Lean Construction Conformance among Construction Contractors in Turkey

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Abstract: Lean construction is the term that corresponds to the reflection of the production system developed at the Toyota Corporation (automotive industry) on the construction industry. Turkish contractors constitute a large portion of the local economy and are important global actors in contracting business. Lean construction–based research and practice, as a production management–based approach for increasing the effectiveness and efficiency of the construction industry, are scarce among Turkish contractors. This paper presents the results of a questionnaire prepared to predict the lean conformance levels of Turkish contractors and discusses the results. The comparative strengths and weaknesses of Turkish contractors for a lean construction initiative are highlighted. The findings that are presented in this paper can be used as a starting point to disseminate the research and practice in lean construction among Turkish contractors in the future. A similar kind of research can be repeated to compare the lean conformance levels in different countries and to evaluate the lean construction programs at different companies after the introduction of lean construction. **DOI: 10.1061/(ASCE)ME.1943-5479.0000145.**

CE Database subject headings: Lean construction; Turkey; Contractors.

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Introduction

The construction industry has long been criticized for being wasteful, unsafe, fragmented, inefficient, and ineffective (Latham 1994; Egan 1998; Sun and Aouad 2000; Salem et al. 2006). Flyvbjerg et al. (2004) evaluated 258 major public transport infrastructure projects worth US$90 billion, constructed across the United States, Europe, Japan, and many developing countries between 1927 and 1998, concluding that cost overrun on average was approximately 30%, and that client revenues failed to meet their targets by approximately 40%. The pressure of the competition at a global scale with political and economic considerations forces the construction industry to improve its modus operandi (Beatham et al. 2004). The general orientation of the business environment, which underlines continuous improvement, critically questions construction's project-realization methods. The repeated complaints of poor performance naturally turn the eyes to other industries for benchmarking and identification of cross-industrial learning opportunities. One of the objects of this attention is the automotive industry (Gann 1996). Indeed, the automotive industry has been subject to remarkable technical and managerial changes since the beginning of the twentieth century (Crowley 1998). Being the birthplace of the major production philosophies, the automotive industry succeeded in manufacturing highly complex automotive products within acceptable quality, cost, and time limits, which catered to the widespread utilization of affordable and safe automotive products throughout the world for people of different economic classes. With fierce competition and taking advantage of a more controlled production context, the manufacturing industry seems to have understood the importance of systematically improving its operations. One of the initiatives in construction that is motivated by the developments in manufacturing is lean construction, which takes its roots from the automotive industry–born lean production.

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Lean Production

As a term, lean production is the collective synonym for the production system that was first developed in the car-manufacturing environment at the Toyota Motor Corporation. It is also known as the Toyota production system (TPS), nonstock production, or just-in-time production (JIT). It underlines a small-batch, one-piece flow of production through integration with suppliers and distributors, reduction of machine setup times, and complete unity of the value chain, while keeping inventories and works in progress at their optimums in a tightly coupled production system (Monden 1998). The English term (lean production) was first coined by a member of the International Motor Vehicle Program team led by James P. Womack and Daniel T. Jones at the Massachusetts Institute of Technology (MIT) and published in their book, *The Machine That Changed the World* (Womack et al. 1990). At the time the book was published (in 1990), Toyota was half the size of General Motors (GM). Today, it has surpassed GM in terms of manufacturing volume, marking its identity as one of the most consistently successful and efficiently working global business enterprises in history.

Toyota engineers were dedicated to eliminating both hidden and obvious waste in a production chain through various operational experiments and trial and error (Fujimoto 1999). The system drew huge attention and has been acclaimed by some as a contemporary successor to the classical mass production (Fordism/Taylorism), especially after Toyota's striking competitive advantage over its

