METU JFA 2016/1
(33:1) *1-20*

DOI: 10.4305/METU.JFA.2016.1.1

LEAN DESIGN MANAGEMENT – AN EVALUATION OF WASTE ITEMS FOR ARCHITECTURAL DESIGN PROCESS (1)

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Received: 08.10.2015**; Final Text:** 26.02.2016

Keywords: Lean thinking; waste; architectural design process; lean design; efficiency.

1. This research paper is based on a thesis study conducted by Salih Kaan Mazlum at Middle East Technical University Building Science Graduate Program.

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INTRODUCTION

One of major issues in the construction industry is waste and its possible preventions. There are ongoing efforts in other sectors for reduction of waste. However, the construction industry has a very traditional way of working and new ideas of production have difficulties in penetrating existing work processes. This is particularly due to the distinctive nature of design and production relationships in comparison with other industries. Lean principles may play an important role for constructing the base for waste minimization activities in construction. The concept of Lean Production is based on elimination of waste as the main focus for process improvement. Providing continuous and efficient information flow is its pivotal practice for advancement of supervision system. The adaptation of lean production philosophy for construction industry requires a special effort when compared to other production industries.

Most of the earlier studies focused on the waste resulting from actual construction processes and studied these as a case for improvement via lean principles (Lee et al., 1999). However, previous studies emphasize the strong influence of early design phases on the uncertainties and output quality of construction projects (Osmani et al., 2008). Design process is often discussed for its role at material waste generation/prevention. Lean thinking names all inefficiencies in the process as waste (Koskela, 1992). The number of decisions to be made in design, planning and construction phases for generating a product is significantly higher than other manufacturing sectors. Accordingly, it is considered that application of lean production philosophy in architectural design phase could be helpful for increasing the efficiency of the whole construction process. In this context, this study focuses on the lean waste items in architectural design processes.

The studies dealing with lean design and design management emphasizes the relationship between different unique tools and their impact over the efficiency of architectural design implementation (El. Reifi and Emmitt, 2013; Tribelsky and Sacks, 2011). However, there is a gap in lean literature focusing on increasing the efficiency of whole architectural design process. As the first step of developing a lean implementation framework for architectural design service, this research aims to contribute for filling the gap by determining lean waste items enhanced in the practice of architectural design and discuss of their impacts over different project value parameters and calculate the risk they pose. As a result it will be possible to specify the priorities of industry for achieving a lean implementation roadmap. It is considered that the increase in efficiency of design process will have positive effect over the value parameters of construction and whole project process accordingly.

For that purpose, the paper aims to determine lean design waste items and evaluate their impact over project value parameters. In this study, a preliminary literature review was conducted; two consecutive surveys were completed and finally statistical analyses of the findings were done along with the calculation of risk for each waste item. The academic contribution of this study is to present a list of architectural design waste items and evaluate their impact over different project value parameters. As a result, it is aimed to guide design industry for determining steps to be taken for increasing efficiency level of both design and production stages of construction projects.

Throughout the study the authors aimed to:

- Compile current wastes in design process,
- Group lean design waste items under 8 waste categories based on Ohno (1988) and Liker's (2004) work,
- Investigate frequency of occurrence, impact over cost, impact over duration and impact over quality parameters for each waste item,
- Find waste items that are highly influential on the reduction of project value,
- Seek if there is any significant difference of answers of architects from different professional backgrounds,
- Evaluate the impact of waste categories for different value parameters,
- Highlight the most effective waste items and their sources to be eliminated for increasing the efficiency of both design and construction phases,
- Determine the risk imposed by the waste item on the overall design process.

CONSTRUCTION WASTE AND LEAN THINKING

The term, construction waste, is used to refer to the waste, which arises from construction, renovation and demolition activities (Kofoworola and Gheewala, 2009) where excessive amount of material is used and damaged products arise (Roche and Hegarty, 2006). Koskela (1992) made the definition of waste as any inefficiency that results in the use of equipment, materials, labor or capital in larger quantities than those considered as necessary in the production of a building. It is more simply described as activities, resources, rules etc. which can be eliminated without reducing customer value (Osmani, 2012). Various stakeholders such as governments, practitioners and academics have been spending efforts for the global reduction of construction waste due to environmental concerns (Esin and Coşgun, 2007; Arditi et al., 1985). There is a large body of work on construction waste management focusing on material loss rather than "non-value adding work". There is a need in the field for more studies investigating non-value adding works in construction (Lu and Yuan, 2011). According to Polat and Ballard (2004), the Turkish construction industry greatly suffers from waste due to lack of lean thinking. In the literature, there is a consensus on the relationship between design and construction waste (Osmani et al., 2008; Gamage et al., 2009; Ordoñez and Rahe, 2013). It is revealed that a proximate of 33% of construction waste generated on-site is related to design directly or indirectly. On the contrary, there are not enough attempts to minimize the construction waste related with design activities.

There are considerable performance improvements achieved in various manufacturing industries with the increase in productivity in the last twenty years (Polat and Ballard, 2004). According to Lee et al. (1999), "Lean Production" is a new philosophy for production, which removes various types of waste in order to provide a continuous improvement. The measurement of waste is a reliable method for evaluating the effectiveness of a production system because it shows the areas of production that needs to be developed and enlightens main reasons for inefficiency. In comparison with traditional parameters to be measured, waste measures offer more effective way to manage the process due to its ability to model the operational costs properly and generate meaningful information for the personnel (Formoso et al., 2002).

The concept of Lean Production is a milestone in manufacturing industry, based on elimination of waste as the main focus for process improvement. Its origins are based on TQM (Total Quality Management) and Just in Time (JIT) philosophies in the 1950s, in Japan (Formoso et al., 2002).

Five principles were identified by Womack and Jones (1996) to present the basics of lean thinking:

1. Accurate specification of value together by client and producer for each product. Value stands for what client accepts to pay in return.
2. Identification of value stream for specific product. Demonstration of value adding, non value adding and unnecessary activities. Exclude non value adding unnecessary activities in short term, minimize non value adding activities in long term.
3. Push for value generation flow without any cut off in process.
4. Do not perform a work until required by next step of production. Let the client pull value from producer.
5. Seek perfection (provide continuous improvement).

