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Improving the Performance of Construction Projects by Employing Concurrent Engineering

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Abstract

In a construction project, various types of contractual agreements are applied. In many of these contract types the different parties, such as owners, architectural and engineering consultants, contractors, and users, are involved in different phase of project. This involvement of many stakeholders at different phases usually result dissatisfaction by these parties. Concurrent engineering concept can provide an answer to undesirable outcomes, such as increased project duration and reduced customer satisfaction, by providing an open platform for all involved stakeholders. In this study, the positive effects of concurrent engineering in construction projects from architects' point of view are investigated. A questionnaire survey was carried out among architects in Turkish industry. The sample of the study consist 97 respondents and it is a pilotstudie. The most likely benefit from applying the concurrent engineering is the reduction in project duration followed by reduced project cost overruns. The most important stakeholder for the success of project is the owner be either his/her involvement in preparation of specifications and plans or his/her interventions during construction. The difficulties encountered by the respondents in their previous projects and their relations to the expected project outcomes are also studied.

Keywords: Owner, Subcontractors, Customer satisfaction, Quality, Suppliers

Eşzamanlı Mühendislik İstihdamının İnşaat Projelerinin Performansına Etkisi

Öz

İnşaat projelerinde çeşitli sözleşmeler uygulanmaktadır. Bu sözleşme türlerinin çoğunda iş sahipleri, mimarlar, mühendisler ve müteahhitler gibi farklı taraflar projenin farklı aşamalarına dahil olurlar. Bir çok paydaşın farklı aşamalardaki dahiliyeti ise genelde bu paydaşların memnuniyetsizliği ile sonuçlanır. Eşzamanlı mühendislik kavramı tüm paydaşlar için açık bir platform sunarak, artan proje süresi ve yetersiz müşteri memnuniyeti gibi istenmeyen sonuçlar için bir çözüm sunabilir. Bu çalışmada, eş zamanlı mühendisliğin inşaat projelerine olumlu etkisi, mimarların bakış açısından araştırılmıştır. Türk inşaat endüstrisinde çalışan mimarlara bir anket uygulanmıştır. Çalışmanın örneklem sayısı 97 kişiden oluşup, pilot çalışma niteliğindedir. Eş zamanlı mühendisliğin en önemli faydası proje süresinde ve maliyetinde azalma olarak tespit edilmiştir. En önemli paydaş olarak, gerek plan ve şartnamelerin hazırlanmasına katkısı gerekse inşaat süresince bulunduğu müdahalelerle iş sahibi olarak tespit edilmiştir.

Anahtar Kelimeler: İş sahibi, Taşeronlar, Müşteri memnuniyeti, Kalite, Tedarikçiler

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1. INTRODUCTION

Concurrent Engineering (CE) is a systematic approach for the simultaneous and integrated design of products, process, and support services to fulfill the requirements of quality, cost, time, and user needs [1-10]. The means of CE were studied over a wide range in the literature [11-13]. Further developments have since been realized in the CE technique, and the methodology has been used in the fields of apparel [14], automotive industry [15], product development [16], chemical [17], and construction [4-12].

CE was described as tactical when the tools and techniques used and the organizational structure of the firm are considered. It was described as strategic when each and every phase of product is considered in parallel. CE was described as objective when the improvements of work performance are considered [13]. CE is affected by many factors, such as, parallel tasks, cross-functional teams, multi-disciplinary work groups, used quality control techniques (for example, QFD: Quality Function Deployment, SPC: Statistical Process Control, Taguchi, DFM: Design for Manufacture, DFA: Design for Assembly, and DFX: Design for Excellence), integrated Computer Aided Engineering (CAE), and design techniques for production [5,18-20]. In another study, however, the forces that affect CE were defined as tasks, teams, techniques, technology, time, and tools leading to “7T concept” [21]. Prasad [21,22] also placed CE on 8 basic principles, such as, early problem discovery, early decision-making approach, the systematic structuring of work, the spirit of teamwork, benefiting from information technologies, common understanding, a sense of ownership, and continuity of purpose.

Within the framework of concurrent engineering definition, the applicability of the concept in the Turkish construction sector and the tactic, strategic and objective perspectives of architects needed to be identified. The difficulties encountered by the architects are important to proceed in the construction process with the least hitches. The architects’ points of view are important because the process usually starts from them. In general, an owner wants something to be built then s/he consults usually with an architect for concept generation. An architect also involves in various stages of construction at different levels. Integration between many disciplines is crucial to get the construction jobs done properly. If the patterns in this process were identified correctly, then any bottlenecks and good applications could become obvious and these efforts in turn aid the construction process.

