007) it is possible to understand that the critical factors of these four elements, in order to have their level of maturity assessed, must be answered in the following context, Figure 2.

FIGURE 2 BEACON Assessment Model



Source: Pretti, 2013

However, Pretti (2013) felt the need to adapt the system to the characteristics of the Brazilian construction industry, since the BEACON proved to be very complex with regard to management questions, which ended up confusing the interviewees.

RESEARCH METHOD

It is a Multiple Case Study because, according to Yin (2010), this type of study is used to understand complex group, organizational and social phenomena, allowing the investigator to retain holistic characteristics of real behavioral events.

According to Yin (2010), the protocol is more than a questionnaire or an instrument. First of all, the protocol contains the instrument, but it also contains the procedures and general rules to be followed in the use of the protocol.

DATA COLLECTION INSTRUMENT

Data collection for the research will be done from interviews with engineers and architects who work in companies of the size relevant to the research. With this data, the level of maturity in relation to the systems will be structured, as well as the flow of project development and execution.

With the maturity analyzed, it was possible to understand how the main computer systems used by companies are related to the activities practiced by them. This relationship will make it possible to evaluate the impact of the computational tools of the three types of companies studied (architecture, engineering and construction).

In the first stage of the questionnaire, the interviewed companies are characterized, with questions related to the time of experience of the professional and the company, field of activity and an initial analysis of the importance of simultaneous engineering objectives in the company.

With the collection of responses from the interviewees concluded, the response process begins according to the maturity of the company in relation to the objectives of Simultaneous Engineering. This stage consists of answering 76 questions. These issues are related to the mapping of the maturity of processes, projects, people and technology of companies and crossed with the objectives of Simultaneous Engineering.

BUSINESS MATURITY ANALYSIS

In Khalfan (2001), it is stated that the BEACON maturity analysis model is based on the RACE maturity analysis, which is a type of analysis that validates software development. BEACON was studied and developed to do this same analysis for the construction industry with a focus on Simultaneous Engineering. From certain levels of maturity, Table 3.

According to Khalfan (2001), there are 5 types of positioning of a company in this industry, which can range from the lowest level in which the company does not have control over any of its processes, through the company that is prepared to introduce the concepts, to the one in which Simultaneous Engineering is already applied and can be improved.

TABLE 3 Maturity Levels

Nível de Maturidade	Pontuação Questionário	Descrição da Situação da Empresa	Escala
Ad-hoc	Até 20%	Este nível é caracterizado por processos e controles não definidos, e por equipes confusas e desorientadas que não entendem suas funções nem como operar eficientemente. Interações informais com o cliente são observadas, o gerenciamento do desenvolvimento dos processos dos projetos não são aplicados consistentemente nos empreendimentos, e ferramentas e tecnologias modernas não são aplicadas consistentemente.	1
Repetição	Entre 20% e 40%	Métodos e práticas padronizados são utilizados para monitorar o desenvolvimento dos processos dos projetos, mudança de requisitos, estimativa de custos etc. O processo é repetitivo. Existem barreiras na comunicação com a equipe de desenvolvimento dos projetos. Interação com o cliente é estruturada, mas é apenas no começo do projeto. Poquíssimo uso de computador ou ferramentas computacionais.	2
Caracterizado	Entre 40% e 60%	O processo de desenvolvimento dos projetos é bem caracterizado e relativamente bem compreendido. Uma série de melhorias organizacionais e de processos são implementadas. Equipes podem brigar e vir a terminar em razão de conflitos, porém a equipe começa a respeitar diferenças individuais. A maioria dos envolvidos tem noção dos requisitos dos clientes, porém o cliente não faz parte do processo. Uso moderado de tecnologia que aprimora a eficiência do grupo.	3
Gerenciado	Entre 60% e 80%	O processo de desenvolvimento dos projetos não só é caracterizada e entendida, como também quantificada, medida, e razoavelmente bem controlada. Ferramentas são utilizadas no controle e gerenciamento dos processos. O trabalho é realizado pela equipe de desenvolvimento de projetos e conflitos são pontuais. O cliente é envolvido em todo o processo. Utilização apropriada da tecnologia disponível e ferramentas computacionais.	4
Otimizado	Acima de 80%	Um alto nível de controle é utilizado para o desenvolvimento dos processos do projeto e existe um foco maior em aprimorar o desenvolvimento das operações de maniera significante e continua. A performance da equipe é regularmente medida, e a medição da performance é continuamente validada. O cliente faz parte da equipe de desenvolvimento do projeto desde o início e todas as decisões do projeto são fundamentadas nas necessidades dos clientes. Utilização ideal de tecnologia pela equipe de desenvolvimento e também a existência de grupo de trabalho focado em tecnologia.	5