J. Manage. Eng., 2013, 29(3): 236-250

American and local rivals, explicitly starting from the 1973 and 1976 global oil shocks. The West first attributed the success in Japan to Japan's protective policies and low wages, but later appreciated Japan's production virtuosity (Hayes and Pisano 1996). This appreciation brought about the expansion of this mindset and methodology, not only to Toyota's close rivals in the West (such as Ford, Chrysler, and General Motors), but also to other industries like aerospace, consumer products, and metal processing (Spear and Bowen 1999). The lean production philosophy has also increasingly found a place in the service sector (Bowen and Youngdahl 1998; Swank 2003). The basic principles of the lean production system, which can be found in their purest form at Toyota, were summarized by Toyota engineer and executive, Taiichi Ohno (Ohno 1988), as follows:

- Pull-driven production;
- Minimization of waste by eliminating non–value adding activities;
- Doing things right the first time by identifying and resolving a defect instantly at its source;
- Continuous improvement (*kaizen*);
- Building of long-term relations with suppliers;
- Ability to produce various goods of various quantities; and
- Teamwork.

One important feature of the lean production system is its claim that the long-believed trade-off between cost/quality/flexibility (delivery) and quality/productivity can and should be challenged persuasively, at least in the name of creating an organization that tirelessly seeks for development opportunities (Shingo 1989). Toyota uses some obviously challenging slogans that are probably impossible to sustain indefinitely (e.g., "zero inventories" or "zero defects") to reflect this point of view (Womack et al. 1990).

Lean Construction

The lean production philosophy caught the attention of people interested in construction. Since the early 1990s, a lean construction concept has been studied and promoted by means of, for example, institutes, governmental reports, construction-management scholars, practitioners, and some occupational organizations. The two most notable of the organizations that have been working solely for the development of lean thinking in the construction industry are the Lean Construction Institute (LCI) of the United States and the International Group for Lean Construction (IGLC). Koskela (1992) pioneered introducing the lean movement to construction in his seminal report and hosted the first conference of the IGLC in Espoo, Finland, in 1993. A group of researchers at the conference adopted the name, lean construction. The IGLC has been organizing annual academic conferences ever since. The LCI, founded in 1997, has been publishing an international refereed journal devoted to lean construction practice and research since 2004.

Lean construction efforts are aimed at contributing to the construction industry via the lean motives and methodologies and an operations-focused project-delivery understanding (Howell and Ballard 1999). Direct copying of the applications from manufacturing would not be feasible because of the differences between the two industries. Ballard and Howell (2003, p. 120) explained the generic background of lean construction as follows: "We understand projects to be temporary production systems linked to multiple, enduring production systems from which the project is supplied materials, information and resources."

Koskela (2000), underlining the fundamental goals of a production system as maximizing value, minimizing waste, and delivering the product, explained the framework through which a production system can be applied to construction. This pyramidal structure is made, from bottom to top, of methodologies/tools, concepts, and principles. The perception of both manufacturing and construction as production systems, including processing stations and transfer of partially completed work by means of machinery and crews, enables some analogies. The goal is to take basic lean motives, such as elimination of waste, cycle-time reduction, variability reduction, pull-driven production control, continuous flow, and continuous improvement (Liker 2004), as pivotal points and to develop methodologies and applications in a construction context.

There is significant implementation of lean construction in the construction industries of Australia, Brazil, Denmark, Ecuador, Finland, Peru, Singapore, the United Kingdom, the United States, and Venezuela (Ballard and Howell 2003). Picchi and Granja (2004) claim that these implementations are often very fragmented and limited to the isolated implementation of some lean tools with inadequate theoretical understanding. Although not abundant, lean construction conformance/penetration–related research has been conducted in some countries. In accordance with Picchi and Granja (2004), the surveys in the United Kingdom (Common et al. 2000) and the Netherlands (Johansen et al. 2002) reveal limited knowledge and some loose practices of lean construction in these countries. Whereas Common et al. (2000) identified a higher awareness of the lean idea in the United Kingdom than in the Netherlands (Johansen et al. 2002), both studies demonstrated a slow adoption rate of the lean movement. The following suggestions of Johansen et al. (2000) for wider lean construction penetration are important: strong drivers for change, such as the Egan (1998) report in the United Kingdom; government involvement; large and long-term innovation programs; and dissemination of best practices and sound conceptual definitions for lean construction concepts.