2. MATERIAL AND METHODS

A questionnaire was prepared and distributed to various regions of Turkey. The results from the architects are returned in paper form. In total, 97 (ninety-seven) questionnaires were returned. The answers are evaluated in basic statistical values, namely arithmetic averages and standard deviations. Since the main purpose is to identify difficulties or opportunities in getting better application of concurrent engineering, these metrics should well serve the purpose. These should provide the base for further investigations.

The questions are divided into two major groups; the first group contains the demographics and main attributes of the respondents; the second group is oriented to answer concurrent engineering issues. The statistical evaluations are also aimed to find any possible relationships between the attributes of respondents and their attitudes about concurrent engineering. This is done by grouping the answers for the question at a time and calculating the statistical values. The survey participants are finally asked to rank the disruptions caused by not implementing concurrent engineering from 1(one) as the most likely to 5(five) as the least likely.

3. GENERAL OBSERVATIONS

In this part of the study, the results will be evaluated.

When the question of “which of the following stakeholders have you had in your realized projects during the design phase of projects” is asked, the evaluation of answers is given in Table 1.

Table 1. The attended stakeholders during the design phase of the previous realized projects

Stakeholders	f (Yes)	St. Dev.
Owner	82	0,36
Civil Engineers	67	0,46
Users	65	0,47
Mechanical Engineers	39	0,49
Electrical Engineers	39	0,49
Subcontractors	38	0,49
Material Providers (Suppliers)	27	0,45
Occupational Health and Safety Specialist	8	0,28
Apartment / Complex Manager	5	0,22
Other	3	0,17

From Table 1, it is seen that in the design timeframe, architects are contacting many disciplines, as it should be. Owners and civil engineers are main players in the design process along with the architects. The role of customers and users may need a clarification in the table. In some projects, the land developer and users could be different such as retail stores and shopping malls.

When the question of "how many times the meetings were made with stakeholders in the design process of your previous projects" was asked, their responses were concluded as follows; once a week (44/97= %45); once in every two weeks (23/97= %24); during startup of design phase (16/97= %17); once during design phase (11/97= %11); there is no meeting (3/97= %3). Of course any two projects and their development could not be the same. Some projects are complex therefore requiring inputs from stakeholders every now and then. Meanwhile some projects are simple thus little inputs suffice. Therefore the given ratios essentially reflect the work undertaken by the architects. Since design process can be a tedious one it may require several changes back and forth between disciplines and stakeholders.

Following the question about the number of meeting during design process the surveyed people are asked about the participated groups in those meetings.

The Table 2 presents the participation ratios of some groups to design decision meetings. At the top row of the table, the total numbers of meetings are given as the same in the previous paragraph. The answers are broken down according to the type participated group, such as owner, civil engineer, mechanical engineers, and so. The bold numbers are the counted answers. These numbers are divided both to the number in each group and to the total answer number. The first percentage calculation is done considering the group answer while the percentage calculations in italic at the bottom rows are done considering whole questionnaire results (all 97 respondents' answers). According to Table 2 in weekly meetings, most of time the owner participates. Similarly in meetings, which held in every two weeks, mostly owners, civil engineers, and users participate. The owner mostly exists in the meeting regardless of how many times the meetings are held. According to the table, mechanical and electrical engineers participate about the same amount. An interesting point surfaces when we look at the mechanical and electrical engineers. The participation of these engineering groups are very high in weekly meetings but their participations become much less in other cases. The same can also be said about the participation of subcontractors.

When the question of "do you experience a demand for project modification during the implementation phase frequently" is asked, the results are obtained as follows: No, never happens: %5 (5/97); Yes, very rare: %18 (17/97); Yes, sometimes: %53 (52/97); Yes, very often: %24 (23/97). The requests for project changes after the design stage is completed are not unusual. These requests can be instigated from various reasons, such as soil conditions and unavailability of specified material.