The first step of starting the production has been seen as to look at the process from the customers' angle of view and determine what they expect in the end of the process. In this way, it is aimed to determine value adding and non-value adding activities. Using this method, Ohno (1988) identified and categorized 7 general categories of waste, which was improved by Liker (2004) by the addition of the 8th category. The list is as follows;

1. Overproduction: Producing more than required leading to overstaffing, storage and transportation costs. Causes significant

amount of resource to be tied up which otherwise could be used for value adding operations.

2. Waiting: All the time which is not spent for value-adding activities.
3. Transportation: Carrying works which does not add value to final product for customer.
4. Overprocessing: Unnecessary transactions involved in the process.
5. Motion: Any unnecessary movement performed by sources.
6. Inventory excess: Excessive amount of supply stored with respect to customer needs and value.
7. Defects: Deviation of products from customer requires or specification.
8. Unused Employee Creativity: This is a situation of not using the potential efficiently, which makes an organization to benefit less than possible.

Architectural design process has become a more difficult field due to sophistication of building projects and increasing demands of clients' with a shift from project completion to whole lifecycle issues (Nicholson and Naamani, 1992). The study conducted by El. Reifi and Emmitt (2013) shows that inefficiency in design stage rises up as deficiency during the procurement stage. In parallel, according to Sacks et al. (2009), the approach employed in the design process has effects over not only the design process but on the whole construction. Moreover, Koskela et al. (2002), indicated that design phase generally characterized as the major source of issues for following phases. High frequency of design changes - including client decision making - is the main reason behind the transmission of negative reflections, which squeezes the preparation of procurement and construction.

Possible developments progressed in design management can help to reduce the amount of waste produced both in design and construction of a project. Information modelling techniques are open to get adopted to contribute waste management strategies (Baldwin et al., 2007). All of the lean design management strategies should internalize the aim of maximizing the overall value for clients, end users and society with providing high level of performance (Emmitt et al., 2005). The reasons of rework are mostly associated with design development phase in a project which may be concluded with delay, budget over-runs and less value being delivered to the client. The other contributing phases were shown as design brief, concept design and technical design (El. Reifi and Emmitt, 2013). Moreover, last minute re-designs, inefficient flow of information, overly complex designs, problems regarding obtaining town planning permission and compliance with regulations had been shown as poor design management factors.

Unnecessary rework is addressed by Koskela et al. (2002) as an important waste type in construction design. Two main reasons are highlighted for unnecessary rework: first; design tasks are not always clarified and ordered efficiently at the beginning. Secondly, even if the order is well established, there are factors forcing the plan to get away from ideal range. As a result, design tasks generally suffer from lack of information. According to Josephson and Hammarlund (1999), the defects caused by design process form the largest category when measured by cost. Furthermore, it is indicated that the defects originated from lack of coordination between different disciplines constitute biggest category of design based defects. Tribelsky and Sacks (2011) claim that the waste can be reduced and value can be improved by design managers with focusing on the information flow and information share characteristics.

Research Design

The literature review on lean thinking and lean construction shows that the relationship between lean thinking and (architectural) design processes are overlooked despite their significance over the efficiency of actual construction processes. Observation on design industry has obviously shown that there are inefficiencies to be eliminated and the whole value of the project development process can be increased.

Increasing lean design maturity level is vital for increasing the efficiency of the whole construction process. The lean literature points at the first step, as the identification of inefficiencies standing as bottlenecks in architectural design process. The aim of this study is to investigate and determine "Lean Design Waste Items" and examine their frequency of occurrence and influence over value parameters of the project. By obtaining such information, it is predicted to have a "Lean Design Waste Item List" with influence magnitudes for each item. That is expected to be a pathfinder for the industry to understand its weak points and work for progress in such areas to increase the efficiency of whole construction industry.

As the first step for achieving lean production in architectural design processes, a series of "semi-structured interviews" were conducted to determine waste items. Each interviewee was presented with a brief on lean thinking and the list of "8 Waste Categories" based on the work of Ohno (1988) and Liker (2004) with simple examples to describe them. During the interviews the design professionals were requested to provide waste examples from their experience to fit in the categorization system presented earlier. Then, interviews were evaluated and sources of design inefficiencies were listed as 28 waste items and classified under "8 Waste Categories", which then became input for the next following step, namely, "Questionnaire". In the questionnaires, respondents were presented with waste items determined during the interviews and requested to provide their views on the probability of occurrence, effect over cost, effect over duration and effect over quality for each waste item.

The approach of grounded theory was internalized to base the results of the study directly on the opinions of professionals from the industry with minimum subjective contribution of researcher. By the term grounded theory, it is meant that a theory comes out from the data itself which has been systematically collected and analyzed via research process (Strauss and Corbin, 1998). There is a strong interrelationship between the data collection, data analysis and final theory trio in the structure of the method. There is no predefined theory in researcher's mind before beginning the study. Instead, the researcher specifies the area to begin the study and allows the theory to be manifested from the data. The argument is that the theory derived from the data is closer to the reality rather than the one derived by putting together an array of conceptual experience or only by fiction. Moreover, it is said that because the theories grounded from data are open to propose inner vision, increased understanding and sensible guide for further action (Strauss and Corbin, 1998).

For analytical purposes, there is a need for determining the risk value for each waste item discovered during the interviews. Risk is addressed as an uncertain outcome by Cretu et al. (2011) that means risk can both be understood as a threat or opportunity and it may both have negative and positive effects. According to Hillson and Hulett (2004), the risk concept is consisted up of two dimensions that can be described as uncertainty (specified as probability of occurrence) and the effect (specified as impact). The authors stated that the risk can be properly assessed by proper assessment of probability and impact of the event. Dumbravă and Iacob (2013) gave place to the mathematical equation as "R = I x P". Where "R" is standing risk value, "I" is for impact size and "P" is for probability.

By considering the possible outcomes and the uncertainty of waste items referred in this study, a considerable relationship can be established between them and risk concept. In short, an evaluation is seen possible to be made with involvement of both frequency of occurrence and impact values of waste items. At this point, it is not aimed to obtain absolute numbers about their probability or impact percentages, but the objective is to reach a rating among waste items over their risk value. As a result, it is intended to guide the industry for creating a meaningful roadmap for reaching a lean design process.