Alarcon and Seguel (2002) give emphasis to identifying the agents of change toward a lean construction mindset and underline a need for commitment and ownership at all levels for successful lean construction penetration in Chile. Although the drivers for lean construction are important parameters in application, the research does not evaluate the current operational practices in Chile in detail.

Johansen and Walter (2007) conducted questionnaire-based research for the managers of top construction companies in Germany with the objective of identifying how lean techniques have been disseminated among construction companies, how lean thinking has penetrated the industry, and how lean concepts are being understood. The conceptual framework of the study covers a wider range in the project life cycle, from design to procurement and collaboration. The findings were discussed in detail, but no quantitative data were presented from the study. The authors conclude that, despite many procedures and techniques that are consistent with the core lean construction concepts and general agreement with the lean philosophy, conventional thinking in construction still prevails, and there is little awareness of lean construction in the German construction industry.

Senaratne and Wijesiri (2008) investigate the types of flow wastes, their causes, and the extent to which the construction workforce accepts the core principles of lean construction in Sri Lanka. The research employs a three-step opinion survey among the workforce of major contractors in the country. The existence of 10 major flow wastes and their eight major causes in Sri Lanka were identified. The study claims that lean construction is suitable for Sri Lanka and that, although the majority is accepting the core principles of lean construction and the importance of having a mentality of continuous improvement, it is important to raise awareness on the benefits gained through lean construction implementations. The study uncovers a conceptual acceptance of the principles of

J. Manage. Eng., 2013, 29(3): 236-250

lean construction in Sri Lanka, but does not evaluate the current practices in the country from a lean construction perspective, which is investigated for Turkey in this study.

Turkish Construction Industry and Lean Construction

Together with automotive, textile, and tourism, the construction industry is one of the major industries and exporters for Turkey. As of 2006, the construction industry generated approximately 20% of the export revenues of the country, creating 35% of Turkey's gross domestic product and taking a 3% share in the world's construction market with US$86 billion worth of international projects completed accumulatively by then (Mac 2007). The devastating Kocaeli (Northwest Turkey) earthquake in 1999 led to intense questioning of the industry's manifestation in the country. The inherent problems of construction had already been underlined right before the earthquake catalyzed discussions. Along with lack of occupational education and penetration of developing technologies, excessive bureaucratic procedures, insufficient technological know-how, inadequate control mechanism, and the lowest-bid politics of the state's procurement process had all been noted as significant problems of construction in Turkey (Toklu 1996; Sorguc 1997).

With cheap labor and cultural and geographic proximity to highly active markets, Turkish contractors have showed solid entrepreneurship on a global scale (Oz 2001). In 2009, 31 Turkish contractors were listed among the top 225 international contractors reported by the *Engineering News-Record* (ENR) on the basis of export revenue from general construction contracting that was generated from projects outside each company's respective home country ("The Top 225" 2009).

Polat and Ballard (2004) identified that time and material waste were common in the Turkish construction industry and that lean construction techniques were not applied to remove waste. Additionally, the necessity of company-based and national initiatives were underlined by the authors to improve the industry's performance through lean construction. Because the world's economies have been passing through a period of monetary crisis, the detrimental effects of waste can be expected to gain more attention worldwide. Dikmen and Birgonul (2003) note that positive company image/reputation, improvement of quality of services, and enhancement of productivity are strategic objectives for Turkish construction companies and perceived as more important than profit maximization. They also argue that most of the managers in the country are not content with how their companies are managed. A study investigating the comparative lean conformance and aptitude of the construction companies in Turkey will be presented subsequently in this paper.

Turkish Construction Industry's Lean Conformance and Aptitude

Methodology

Because of the size of the population and limited resources at hand, a questionnaire-based research methodology was employed for the following research question: What is the lean conformance level among the construction companies in Turkey? The prepared questionnaire contains a total of 35 questions. The first four questions aim at clarifying the respondent's professional and occupational attributes. The subsequent fifth through 10th questions are primarily related to the operational characteristics of the companies interviewed. The remaining 25 questions measure the lean conformance of the construction company. The questionnaire was designed to be explanatory, avoiding lean construction jargon or advanced terminology. The lean conformance–related questions were prepared from the model proposed by Diekmann et al. (2003). The model is presented as shown in Fig. 1. There are other conceptual frameworks (e.g., Common et al. 2000; Johansen and Walter 2007) that can be used to evaluate lean construction conformance, but Diekmann's model was found to be more operations focused and practical (easier to understand) for Turkish contractors who possess limited knowledge or are completely unaware of lean construction and lean construction–related terminology.