Table 2. The major participated groups to design decision meetings

	Once a week (44/97=%45)	**Once in every two weeks** (23/97=%24)	**During startup of design phase** (16/97=%17)	**Once during design phase** (11/97=%11)	**There is no meeting** (3/97=%3)
Owner	**36** *(36/97=%37)*	**19** *(19/97=%20)*	**16** *(16/97=%16)*	**9** *(9/97=%9)*	**2** *(2/97=%2)*
Civil Engineer	**30** *(30/97=%31)*	**16** *(16/97=%16)*	**10** *(10/97=%10)*	**9** *(9/97=%9)*	**2** *(2/97=%2)*
Customers / Users	**34** *(34/97=%35)*	**13** *(13/97=%13)*	**11** *(11/97=%11)*	**7** *(7/97=%7)*	**0** *(0/97=%0)*
Mechanical Engineers	**18** *(18/97=%19)*	**7** *(7/97=%7)*	**6** *(6/97=%6)*	**6** *(6/97=%6)*	**2** *(2/97=%2)*
Electrical Engineers	**18** *(18/97=%19)*	**7** *(7/97=%7)*	**7** *(7/97=%7)*	**5** *(5/97=%5)*	**2** *(2/97=%2)*
Subcontractor	**20** *(20/97=%21)*	**8** *(8/97=%8)*	**7** *(7/97=%7)*	**2** *(2/97=%2)*	**1** *(1/97=%1)*

The respondents are asked the question of "do you experience changes that have been made without informing you in the project during the implementation." The answers are as follows: No, never happens: %18 (17/97); Yes, very rare: %30 (29/97); Yes, sometimes: %38 (37/97); Yes, very often: %14 (14/97). These results indicate that changes to the project happen without notifying the architect. If we consider these results along with the previous question, we see that even the requests for changes occur very frequently, the implemented changes without notification do occur less frequently.

Following the previous questions, the subsequent question of "when you notice that your project is being implemented with some changes, what justification is given (you may select more than one)" is asked. The choices are arranged according to the calculated values of "yes" responses:

- ✓ (77) Request for changes by the owner,
- ✓ (37) Inapplicability of architectural details by the subcontractor,
- ✓ (24) The architectural design with the static project mismatch,
- ✓ (21) Unavailability of a material given in architectural plans,
- ✓ (17) The architectural plan does not contain enough detail,
- ✓ (16) Details in the architectural plans are vague,
- ✓ (11) The architectural design with the mechanical project mismatch,
- ✓ (10) The architectural design with the electrical project mismatch.

These answers indicate that the participation of owner in design phase and clarifying many grey areas during the preparation of plans are important to avoid subsequent changes during implementation as much as possible. Actually who requests the changes are somewhat related to the percentage of participants during the design phase. For example, owner participation is %85 in design phase (see Table 1) and %79 percent change orders originated from the owner. Similar things can be said about civil engineering, and subcontractors.

The survey participants are finally asked to rank the disruptions caused by not implementing concurrent engineering from 1(one) as the most likely to 5(five) as the least likely. The results are given in Table 3.

The letters next to the choices are showing the positions of choices in the questionnaire. According to the results in Table 3, the most likely outcomes are the increase in the project and the increase in the project cost. Reduced customer satisfaction is the least likely outcome according to the results.

Table 3. Ranking the outcomes resulted by not implementing the concurrent engineering

	Average	St. Dev.
Increase in the project duration	2.45	1.24
Increase in the project cost	2.82	1.44
Decreased level of capacity and competitiveness of the firm	3.07	1.34
Lower quality production	3.12	1.48
Reduced customer satisfaction	3.53	1.36

4. RESULTS RELATED TO CONCURRENT ENGINEERING CONCEPTS

In this section, the questionnaire results are analyzed according to the expected outcomes if the concurrent engineering concepts are employed. The outcome of a project can be affected by many variables. The studied factors in this study are; (i) the frequency of meetings during design stage, (ii) implemented changes in design specifications, (iii) the activities performed by the respondents in their previous projects, and (iv) the difficulties encountered by the respondents in their previous projects.

4.1. The Relationships Between the Likely Outcomes of Projects and Frequency of Meetings During Design Stage

Figure 1 shows the effects of the frequency of meetings during design phase on the likelihoods of outputs resulted by not implementing the concurrent engineering. As seen, the project duration is likely to increase if meeting are less frequent. The project cost, however, tends to decrease with less number of held meetings during design. More meeting means that many bottlenecks are resolved during design so that problems are less occurred during the implementation hence less likely for an increase in project duration. There is sharp contrast between choice “e” and choice “d”. Since no logical explanation could be given for these behaviors, better clarifications are left to future studies on this issue.