Preliminary Interviews

In order to obtain the input data required for questionnaire generation, a series of interviews were executed with professionals from Turkish architectural design sector. Main aim of the interviews was to reach a lean design waste items list. The waste concept referred in this section obviously internalizes the waste definition of lean thinking.

It was chosen to conduct the interviews with experienced and skilled professionals. Conducting interviews with a limited number of experts was preferred in this phase due to the necessity of:

- obtaining the opinions of qualified individuals from competent and relevant perspectives;
- covering the inefficiencies of design industry in depth;
- information providing about lean concept, its waste definition and 8 waste categories before having their opinions for adaptation; and
- clarifications for answers of open questions to be understood efficiently.

The phase was conducted by executing; semi-structured; two way communication involved; open-ended questioned; and non-linear interviews with the owners and managers of architectural design offices performing for at least 10 years in Çankaya province of Ankara, Turkey. Due to time limitation and busy schedule of possible respondents, the interviews were conducted in next step with 8 interested respondents out of total 23 reached.

8 waste categories with the design waste items expressed by the interviewees are shown in **Table 1**.

Frequency and Impact Evaluation Questionnaires

After the information about lean design waste items and their sources were obtained for each lean waste category, it was used as an input in the

1.Overproduction	
	Undelivered production
2.Defects / Correction	
	Production of defective technical drawings and details etc.
	Revision works according to data provided from other disciplines
	Explanation requirements (unfinished works)
	Architectural decision alterations
	Compliance to regulations
3.Waiting	
	Waiting for information from other disciplines
	Protracted previous works
	Late information from client
	Waiting for stationery, print and model works
	Discontinuation in the project
	Relationship problems with public administration
4.Motion	
	Works/actions performed for providing site information
	Works/actions performed for providing presentation - design materials
	Works/actions performed for providing reference technical information
	Inefficient meeting organizations
5.Inventory	
	Ineffective use of qualified source
	Work finished earlier than required
6.Overprocessing	
	Rework
	Low speed working
	Ineffective employee performance
	Unqualified data from other disciplines
	Ineffective – unnecessary information exchange
	High expectations from unqualified sources
	Incapability to have institutional habits
	Problems with client relations
7.Unused Employee Creativity	
	Unused employee creativity
8.Transportation	
	Unnecessary transportation processes

Table 1. Design waste items under 8 waste categories

configuration of the questionnaire. All of the interviews were evaluated and a list of 28 items for lean design wastes was reached with their sources.

The aim of the questionnaire is to reach architects actively working in the field and ask their opinion about;

- the frequency of occurrence and their
- impact over cost,
- impact over duration and
- impact over quality of the project for each waste item.

In this way it is targeted to provide waste item list with probability of occurrence and impact evaluation information for a further possible lean design management model study.

Questionnaire was preferred due to its effectiveness and practicality for surveying over respondents from a broad population. The questionnaire was created in online environment in order to reach the ideas of a wide population in relatively short time period with less physical effort. Moreover, online questionnaire increases the efficiency of evaluation process by providing data in digital environment.

The execution of the pilot study started on 10.01.2015 and finished on 17.01.2015 with involvement of 30 participants from a variety of backgrounds in architectural profession. The objective was to determine whether there was a potential problem about the general layout of questionnaire and clarity of questions.

The web URL of questionnaire was held open from 20.01.2015 to 04.02.2015 and 244 initial responds collected out of 1632 active members of Ankara Chamber of Architects in this time period. That corresponds to 14,95% initial response rate. However, only 151 of those questionnaires' compulsory areas were fully completed. So, the evaluation was conducted with involvement of 151 responds.

34 total questions of questionnaire were divided into two main question groups;

1. Information about professional identity (6 questions); and
2. Waste items frequency and impact evaluation (28 waste items).

The first question group named as "Information about professional identity", focused on personal information including; (1) number of years that the participant is working in project environment; (2) number of years that the organization of participant is working in project environment; (3) the job position that the participant is working; (4) the amount of projects that the organization of participant finished annually; (5) the total number of personnel working in the organization of participant; and (6) building types that the participants are involved in project process of.

The second question group – "Waste items frequency and impact evaluation" - was consisted of a list of 28 lean design waste items with two explanatory illustrations under each of them. Each waste item is considered as a question and their: (1) probability of occurrence, (2) impact over project cost, (3) impact over project duration, and (4) impact over project quality are examined with multiple choice questions.

After reading the relevant explanations and illustrations, the respondents are expected to choose four range defining answers determined as "4-very high", "3-high", "2-low" and "1-zero" were the possible answers for each four parameter. A four point scale for the answer options was preferred instead of 3-5 point in order to prevent respondents opt out or give uncertain decisions by selection of the answer in the middle with no-decision (Fellows and Liu, 2008).

RESULTS

This section contains the analysis and illustrations of mean scores and standard deviations belonging to 28 waste items and their parameters. For each waste item, mean scores and standard deviations were quantitatively calculated for the frequency of occurrence, impact over cost, impact over duration and impact over quality values. The answers from all respondents were evaluated together without any discrimination in this part.

1. $\bar{x}$ = mean value
SD = standard deviation

Comparison of Waste Items According to Parameters

Firstly, the ranking of waste items according to mean scores of their frequency of occurrence values is illustrated in **Figure 1**. The data reveals that "revision works according to data provided from other disciplines" $\bar{x}$ = 2,92 (SD = 0,78) (**1**) is the most frequently encountered waste out of 28 items. This is an item from "defects/correction" waste category. In reference to evaluations of interviewees, the waste can be resulting from (1) impossibility of co-operation between all disciplines from the commencement of the project, (2) stakeholders' lack of core knowledge about different disciplines, (3) jumping to the next phase before necessary information reached from other disciplines, (4) clients' special desire to work with a previously determined engineering team, (5) not following the innovations in the industry, and (6) lack of self-evaluation of the organization. So, the interviews and questionnaires together reach the point that the waste item occurred as a result of the factors above is the most frequently experienced one among the 28 items determined. It is also remarkable that 4 of the first 7 wastes on the table belongs to "waiting" category.