Source: Translated and adapted from Khalfan, 2001

PRESENTATION OF RESULTS

CHARACTERIZATION OF COMPANIES

The companies surveyed should operate in Curitiba, according to section 1.2 of the survey. Chart 4 shows the place of headquarters, the cities in which it has services performed and also the area of operation. Table 16 summarizes the characteristics of the companies according to the items location, area of operation and construction models executed, which should be met so that they could be part of the body of data.

TABLE 4 Situation of enterprises

Empresa	Sede	Local	Unifamiliar	Multifamiliar	Comercial	Industrial	Reformas	Outros
1	SÃO JOSÉ DOS PINHAIS	CTBA, MAFRA, SÃO JOSÉ DOS PINHAIS E FAZENDA RIO GRANDE	X	X			X	
2	CURITIBA	PARANÁ E SANTA CATARINA	X	X	X	X		
3	CURITIBA	CURITIBA	X	X	X	X	X	LAUDOS
4	SÃO JOSÉ DOS PINHAIS	CURITIBA, REGIÃO METROPOLITINA E SANTA CATARINA	X	X	X		X	
5	CURITIBA	CURITIBA, VIDEIRA E RONDONÓPOLIS	X		X			INTERIORES
6	CURITIBA	CURITIBA E REGIÃO METROPOLITANA	X	X	X		X	
7	CURITIBA	CURITIBA E REGIÃO METROPOLITANA	X		X		X	
8	CURITIBA	PARANÁ E MINAS GERAIS						ORÇAMENTOS
9	CURITIBA	CURITIBA E SÃO JOSÉ DOS PINHAIS		X				

Source: The Author (2017)

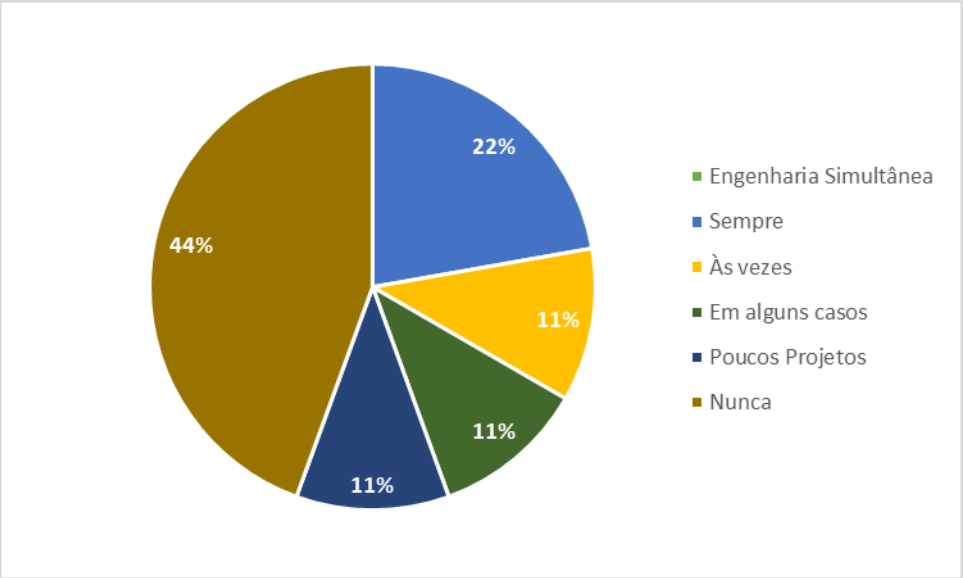
BUSINESS MATURITY ANALYSIS

Continuing with the interview script, the next step was directed to the 77 questions about the company's maturity based on the five main objectives of Simultaneous Engineering, distributed within the four items in the BEACON analysis, already described in Chapter 4 of this research.

The first question was directed to the interviewees' knowledge about Simultaneous Engineering. After a brief explanation on the subject, the interviewee should answer whether he acts in accordance with the principles of Simultaneous Engineering, or if the projects do not have this focus. It can vary within the Likert scale, from 1 to 5, being 5 always and 1 never.