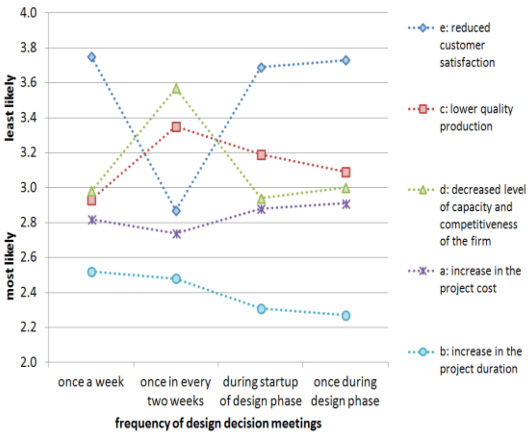

Figure 1. The relationship between frequency of design decision meetings and outcomes of projects

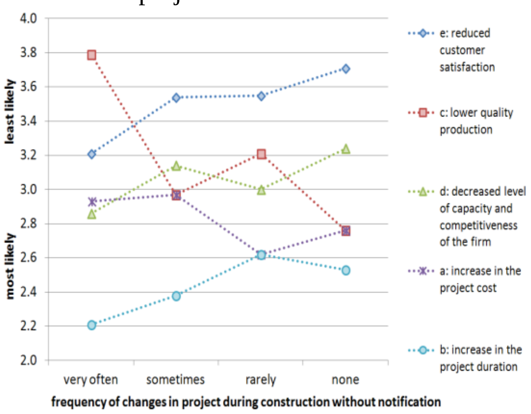

Figure 2. The relationship between frequency of change demand during construction and project outcomes

From Figure 2 it is seen that an increase the project cost and duration behave in opposite directions. For example, if there is no demand for a change during construction then project cost is less likely to increase while project duration is more likely to increase. Additionally, in other cases for frequency for change demands during construction there are opposite behaviors for these two outcomes.

From Figure 2, the frequency for change demands during construction does not have a pronounced effect on quality and competitiveness. It is interesting to note that very often made demands for changes during construction is likely to increase project duration and less likely to an increase in project cost. If the choice “none” is put aside, it can be said that the less demand for change the less likelihood for an increase in project duration. But the less likelihood of an increase in project duration comes with a price; the more likelihood of an increase in project duration. The best solution could be interacting with other stakeholders only when needed which means change demand should be only at “sometimes” thus the output results with more customer satisfaction. From other point of view, the intervention during construction should only be when it is really necessary. The possible reasons for a change demand but not limited to are; owner request, production and technological requirements, mismatches between different project blueprints, and insufficiency in some project plans.

Figure 3. The relationship between frequency of changes in project during construction without notification and project outcomes

Having very frequent changes in project during construction without notification means there has been very little interaction or not enough thinking before construction or during design phase (see Figure 3). If all the possible issues are considered before construction begins then the requests for changes in project can be minimized. Frequent changes without notification can easily result reduced customer satisfaction along with an increase in project duration. One positive effect could be that the construction have less likely of low quality production.

4.2. The Relationships Between the Likely Outcomes of Projects and Implemented Changes in Design Specifications

In this section, the relationships between the likely outcomes when the concurrent engineering concepts are not applied and implemented changes in design specifications are given. For this analysis, the data is arranged in such a way that the outcomes related to concurrent engineering applications are sorted according to their values, namely from 1 to 5 for each and every case and the arithmetic means for those groups are calculated for all choices. The Figure 4 shows the results for each choice in the question of likelihood of an output if CE is not implemented.

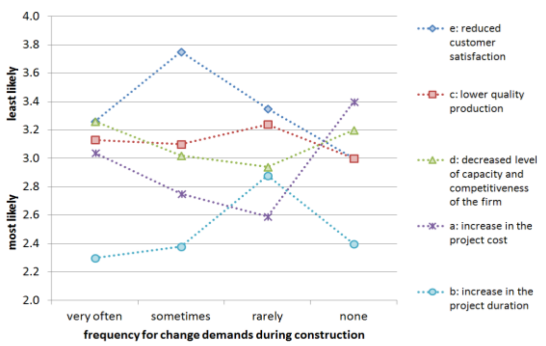

Figure 4. The relations between the likely outcomes resulted by not implementing concurrent engineering and the reasons for changes in design specifications