Following the frequency of occurrence scores, the ranking of items with respect to the average of mean scores for "impact over cost, duration, and quality" values is presented in **Figure 2**. For each waste item, the individual mean score for the impact is provided as a bar chart, including the standard deviation value presented next to it.

When "impact over cost" scores are considered, all the 7 items at the top of the list are from only two waste categories: overprocessing and defects/correction. "rework" $\bar{x}$ = 2.91 (SD = 0,78), "ineffective employee performance" $\bar{x}$ = 2.80 (SD = 0.81), "problems with client relations" $\bar{x}$ = 2.78 (SD = 0.78) and "unqualified data from other disciplines" $\bar{x}$ = 2.73 (SD = 0,72) are the items of overprocessing category. And "architectural decision alterations" $\bar{x}$ = 2.80 (SD = 0.75), "revision works according to data provided from other disciplines" $\bar{x}$ = 2.79 (SD = 0.75) and "production of defective technical drawings and details *etc.*" $\bar{x}$ = 2.75 (SD = 0.73) are the items from defects/correction category. Conversely, "waiting for stationery, print and model works" $\bar{x}$ = 2.03 (SD = 0.72) has been evaluated as the item has least effect over the project cost. Interestingly, 4 of the 7 items at the bottom of the list belong to *motion* waste category. According to the impact over cost scores, the respondents pointed at rework and employee/client (interpersonal) relationship based problems for the highest waste source in architectural design process. Following that, design changes due to architectural concerns, coordination with other disciplines, and errors in the generation of technical drawings were mentioned as the next important source of waste causing increased cost.

When "impact over duration" scores are considered, "*rework*" $\bar{x}$ = 3.20 (SD = 0.73) is the waste item that has the greatest impact over the project duration as like previous parameter -impact over project cost. 5 of the first 6 waste items on top of the list belong to the "waiting" category. The wastes in question are: "discontinuation in the project" $\bar{x}$ = 3.18 (SD = 0.85), "late information from client" $\bar{x}$ = 3.18 (SD = 0,70), "relationship problems with public administration" $\bar{x}$ = 3.11 (SD = 0.76), "protracted previous works" $\bar{x}$=3.11 (SD = 0.69) and "waiting for information from other disciplines" $\bar{x}$=3.08 (SD = 0.70). Conversely, the only left waste item of waiting category is placed at the bottom of the table surprisingly: "waiting for stationary, print and model works" $\bar{x}$ = 2.16 (SD = 0.76). These results show that