The model has five main principles and 16 subprinciples. The main principles are standardization, culture/people, customer focus, continuous improvement/built-in quality, and elimination of waste. In general, there is more than one question that corresponds to each subprinciple. The metrics, flexible resources, optimize value, supply chain management, and visual management subprinciples have two corresponding questions. The optimize production system and reduce process cycle time subprinciples have three corresponding questions. The rest of the subprinciples have one corresponding question each in the questionnaire.

While answering the questions related to lean conformance, the respondents were asked to evaluate the practices within their companies. They were given two statements and asked to identify the proximity or conformance of the actual practices to one of these two statements. A sample question is presented in Fig. 2. The complete lean conformance questionnaire by each main principle can be seen in the appendix.

Limitations

The study was conducted only among the contractors operating in Turkey, constituting a portion of the construction supply chain. The questionnaire was answered by people at different managerial levels (lower, mid, or upper) by means of self-assessment. Thus, a certain amount of bias can be expected. Moreover, because the lean construction movement and its terminology are still observed to be alien to many contractors in Turkey, some concepts might have been understood insufficiently or incorrectly by the respondents. The questions primarily focus on the operations-management aspects of the studied contractors, and the questions were chosen to yield the closest representation of reality with a limited number of questions.

Presentation of Results

The questionnaire was distributed to the contractors chosen among the members of the Turkish Contractors Association (TCA). A total of 44 responses were collected, yielding a response ratio of 50%; 77.28% of the participants responded using the Internet. The first four questions are for identifying the profession, level of education, managerial position, and experience level of the respondent. A detailed summary of the respondents' attributes, with interrelations, is shown in Table 1.

There are six questions in the questionnaire to identify organizational attributes. These questions are about the companies' average annual turnovers (in millions of U.S. dollars), numbers of employees, operational times (in years since founding), geographical/operational locations, major clients (public organizations, private individuals/organizations, or both), and areas of operation. The first seven parameters are shown in Table 2. The last parameter, regarding the companies' attributes (namely, the areas of operation), are shown in Table 3.