Incompatibility between the mechanical and mechanical with electrical plans and architectural plans greatly affects the customer satisfaction as the most likely cause. The causes for lower quality production may most likely stem from not having enough details in architectural plans, having incompatibility between the mechanical and architectural plans and inapplicability of architectural details by the subcontractor. The incompatibilities between the mechanical and electrical and architectural plans tend to have the similar effects on the outputs. Decreased level of capacity and competitiveness of the contractor firm is largely affected by request of the owner for a change and also by the unavailability of the material given in architectural plans.

The vagueness of details in architectural details, unavailability of the material specified in architectural plans, and incompatibility between the civil engineering and architectural plans are more likely to cause an increase in the project cost. The project duration is likely to increase because of the inapplicability of architectural details by the subcontractor, incompatibility between the civil engineering and architectural plans and vagueness of details in architectural plans. In other words, it can be said that vagueness of details in architectural plans likely to cause an increase in the project cost and duration. The unavailability of material specified in architectural plans likely to cause decreased level of capacity and competitiveness of the firm.

4.3. The Relationships Between the Activities Performed by the Respondents in Their Previous Projects and the Disruptions Caused by not Implementing Concurrent Engineering

The respondents are asked about which activities they performed in their previous projects. The results are given in Table 4.

According to Table 4, respondents mostly performed “the minimization of design changes before construction” and “adoption of a collaborative form of business” in their previous projects. In fact, the minimization of design changes before construction can be made possible by adopting a collaboration of various disciplines as seen from Table 4. The least performed activities are special management functions as shown in Table 4. These least performed activities, such as “b”, “c”, and “g” are generally related to managerial or organization structure. The changes in managerial structure are more radical than applying small steps toward concurrent engineering. In other words, there may be no need for formal and radical changes in managerial structure to appropriately apply concurrent engineering concepts.

The results about the activities performed by the respondents in their previous projects given in Table 4 reflect the general opinions of respondents. The relationships between the activities performed by the respondents in their previous projects and the outputs resulted by not implementing concurrent engineering are also investigated. For this purpose, the questionnaire results are grouped according to answers (0:’no’; 1:’yes’) in each choice for the question of efforts spent on previous projects. Then again for the "yes" group the arithmetic averages for the outputs caused by not implementing CE are calculated. The results are given in Figure 5.

According to Figure 5, the outputs resulted by not implementing CE are about in the same order as in Table 4. The increase in the project duration is the most likely and reduced customer satisfaction is the least likely output resulted by not implementing the CE. However, these outputs are in differing degrees are affected by the efforts spent in previous projects. The most considerable changes are observed about the choices of “lower quality production” and “decreased level of capacity and competitiveness of the firm”.

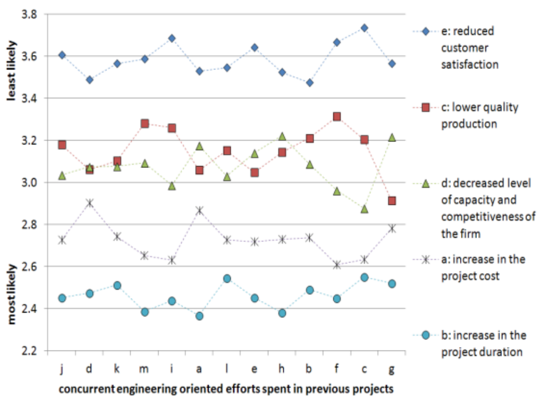

Figure 5. The relationship between efforts spent in previous projects and project outcomes

The most probable outcome is the increase in the project duration as shown in Table 4. This outcome is, however, aggravated by some efforts, such as “m: lessons learnt”, “a: leader profile to promote managerial structure” and “h: development of computer based systems”, that seem more important than others. As an another example for those more important factors than others, “m”, “i”, “f” and “c” can be mentioned for the increase in the project cost outcome.

There is also another way to see the data in Figure 5 for possible improvements. For example, customer satisfaction is lessened by focusing on choices of “i: using new materials and technologies for the success of design and construction”; “f: creation of multi-disciplinary, cross-functional, and continuously-learning teams to bear full responsibility of new products from conceptualizing to manufacturing”; and “c: benchmarking the design and construction implementations of the last project or recent projects”.