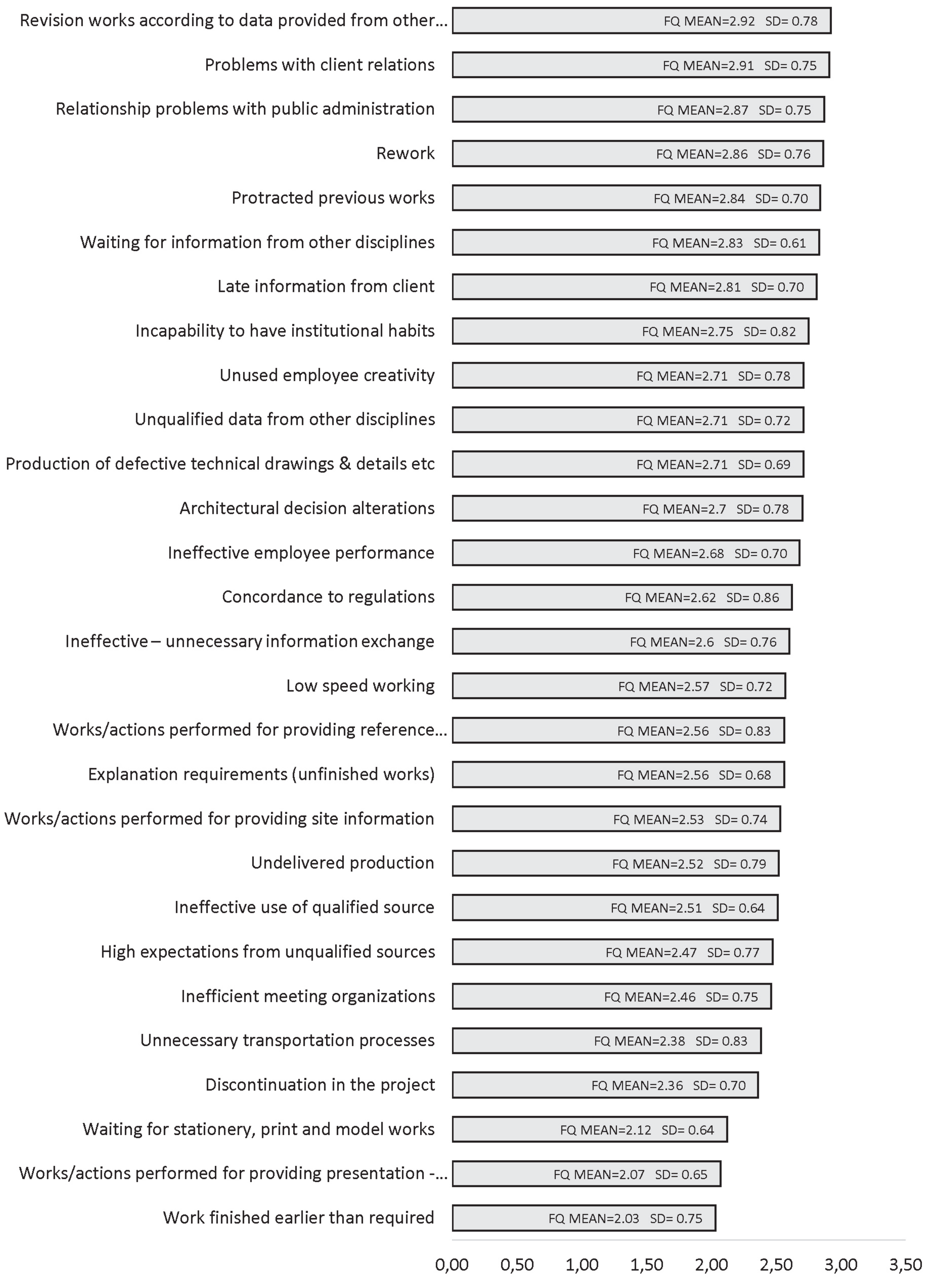

Figure 1. Waste item rankings according to their frequency of occurrence scores

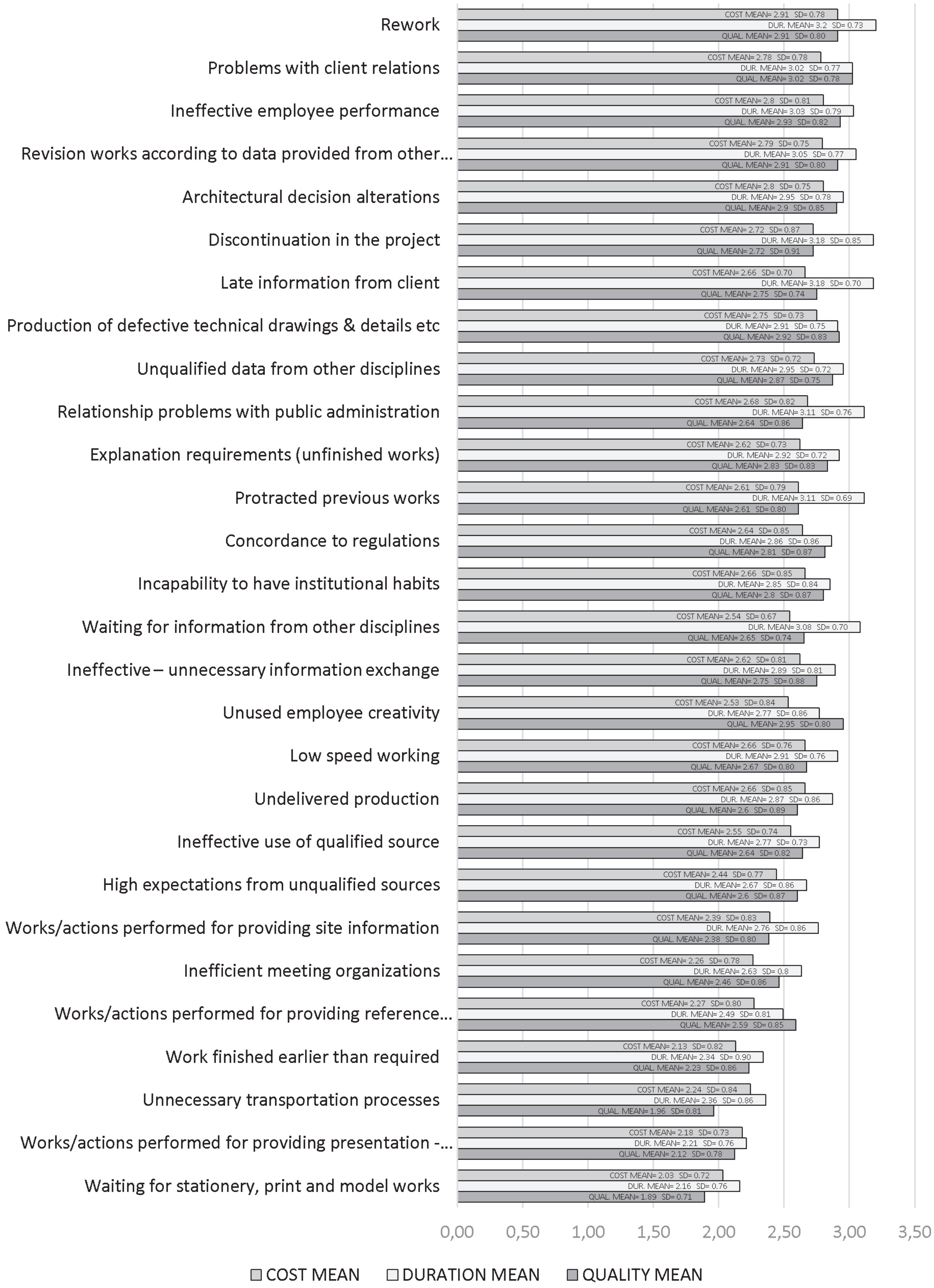

Figure 2. Waste item rankings according to their impact over project quality, duration, cost scores

most of the time related waste in design process occurs due to the delays resulting from third parties' responses, such as project discontinuations and cuts in the flow of information from clients, public administrations, or other disciplines.

"Impact over quality" scores show that two categories: overprocessing and defects/correction dominated 11 of the first 12 rows according to the architects' answers. The mentioned waste items included in overprocessing category are: "problems with client relations" $\bar{x}$ = 3.02 (SD = 0,78), "ineffective employee performance" $\bar{x}$ = 2.93 (SD = 0.82), "rework" $\bar{x}$=2.91 (SD = 0.80), "unqualified data from other disciplines" $\bar{x}$ = 2.87 (SD=0.75), "incapability to have institutional habits" $\bar{x}$ = 2.80 (SD = 0.87) and "ineffective-unnecessary information exchange" $\bar{x}$ = 2.75 (SD = 0.88). And "production of defective technical drawings and details" $\bar{x}$ = 2.92 (SD=0.83), "revision works according to data provided from othder disciplines" $\bar{x}$=2.91 (SD = 0.80), "architectural decision alterations" $\bar{x}$ = 2.90 (SD = 0,85), "explanation requirements (unfinished works)" $\bar{x}$ = 2.83 (SD=0.83) and "concordance to regulations" $\bar{x}$ = 2.81 (SD = 0.87) are the items in the body of defects/correction category. Another significant result derived from the figure is that unused employee creativity category is placed in the 2nd rank with its unique waste item with the same name $\bar{x}$ = 2.95 (SD = 0.80). So, unused employee creativity is noticed by designers as a major resource for unqualified architectural projects. Being similar with the "impact over cost" rankings, all 4 waste items of motion category are placed within the last 7 rows by respondents. These findings clearly show that the internal problems within architectural design organizations were pointed at as waste items for their negative influence on the quality of outputs.