Of the nine companies interviewed, four answered that they had never worked within these principles, and that the fulfillment of these requirements, if they happened, would be purely coincidental. Two companies responded that they believed they would always work with these principles, as shown in Chart 1.

CHART 1 Answers about Concurrent Engineering



Source: The Author (2017)

This first approach serves as an analysis to understand how integrated and collaborative small businesses are, even without formal knowledge of the techniques and tools. The answers to the other questions should prove or not this distancing of companies in relation to the concepts of Simultaneous Engineering.

Chart 5 shows that of the 9 companies that were interviewed, only one had a characterized performance. The other respondents have a maturity at the managed level.

QAUDRO 5 Maturity Analysis of the Interviewed Companies

	Clientes	Colaboração	Eficiência	Variações	Custos	MAT. ES	Processos	Pessoas	Projetos	Tecnologia	BEACON	GERAL	
1	73,33%	81,33%	69,33%	73,33%	77,33%	74,93%	76,00%	66,67%	89,33%	70,40%	75,60%	75,27%	Gerenciado
2	65,33%	78,67%	58,67%	41,33%	73,33%	63,47%	65,00%	60,00%	80,00%	54,40%	64,85%	64,16%	Gerenciado
3	70,67%	76,00%	77,33%	24,00%	88,00%	67,20%	61,00%	73,33%	69,33%	67,20%	67,72%	67,46%	Gerenciado
4	74,67%	76,00%	50,67%	70,67%	88,00%	72,00%	68,00%	56,00%	70,67%	85,60%	70,07%	71,03%	Gerenciado
5	56,00%	65,33%	58,67%	64,00%	69,33%	62,67%	51,00%	68,00%	64,00%	68,00%	62,75%	62,71%	Gerenciado
6	76,00%	76,00%	54,67%	72,00%	92,00%	74,13%	51,00%	46,67%	92,00%	98,40%	72,02%	73,08%	Gerenciado
7	57,33%	80,00%	80,00%	66,67%	70,67%	70,93%	79,00%	81,33%	78,67%	53,60%	73,15%	72,04%	Gerenciado
8	76,00%	94,67%	54,67%	64,00%	89,33%	75,73%	69,00%	88,00%	77,33%	72,80%	76,78%	76,26%	Gerenciado
9	52,00%	45,33%	46,67%	52,00%	56,00%	50,40%	47,00%	46,67%	77,33%	39,20%	52,55%	51,48%	Caracterizado
GERAL	65,99%	75,76%	61,07%	60,23%	77,11%	68,03%	62,30%	64,93%	76,93%	69,46%	68,41%	68,22%	Gerenciado

Source: The Author (2017)

The maturity analysis in relation to the objectives of simultaneous engineering indicates that the interviewed companies have a greater vocation for collaboration between teams and also with the control of costs and deadlines. On the other hand, maintaining production efficiency, aligning designers and execution teams, in addition to controlling project variations and non-conformities in the works, are items that, even at a managed level, are not the main objectives.

In order to understand the aspects that most influence each of the objectives of Simultaneous Engineering, the answers were transposed according to the aspects of BEACON analysis. In this way, it was possible to verify which element, including processes, people and technology, most affected

the maturity of companies.

Thus, the maturity results of the project item are those that most influence the maturity presented by the companies. At this point, it can be said that companies have in the development of projects their most striking characteristic and, as a result, the objectives of Simultaneous Engineering are positively benefited.

In the first part of the analysis, eight of the nine companies have at least one item that is not at the managed level, but six of the nine companies have at least one item that is at the optimized level. This means that there is still room for development and consequent balance between the various objectives.

Another analysis is related to the level of integration between the systems used, Chart 6, with the BEACON maturity levels of the companies in relation to the use of technological tools in the various activities. This relationship indicates that companies are increasingly using computational tools. However, of the companies interviewed, only one was at a level of integration of the tools that makes it possible to exploit them in the implementation of all the objectives of Simultaneous Engineering.

This analysis opens up the possibility of carrying out studies with more collaborative tools that integrate the various stages of the project development process: Incorporation, Planning, Management and Control of Works.

The last part of the maturity analysis consists of verifying whether the objectives of Concurrent Engineering are aligned with the policies of the interviewed companies. To this end, the companies, when answering the questionnaire, presented the order of priority of the same In relation to these objectives, and depending on the degree of maturity of each one, it is possible to understand if what is done and what is believed is really ready to be achieved.