Table 4. Performed activities in previous projects

		f of “YES”	St.Dev. of “YES”
j	The design changes before manufacturing/construction were minimized?	84	0,34
d	A collaborative form of business was adopted?	82	0,36
k	Activities of various disciplines involved in the project were integrated?	78	0,40
m	Processes to be used in product development projects were developed along with the lessons learned from previous phases and experiences?	75	0,42
i	For the success of design and manufacturing/construction, new materials and technologies were used?	73	0,43
a	A leader profile that provides the foundation and support for a change in the managerial structure was created?	68	0,46
l	Strategic relationships with material and component suppliers and subcontractors were established?	64	0,47
e	To manage the project, a general framework for concurrency was developed?	64	0,48
h	For the success of design and construction stages, appropriate computer-based systems (such as CAD / CAE / CAM software) were developed?	63	0,48
b	A preparatory work was included to understand and persuade this change in managerial structure?	57	0,49
f	To bear full responsibility of new products from conceptualizing to manufacturing, multi-disciplinary, cross-functional, and continuously-learning teams were created?	51	0,50
c	The design and construction implementations of the last project or recent projects were benchmarked based on competition?	49	0,50
g	To ensure parallelism and overlapping in design and construction activities, modern project management techniques which are based on POCCC (Planning, Organization, Coordination, Command, and Control) management functions were utilized?	46	0,50

The data in the figure is also commented as follows: Let us take choice "i" (*for the success of design and manufacturing/construction, new materials and technologies were used: Yes{1}/No{0}*) as an example. Spending less effort for this choice result reduced customer satisfaction quite probably. Meanwhile spending more effort for this choice results reduced customer satisfaction to be less likely. Thus it can be said that for more customer satisfaction, more efforts should be spent for this choice. In short, the efforts which cause reduced customer satisfaction most probably should be lessened. As an another example let us take choice "j" (*The design changes before manufacturing/construction were minimized: Yes {1}/No{0}*). As expected more efforts for this choice should cause less likelihood for reduced customer satisfaction. The results are found to be along this expectation.

4.4. The relationships between the difficulties encountered by the respondents in their previous projects and the disruptions caused by not implementing Concurrent Engineering

The best results can be achieved by focusing on the choices with likelihood is sorted from most to least. In some choices the results of less/little likelihoods and most/quite likelihoods are overlapping. Since these choices do not provide a clear picture of what should be done, these choices should be left aside. For example let us consider choice "i" (*for the success of design and manufacturing /construction, new materials and technologies were used: Yes{1}/No{0}*) and "m" (*processes to be used in product development projects were developed along with the lessons learned from previous phases and experiences: Yes{1}/No{0}*). If efforts were spent about them, there is no much difference for a change in quality production. Since there are thirteen choices as efforts performed in the previous projects more discussion can be done related to other outputs resulted by not implementing concurrent engineering.

The respondents are asked about the difficulties encountered during the implementation of concurrent engineering. The choices and results are given in Table 5.

Table 5 shows the possible difficulties encountered by the respondents while implementing the concurrent engineering. According to the table, the most important factor is the insufficient knowledge about the concurrent engineering against the implementation of CE. Hurdles related to teams and stakeholders are also present challenges in various degrees for the application of concurrent engineering.

The effects of these difficulties on the outcomes resulted by not implementing concurrent engineering is also investigated. The questionnaire results are grouped according to answers (from 1:'least important' to 5:'most important') in each choice for the question of difficulties encountered during the possible implementation of concurrent engineering. Then for each group the arithmetic averages for the outputs caused by not implementing CE are calculated. The results are given in Figure 6.

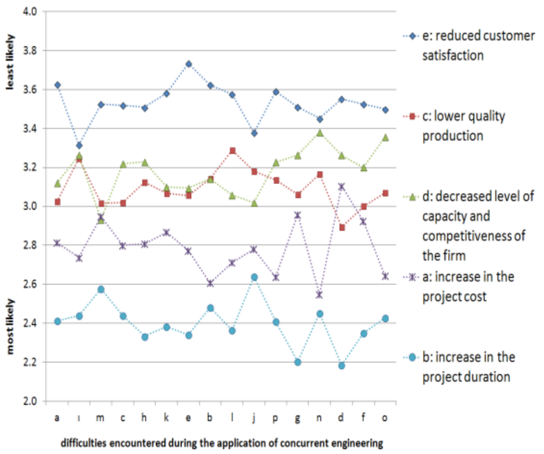

Figure 6. The relationship between difficulties encountered during the application of CE and project outcomes