J. Manage. Eng., 2013, 29(3): 236-250

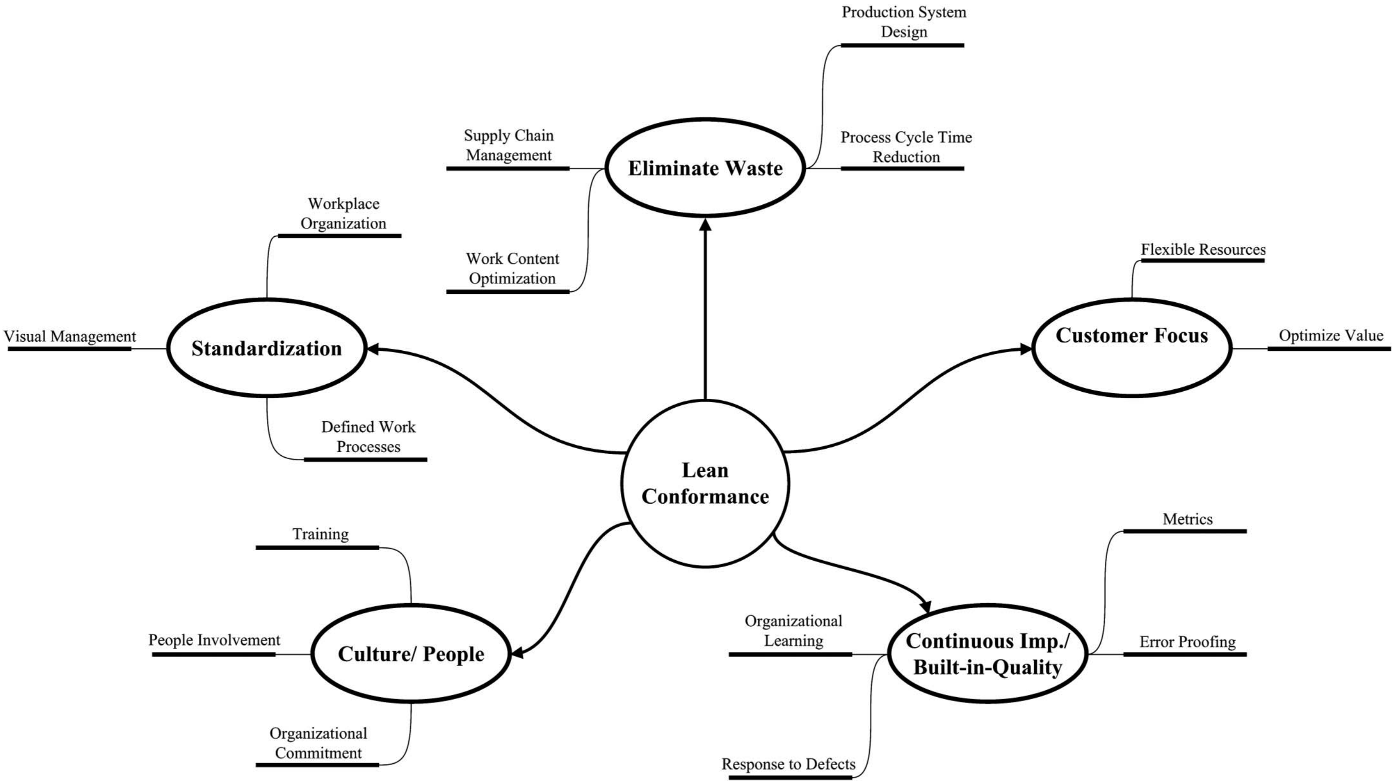

Fig. 1. Lean conformance model chart (data from Diekmann et al. 2003)

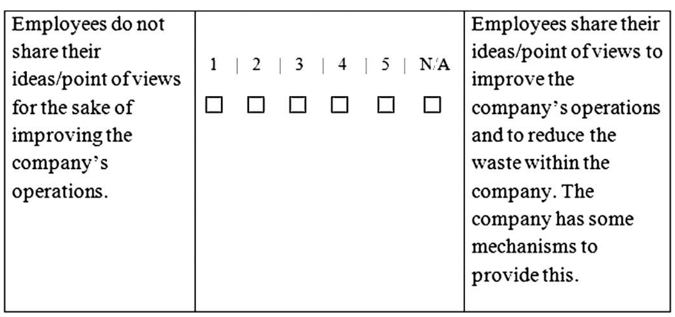

Fig. 2. Sample lean conformance question

There are 25 questions related to measuring lean conformance in each of the 44 completed questionnaires, which yields 1,100 answers in total. The answer frequencies are as follows: 1, 6.18% (68 times); 2, 11% (121 times); 3, 19% (209 times); 4, 31.27% (344 times); 5, 29.73% (327 times); and not applicable (NA), 2.82% (31 times). A detailed summary of the answer frequencies is shown in Table 4.

Analysis of Results

The lean conformance values for the sample data set in hand were calculated in percentages. Each lean conformance question was assigned the same weight in terms of lean conformance. Because there are 25 questions in total, the answer value for each question (which can be 1, 2, 3, 4, 5, or NA) was multiplied by 0.8. The NA answers were assumed as 1 because of the idea that all of the