TABLE 6 Objectives of Concurrent Engineering by Company

OBJETIVOS ENGENHARIA SIMULTÂNEA	Empresa 1			Empresa 2			Empresa 3			Empresa 4			Empresa 5			Empresa 6			Empresa 7			Empresa 8			Empresa 9		
	FAZ	ACREDITA	RESPOSTAS	FAZ	ACREDITA	RESPOSTAS	FAZ	ACREDITA	RESPOSTAS	FAZ	ACREDITA	RESPOSTAS	FAZ	ACREDITA	RESPOSTAS	FAZ	ACREDITA	RESPOSTAS	FAZ	ACREDITA	RESPOSTAS	FAZ	ACREDITA	RESPOSTAS	FAZ	ACREDITA	RESPOSTAS
Entender os requisitos dos clientes e usuários finais	1	1	2	5	4	3	1	1	4	1	1	3	1	2	5	1	1	3	5	1	5	2	2	3	1	1	2
Colaboração entre os participantes do projeto	4	2	1	2	5	1	2	2	3	4	4	2	2	5	2	4	4	2	4	5	1	3	4	1	3	2	5
Efetividade entre equipes e projetos	5	3	2	3	2	4	3	3	2	5	5	5	3	4	4	3	3	5	2	3	1	4	3	5	2	3	4
Reduzir retrabalho e variações dos projetos e também não conformidades na obra	2	5	5	1	3	5	4	4	5	3	3	4	4	1	3	2	2	4	3	4	3	5	1	4	4	4	2
Reduzir tempo e custo dos projetos (Global)	3	4	2	4	1	2	5	5	1	2	2	1	5	3	1	5	5	1	1	2	2	1	5	2	5	5	1

Source: The Author (2017)

The objective of understanding the requirements of customers and end users, according to

seven of the nine interviewees, is or should be the main item for the good development of projects. However, based on the answers presented, it is concluded that none of the companies has this criterion sufficiently developed, in relation to the others, to meet it as a priority.

In other words, although they understand that analyzing these requirements and understanding them is the best way to achieve good results, companies do not have, in their structure, the necessary balance to make this item the most prepared.

It is then possible to understand the reason why the client was cited as responsible for problems at all stages of project development. It is, therefore, one of the needs that any designed system must solve.

On the other hand, the objective of reducing time and costs, which can be understood as a result of the first four, was also mentioned by most companies as the lowest priority, but based on the results, it was possible to identify that companies, in fact, are more prepared for this item.

These two analyses are indications that the companies, through their representatives, have a vision of what should be done, but their formation and the conditions of the market, the They encourage them to prepare for objectives that could be a consequence of a better structuring of their processes. This item had the worst results among the companies interviewed.

In addition, the combination of technology with integration, collaboration and simultaneity between those involved in the various activities is one of the aspects to obtain better results in the enterprises.

The results presented by the interviewed companies exceeded expectations, since the companies are small, most of them without the implementation of process control systems, they had their results converging to the management of their activities, some of them almost at an optimized level.

This result may indicate that small companies have collaboration as their main market strategy, since the integration of diversified companies produces a mix of services that reaches various types of enterprises, from renovations to the construction of more elaborate structures.

CONCLUSIONS AND RECOMMENDATIONS

The research was based on an interview protocol that was validated by the pilot case study. In the same study, it can be concluded that some of the questions needed adjustments to obtain results under conditions of analysis in the other interviews.

The first result reveals that most small companies do not feel the need to obtain quality certifications in relation to their processes. This can be understood, according to the authors [Ugwu et al. (2000); Whyte et al. (2002); and Aouad (2010)] due to the lack of long-term planning.

According to these authors, due to the possible fluctuations, these companies do not usually make medium and long-term investments and, therefore, end up using only their own knowledge bases for the development of the companies.

The result of this lack of long-term planning is evidenced in the use of informal processes within companies and, therefore, a lack of self-knowledge regarding their strengths and weaknesses, according to analyses of the characteristics of companies.

This great variation in maturity reflects difficulties in the implementation of Simultaneous Engineering concepts, since companies must initially balance their difficulties to then implement new management concepts.