Comparison of Waste Items According to Risk Values

So far, the evaluation was processed through four main parameters independently. The impact values were not considered when the assessment is made for frequency of occurrence. Similarly, impact values are scored and analyzed independent from the probability of occurrence. In this context, after the presentation and evaluation with mean scores of four parameters' separately, it is considered necessary to make an overall evaluation by incorporating both frequency of occurrence and impact values. At this point, risk concept is referred for framing the combination of such values meaningfully.

In this direction, this section contains evaluations and illustrations that use both the probability and impact values for reaching an overall risk value for each waste item. In **Figure 3**, risk items are ranked according to the average of risk values calculated for each group impact, namely cost, duration, and quality, following the method as described in Section 3.

For the risk of impact over cost parameter, there are wastes from 3 waste categories in top 5: "rework" (freq = 2.86, i_c = 2.91) and "problems with client relations" (freq = 2.91, i_c = 2.78) from overprocessing, "revision works according to data provided from other disciplines" (freq = 2.92, i_c= 279) and "architectural decision alterations" (freq = 2.70, i_c = 2.80) from defects/correction and "relationship problems with public administration" (freq = 2.87, i_c = 2.68) from waiting category. On the other hand, wastes from 4 different categories are placed on the bottom of the list. The waste items that have lowest risk value ratings are "waiting for stationery, print and model works" (freq = 2.12, i_c = 2.03) from waiting category, "Work finished earlier than required" (freq = 2.03, i_c = 2.13) from inventory

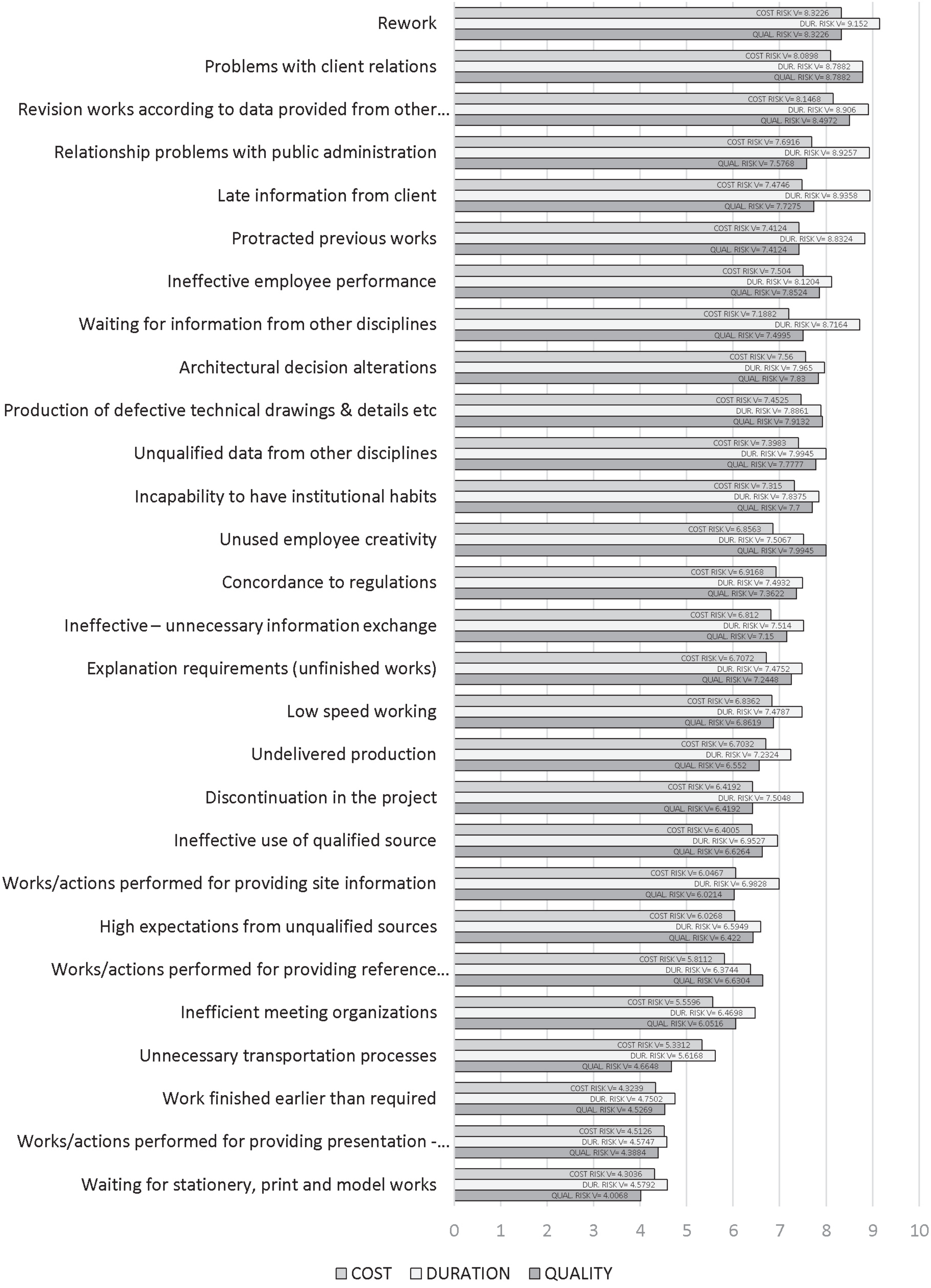

Figure 3. Waste item rankings according to their quality, duration, cost risk value scores

category, "works/actions performed for providing presentation - design materials" (freq = 2.07, i_c = 2.18) and "inefficient meeting organizations" (freq = 2.46, i_c = 2.26) from motion category and "unnecessary transportation processes" (freq = 2.38, i_c = 2.24) from transportation category. It should be noted that the waste items in first and last three rows have remarkably distinctive values compared to others.