Table 5. Ranking the difficulties encountered during the implementation of Concurrent Engineering according to importance: (1: least important; 5: most important)

		Average	St. Dev.
a	Insufficient knowledge about concurrent engineering concept	4.10	1.31
i	Lack of teamwork	3.75	1.26
m	Inadequacies of employees (skills, knowledge, personality, honesty, performance, and so on.)	3.69	1.26
c	In practice, the presence of a multi-disciplinary and transient organizational structure	3.62	1.10
h	Lack of participation of professional groups, which will be involved in implementation, to the design team as a result of separation of design and manufacturing phases in projects	3.62	1.19
k	Non-developed culture of information sharing and ideas between stakeholders in concurrent engineering	3.61	1.12
e	Consistence of the performed work from the successive and inter-dependent tasks	3.58	1.22
b	The lack of support from top management	3.58	1.28
l	Attitudes and behavior of owner (such as, changes in production lineage and specification, and failure in doing timely payments)	3.53	1.28
j	Uninformed and sudden changes in the project teams	3.44	1.27
p	Absence of a common database that include important decisions about the projects and that the factors affecting these decisions	3.38	1.28
g	The lack of participation of the customer to the design process	3.33	1.30
n	Mistrust, fear and the habit of not saying about the mistakes among the people who worked in the project during both the design and the construction phases	3.20	1.36
d	The production type of organization (mass production or custom-made production and such)	3.18	1.23
f	Insufficient use of computer technology in design, manufacturing, and sharing all kinds of information	3.16	1.28
o	The cultural problems among the professional groups of the project	2.84	1.31

According to Figure 6, customer dissatisfaction can be reduced by focusing on choice “e: consistence of the performed work from the successive and inter-dependent tasks”. On the other hand, lack of teamwork (choice i) and uninformed and sudden changes in the project teams (choice j) have an adverse effect on customer satisfaction.

The increase in project duration becomes more likely if choices “g” and “d” are stressed out. These choices are the lack of participation of the customer to the design process and the production type of organization (mass production or custom-made production and such). On the other hand, paying more attention to choices “m” and “j” may result positive impact on project duration. These choices are inadequacies of employees (skills, knowledge, personality, honesty, performance, and so on) and uninformed and sudden changes in the project teams.

For the purpose of completing the project within the budget, from the figure it can be said that: the difficulties of choices “m”, “g”, and “d” should be tackled. On the other hand, if the difficulties of choices “b”, “p”, “n”, and “o” are not given enough importance then the increase in project cost becomes more likely.

These analyses should provide the emphasis areas to achieve the improvements toward the desired output, such as, reduced project time or lowered project cost.

5. CONCLUSIONS

Concurrent Engineering provides the necessary design and production details about all requirements in construction works. Therefore, in this paper, concurrent engineering approach in terms of architects' tactical, strategic and objective viewpoints are studied. According to the analysis results, inadequate top management support, inadequate staff training and team work, failure of the stakeholders involved in the process of project design decisions and the lack of effective exchange of information between departments precluded the use of CE in construction industry widely. In addition, it can be said that concurrent engineering approach should include owner, engineers, material producers, contractors, subcontractors and similar other sector representatives.

The overall result deduced from this study is that the construction companies do not have an adequate approach to concurrent engineering concepts. The many parties involved in the sector have adopted primarily the approaches to keep their existing places (statuesque). Starting from this point on, in future studies, a model, which helps to implement a concurrent engineering approach for the construction companies, will be prepared. Also in future studies, additional surveys among the professions other than architecture will be done. With that kind of information it could be possible to correlate the problem areas. For example an architect may see a weekly meeting is sufficient however for a contractor it may not be enough or a contractor may want to involve from the concept development phase. It can be said that the increased awareness about concurrent engineering in the sector with the experiences and the knowledge about existing practices help to improve on project outcomes such as, duration, budget and quality.