Another factor that prevents the use of Concurrent Engineering in these companies is the problems with customers. Since this is the main objective of HE, it could not be among the main causes of problems in projects, from their conception to their completion. Admitting that the processes used by companies are not yet sufficiently capable of involving and delivering the needs of customers in the processes is the first step to using the methodology.

Another factor that was also raised by several companies is the relationship with the approvals of projects in public agencies, whether due to bureaucracy or the frequent changes that are made in the legislation, companies continue to face the rules and have difficulties in the development of their projects.

This issue, unlike the survey of customer requirements, is not yet supported by computational tools (except protocol monitoring tools) that provide a more collaborative relationship between the public and private sectors.

Still on the issue of the maturity of the companies, it was possible to understand that there is a relationship between technology and business maturity, since the managerial levels of the companies were strongly influenced at the time when the data related to technology were removed from the analyses.

In architecture firms, a favorable ratio was perceived in relation to the use of technology, which means that these firms are positively influenced by the tools they use, and without them firms tend to lose control over management in all other indexes surveyed.

However, engineering and construction companies showed an inverse relationship, i.e., the technological tools used are influencing management levels downwards, which indicates a low maturity in relation to the use of technology in almost all companies.

REFERENCES

1. Anumba, C. J., Kamara, J. M., & Cutting-Decelle, A. F. (2007). Introduction to concurrent engineering in construction. *Concurrent engineering in construction projects*, 1-9. Taylor and Francis Books Ltda.

2. Aouda, G., & Arayici, Y. (2010). Requirements Engineering for computer integrated environments in construction. Wiley-Blackwell.

3. Chen, Y., & Kamara, J. (2008). The mechanisms of information communication on construction sites. *FORUM EJournal*, Newcastle University.

4. Chibinski, M. (2012). Modelo de planejamento baseado no conceito do Last Planner como apoio à implementação da Lean Construction em obras de edificações. Dissertação de mestrado, Universidade Tecnológica Federal do Paraná, Curitiba, Paraná.

5. Elsevier B. V. (2017). Scopus The most comprehensive database of peer-reviewed research. Recuperado de https://www.elsevier.com/solutions/scopus

6. Gil, A. C. (2016). *Como elaborar projetos de pesquisa* (5ª ed.). Editora Atlas.

7. Khalfan, M. M. A. (2001). Benchmarking and readiness assessment for concurrent engineering in construction (BEACON). Tese de doutorado, Universidade de Loughborough, UK.

8. Khalfan, M. M. A., Anumba, C. J., & Carrillo, P. M. (2007). Readiness assessment for concurrent engineering in construction. *Concurrent engineering in construction projects*, 30-56. Taylor and Francis Books Ltda.

9. Lakka, A., Sulankivi, K., & Luedke, M. (2001). Measuring the benefits of CE-environment in multi-partner projects. *Symposium Report on the 2nd Worldwide ECCE Symposium*. RIL - Association of Finish Civil Engineers; VTT - Technical Research Centre of Finland, Building Technology, Espoo, Finland.

10. Love, P. E. D., Gunasekaran, A., & Li, H. (1998). Concurrent engineering: a strategy for procuring construction projects. *International Journal of Project Management*, 16(6), 375-383.

11. Pretti, S. M. (2013). Engenharia simultânea em construtoras-incorporadoras: uma análise de maturidade. Dissertação de mestrado, Universidade Federal do Espírito Santo, Vitória, Espírito Santo.

12. Silva, O. R. C. (2013). Engenharia simultânea na produção de edifícios de múltiplos pavimentos: cenário potencial na região metropolitana de Curitiba. Dissertação de mestrado, Universidade Tecnológica Federal do Paraná, Curitiba, Paraná.

13. Ugwu, O. O., Anumba, C. J., Newnham, L., & Thorpe, A. (2000). The application of DAI in the construction industry. *Construction Information Technology*. Reykjavik, Iceland.

14. Whyte, J., Bouchlaghem, D., & Thorpe, T. (2002). IT implementation in the construction organization. *Engineering, Construction and Architectural Management*, 9, 371-377.

15. Winner, I. R., Pennel, J. P., Bertrand, H. E., & Slusarczuk, M. M. G. (1988). The role of concurrent engineering in weapons system acquisition. *IDA Report R-338*, Institute for Defense Analyses, Alexandria, VA, EUA.

16. Yin, R. K. (2010). *Estudo de Caso: Planejamento e Métodos* (4ª ed.). Editora Bookman.