Considering the risk of impact over duration parameters; in a similar direction with the impact over project duration rankings, waiting category is prominent with 3 waste items out of first 5. "Late information from client" (freq = 2.81, i_d = 3.18), "relationship problems with public administration" (freq = 2.87, i_d = 3.11), and "protracted previous works" (freq = 2.84, i_d = 3.11) are the items from waiting category. The other two outstanding items are "rework" (freq = 2.86, i_d = 3.20) from overprocessing category and "*r*evision works according to data provided from other disciplines" (freq = 2.92, i_d = 3.05) from defects/correction category. Being similar to data of cost risk value rankings, there are waste items from 4 different categories in last 5 row of ranking according to duration risk value. "Works/actions performed for providing presentation - design materials" (freq = 2.07, i_d = 2.21) and "Works/actions performed for providing reference technical information" (freq = 2.56, i_d = 2.49) from motion category, "waiting for stationery, print and model works" (freq = 2.12, i_d = 2.16) from waiting category, "Work finished earlier than required" (freq = 2.03, i_d = 2.34) from inventory category and "unnecessary transportation processes" (freq = 2.38, i_d = 2.36) from transportation category.

Considering the risk of impact over quality parameters; there is no dominance of a specific waste category in the first 5 waste items. There are two waste items: "problems with client relations" (freq = 2.91, i_q = 3.02) and "rework" (freq = 2.86, i_q = 2.91) from overprocessing category, two items: "revision works according to data provided from other disciplines" (freq = 2.92, i_q = 2.91) and "production of defective technical drawings and details etc." (freq = 2.71, i_q = 2.92) from defects/correction category, and "unused employee creativity" (freq = 2.71, i_q = 2.95) as the single item of the category with the same name. Similarly, there are wastes from 4 different category in 5 waste items having minimum scores of quality risk value. Namely: "waiting for stationery, print and model works" (freq= 2.12, i_q = 1.89) from waiting category, items according to their duration risk value have items from 4 different category; "works/actions performed for providing presentation - design materials" (freq = 2.07, i_q = 2.12) and "works/actions performed for providing site information" (freq = 2.53, i_q = 2.38) from motion category; "work finished earlier than required" (freq = 2.03, i_q = 2.23) from inventory category and "unnecessary transportation processes" (freq = 2.38, i_q = 1.96) from transportation category.

When the risk values for different project parameters (cost, duration, quality) are analyzed together, it is monitored that some waste items are emphasized by answers of respondents in different manners. It is observed that:

- "rework" is placed in first 3 rows;
- "revision works according to data provided from other disciplines" is placed in first 4 rows;
- "waiting for stationery, print and model works" is placed in last 2 rows;

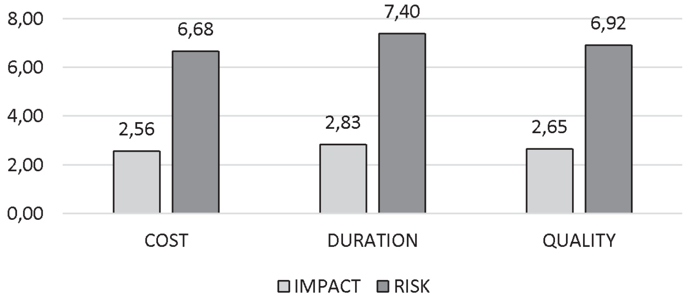

Figure 4. Mean scores of answers

- "work finished earlier than required" is placed in last 3 rows;
- "works/actions performed for providing presentation - design materials" is placed in last 3 rows and;
- "unnecessary transportation processes" is placed in 4th row in all three rankings.

Figure 4 is prepared with mean scores of answers given by 151 respondents for 34 questions. As seen from the illustration, the respondents thought that the waste items listed in the questionnaire are mostly influential over the duration of the project. Quality and cost parameters follow duration respectively. The same grading is valid for risk value of each parameter similarly. So the thoughts of respondents can be expressed as:

impact over duration $\bar{x} = 2.83$ > impact over quality $\bar{x} = 2.65$ > impact over cost $\bar{x} = 2{,}56$; and paralelly:

duration risk value $\bar{x} = 7.40$ > quality risk value $\bar{x} = 6.92$ > cost risk value $\bar{x}$=6,68.

DISCUSSION

The evaluation of interviews - which is the first phase of the study - revealed 28 lean design waste items under 8 waste categories. Furthermore, 59 different waste sources were stated 141 times by interviewees. All waste items had at least two sources while top number of sources for a waste item was 13. Some sources were repeated up to 8 times while some of them were stated only once. That means some of the sources can lead up to 8 different waste items noted by the respondents.

In the next phase, the evaluation of questionnaires was performed. Firstly, waste items were compared according to four parameters directly asked in the survey. "Revision works according to data provided from other disciplines", "problems with client relations", "relationship problems with public administration", "rework" and "protracted previous works" were stated as the most frequently occurred waste items. When impact over project cost is in question, "rework" is placed in the first place and followed by "ineffective employee performance", "architectural decision alterations", "revision works according to data provided from other disciplines" and "problems with client relations". "Rework" addressed by respondents as the most effective waste item over increasing project duration. "Discontinuation in the project", "late information from client", "relationship problems with public administration" and "protracted previous works" were other prominent ones. The waste items that causes decrease in project quality were lined as "problems with client relations", "unused employee creativity", "ineffective employee performance", production of defective technical drawings and details *etc*." and "revision works according to data provided from other disciplines".

Then the evaluation continued with risk values determined by multiplication of frequency of occurrence and impact scores. When risk values for different project parameters (cost, duration, quality) were analyzed together, it was monitored that some waste items were emphasized by the answers of respondents in different ways. As a result, it was observed that rework and revision works according to data provided from other disciplines were among high-risk waste items. In contrast, waiting for stationery, print and model works, work finished earlier than required, and works/actions performed for providing presentation - design materials were listed as low risk waste items by the respondents.

In order to achieve an absolute lean architectural design process, all waste items should be eliminated. However, it can be a right decision to focus on the items that have the highest negative impact over project value parameters (cost, duration and quality) and work for eliminating their sources.