6. REFERENCES

1. Winner, R.I., 1988. The Role of Current Engineering in Weapons System Acquisition, Institute for Defence Analyses, Report R-388, December.
2. Cleetus, K.J., 1992. Definition of Concurrent Engineering. CERC (Concurrent Engineering Research Center) Technical Report Series, Research Notes, CERC-TR-92003, West Virginia University.
3. Anumba, C.J., Evbuomwan, N.F.O., 1997. Concurrent Engineering in Design-Build Projects. Construction Management and Economics, 15(3): 271-281.
4. Love, P., Gunasekaran, A., 1997. Concurrent Engineering in the Construction Industry, Concurrent Engineering: Research and Applications, 5(2): 155-162.
5. Brookes, N.J., Backhouse, C.J., 1998. Understanding CE Implementation: A Case-Study Approach, 36(11): 3035-3054.
6. Love, P., Gunasekaran, A., Li, H., 1998. Concurrent Engineering: A Strategy for Procuring Construction Projects. International Journal of Project Management, 16(6): 375-383.
7. Anumba, C. J., Baldwin, A. N., Bouchlaghem, D., Parasad, B., Cutting-Decelle, A. F., Dufau, J., Mommessin, M., 2000. Integrating Concurrent Engineering Concepts in a Steelwork Construction Project. Concurrent Engineering: Research and Applications, 8(3): 199-212.
8. Kamara, J.M., Anumba, C.J., Evbuomwan, N. F.O., 2000. Establishing and Processing Client Requirements-A Key Aspect Concurrent Engineering in Construction. Engineering, Construction and Architectural Management, 7(1): 15-28.
9. Khalfan, M.M.A., Anumba, C.J., Siemieniuch, C.E., Sinclair, M.A., 2001. Readiness Assessment of the Construction Supply Chain for Concurrent Engineering. European Journal of Purchasing & Supply Management, 7(2): 141-153.
10. Khalfan, M.M.A., Anumba, C.J., Carillo, P.M., 2001. Development of a Readiness Assessment

Model for Concurrent Engineering in Construction. Benchmarking: An International Journal. 8(3): 223-239.

11. De la Garza, J. M., Alcantara, P., Jr., Kapoor, M. and Ramesh, P.S., 1994. Value of Concurrent Engineering for A/E/C Industry. J. Manage. Eng., 10(3): 46–55.

12. Sekerci, B., 2008. Eszamanlı Muhendislik Kavramının Turk Insaat Sektorunde Uygulanabilirlik Duzeyinin Irdelenmesi, Cukurova Universitesi Fen Bilimleri Enstitusu Yuksek Lisans Tezi (Turkish), 142p, M.S. Thesis, Adana, Turkey.

13. Shouke, C., Zhuobin, W. and Jie, L. 2010. Comprehensive Evaluation for Construction Performance in Concurrent Engineering Environment. International Journal of Project Management, 28(7): 708-718.

14. Doris, H.K., Cynthia, R., Fay, Y.G., 2007. Concurrent Engineering for Product Development in Mass Customization for the Apparel Industry, International Journal of Operations & Production Management, 27: 627-649.

15. Sapuan, S.M., Osman, M.R., Nukman, Y., 2006. State of the Art of the Concurrent Engineering Technique in the Automotive Industry, Journal of Engineering Design, 17: 143-157.

16. Hong, Suk-Ki and Marc, J.S., 2000. Balancing Concurrent Engineering Environmental Factors for Improved Product Development Performance, International Journal of Production Research, 38: 1779-1800.

17. Paulien, M.H. and Margot, P.C.W., 2000. A Concurrent Engineering Approach to Chemical Process Design, International Journal of Production Economics, 64: 311-318.

18. Meyer, B., 1990. Sequential and Concurrent Object-Oriented Programming, Technology of Object-Oriented Languages and Systems, 17-28.

19. Shina, S.G., 1991. Concurrent Engineering: New Rules for World Class Companies, IEEE Spectrum, 28(7): 22-26.

20. Yang Ching-Chow, Chen Shun-Hsing, Shiau Jiun-Yan., 2006. A DFX and Concurrent Engineering Model for the Establishment of a New Department in a University, International Journal of Production Economics, 107: 179-189.

21. Prasad, B., 1996. Concurrent Engineering Fundamentals: Integrated Product and Process Organizations, Volume I., 478p, Prentice Hall PTR, New Jersey.

22. Erdiş, E., Coskun, H., Genc, O., 2015. Architects' View of Concurrent Engineering in Construction Projects. International Journal of Thales Engineering Sciences, 1:1, 1-15.