Although a difference in responses of architects with different professional backgrounds (such as architects working in different positions, having different experience levels, working in different experience leveled companies *etc*.) was searched, no statistically significant variation has been founded. Further statistical tests were performed for determining whether there was a significant difference between the average scores of waste categories. According to respondents, "unused employee creativity" = 2.71 (SD = 0.63) had the highest value in probability of occurrence with its only waste item by surpassing average values of all waste categories. Similarly, average of waste items in "defects/correction" = 2.72 (SD = 0.45) category was the highest one for impact over project cost; while average of waste items in "waiting" = 2.97 (SD = 0.38) category was the highest one for impact over project duration and finally, the score of "unused employee creativity" = 2.95 (SD = 0.65) waste item was higher than average value of all other waste categories by considering its impact over project quality.

In addition, average value of waste items under "defects/correction" = 7.52 (SD = 0.31); = 8.12 (SD =0.22); category had the highest score in both cost and duration risk value parameters respectively. None of the categories' average value could have reached the score of only waste item in "unused employee creativity" = 8.38 (SD = 0.34) in terms of quality risk value parameter. The average values of wastes in motion, inventory and transportation categories have significantly lower scores when compared to other 5 waste categories. Similarly, the average values of waste items under those categories shared last 3 rows in all 7 parameter scores.

CONCLUSIONS

This study mainly provides the waste items and sources catalogue for architectural design process. Then investigates and evaluates their frequency of occurrences and impacts with risks over different project value parameters. The findings of this study can be seen as the first step for the aim of increasing the efficiency of architectural design process with a lean perspective. While lean philosophy requires the elimination of all wastes in a process, it is impossible to achieve this immediately. This is why the focus should strategically be on the highest impact waste items at the outset. Lean production techniques require continuous improvement based on reduction of waste. The study provides a roadmap for elimination of waste from architectural process from cost, duration, and quality perspectives. Starting from the highest impact waste items, design professionals may target improving the efficiency of their business via employment of new technologies, critically assessing their design processes, and improving the communication within and outside their organisations.

The relationship between waste sources and lean principles and tools is briefly mentioned in this research. Future studies may evaluate such relationships in a detailed manner. Possible works investigating lean principles and tools to be employed for eliminating the waste items presented in this study may be helpful for the adaptation of lean philosophy through architectural design industry.

The limitations of the study arise from small number of interviews due to restricted time and availability of design offices and scope of the questionnaire. A larger set of interviews and a broader questionnaire survey would dramatically increase the accuracy and universality of the results.

In this study, design process was evaluated from architectural point of view only. By considering contemporary project delivery methods, another future research area may be to evaluate architecture – engineering and design – construction issues together. Such integration scenarios may open the way for increasing the efficiency and create new possible waste prevention strategies. Furthermore, the relationships between waste items and their impact over construction phase may be investigated. By considering the sensitivity of decision makers in the industry is directed towards construction works, it may be constitutive for design industry to establish the relationships of lean design waste items and their possible consequences in construction phase of projects.

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LEAN DESIGN MANAGEMENT – AN EVALUATION OF WASTE ITEMS FOR ARCHITECTURAL DESIGN PROCESS

Inefficiency stands as a major problem in construction industry. Lean thinking is a relatively new process improvement philosophy which approaches inefficiency by reducing the waste. Although the inefficiency of design stages has been associated with the poor results of construction projects, less attention has been paid on the relationship between lean thinking and architectural design process. While there is a strong potential for improvement in the design processes via application of lean thinking, an analysis of waste items has never been done. Thus, this study aims to identify, categorize, and rank the waste items in architectural design sector. In the first stage of the study 28 design waste items were identified and classified under 8 lean production waste categories as a result of semi-structured interviews conducted with senior architects performing in Ankara, Turkey. In the second stage, a questionnaire was executed over a larger population of architects to examine the "frequency of occurrence", "impact over cost", "impact over duration", and "impact over quality" for each design waste item. The findings were statistically analysed and an evaluation of risk was completed. The statistical analysis of the questionnaires shows that there is a shared understanding of impacts of waste items over architectural design processes, with strong statistical evidence over their validity. The results of the study can be utilized for the strategical implementation of lean production philosophy in architectural design process.

Alındı: 08.10.2015; **Son Metin:** 26.02.2016

Anahtar Sözcükler: Yalın düşünce; israf; mimari tasarım süreci; yalın tasarım; verimlilik

YALIN TASARIM YÖNETİMİ – MİMARİ TASARIM SÜRECİNDE İSRAF KALEMLERİ DEĞERLENDİRMESİ

Verimsizlik inşaat sektörü için büyük bir problem olarak göze çarpmaktadır. Yalın düşünce verimsizliğin önüne israfı azaltarak geçmeye çalışan göreceli olarak yeni bir felsefedir. Her ne kadar tasarım süreçlerindeki verimsizliğin inşaat projeleri üzerindeki negatif etkisi kanıtlanmış olsa da yalın düşünce ile mimari tasarım süreçlerinin iyileştirilmesi pek önemsenmemiştir. Tasarım süreçlerinin yalın düşüncenin uygulanması ile iyileştirilmesi mümkün olsa da, bu alanda israf kalemleri hiç saptanmamıştır. Bu yüzden bu araştırma mimari tasarım sektöründeki israf kalemlerini belirlemeyi, kategorize etmeyi ve sıralamayı amaçlar. Araştırmanın ilk aşamasında Ankara'da çalışan kıdemli mimarlarla yürütülen yarı-yapılandırılmış görüşmeler sonucunda 28 tasarım israf kalemi belirlenmiş ve 8 yalın düşünce israf kategorisi altında sınıflandırılmıştır. İkinci aşamada ise mimarlardan oluşan daha geniş bir araştırma evreni üzerinde uygulanan bir anketle söz konusu israf kalemlerinin karşılaşılma sıklığı ile proje maliyeti, proje süresi ve proje niteliği üzerine etkileri araştırılmıştır. Bulgular istatistiksel olarak analiz edilmiş ve bir risk değerlendirmesi yapılmıştır. Anket sonuçları üzerinden yürütülen analizler israf kalemlerinin mimari tasarım süreci üzerinde etkileri ile ilgili bir uzlaşma olduğunu ortaya koymuştur. Bu araştırmanın sonuçları yalın üretim felsefesinin mimari tasarım süreçlerinin iyileştirilmesi için stratejik olarak uygulanmasında kullanılabilir.

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