Table 1. Respondent Attributes

Profession	Position	Level of experience (years)	Level of education		
			B.Sc.	M.Sc.	Total
Accountant	Upper-level manager	15–20		1	1
Architect	Midlevel manager	>20	1		1
	Upper-level manager	>20	6		6
		10–15	1		1
		5–10	1	1	2
Chemical engineer	Upper-level manager	>20		1	1
Civil engineer	Lower-level manager	10–15	2		2
		0–5		1	1
	Midlevel manager	>20	3	1	4
		10–15		1	1
		15–20		1	1
		0–5	1	1	2
	Upper-level manager	>20	5	3	8
		10–15	1	1	2
		15–20	1		1
		5–10		1	1
Electrical engineer	Upper-level manager	>20		1	1
Geology engineer	Midlevel manager	>20		1	1
	Upper-level manager	>20	1		1
Interior architect	Upper-level manager	5–10	1		1
International relations	Midlevel manager	10–15		1	1
Mechanical engineer	Midlevel manager	>20		1	1
		5–10		1	1
	Upper-level manager	15–20	1		1
Industrial engineer	Midlevel manager	10–15		1	1
Grand total			25	19	44

Table 2. Company Attributes

Annual turnover (U.S. dollars)	Number of employees	Operational time (years)	Operational locations	Both public and private figures	Private individuals and organizations	Public organizations	Grand total
>\$1,000 million	>1,500	>20	Spread in country and abroad	2	1		3
\$100–\$1,000 million	>1,500	>20	Spread in country and abroad	5	1	3	9
	500–1,500	>20	All in country	1			1
			Spread in country and abroad	1		1	2
\$10–\$100 million	>1,500	>20	Spread in country and abroad	1			1
	100–500	>20	All in country			2	2
			Spread in country and abroad		2		2
		5–10	Spread in country and abroad	1			1
	10–100	>20	All in country			1	1
			Spread in country and abroad	1			1
		5–10	All in country		1	1	2
	500–1,500	>20	Spread in country and abroad	1		4	5
\$1–\$10 million	10–100	>20	All in country	2	1	1	4
		0–5	All in country	2	1		3
			Spread in country and abroad	1			1
		10–15	All in country	1	3		4
		5–10	All in country		2		2
Grand total				19	12	13	44

Table 3. Company Areas of Operation

Areas of operation	Number of companies
Residential and commercial buildings	35
Infrastructural facilities	29
Highway and transportation facilities	25
Pipelines	20
Project and design	19
Tunnel works	18
Industrial facilities	17
Energy projects	14
Dams	12
Airports	10
Marine and shore works	9
Strengthening–restoration	8

questions should be related to lean practices and symbolize essential activities in a construction company. Thus, if a respondent answers NA, it implies that the respondent either has no knowledge about the practice in his/her company or has no idea about the lean statements contained in the question. The NA choice is also believed to act as a buffer against unrealistic answers. The lean conformance calculation (in percentages) was performed as follows:

$$\text{Lean conformance}\,(\%) = \frac{\sum(\text{Answer value}) \times 4}{5} \qquad (1)$$

For each company, the lean conformance percentage values were calculated using Eq. (1). Moreover, the lean percentage values for each of the five main principles were also calculated. No objective weight distribution suggestion or study for the main principles and subprinciples was identified from the lean construction literature. It is also believed that each subprinciple holds a specific role and is important in identifying the lean conformance of the companies. Therefore, equal weights were employed for each subprinciple in Eq. (1). The summary descriptive statistics for the sample lean conformance values (percentages) are shown in Table 5. The histogram for the sample lean conformance values in percentages, with the normal curve, are shown in Fig. 3.

The Anderson–Darling goodness of fit test for the normal distribution with 95% confidence interval ($\alpha = 0.05$) was applied to test the normality of the lean conformance data set in hand. The

Table 4. Lean Conformance Answer Frequencies

	Answer frequency					
Type of question	1	2	3	4	5	NA
Culture/people						
People involvement	2	4	7	23	8	
Organizational commitment	5	6	7	12	14	
Training	4	8	6	12	13	1
Continuous improvement/built-in quality						
Metrics—1		10	10	12	11	1
Metrics—2	3	3	13	15	9	1
Response to defects	1	3	10	13	17	
Error proofing	1	5	14	15	8	1
Organizational learning	1	5	10	17	10	1
Customer focus						
Flexible resources—1	7	6	4	15	11	1
Flexible resources—2	1	7	10	18	6	2
Optimize value—1		6	7	14	14	3
Optimize value—2	2	4	13	7	11	7
Eliminate waste						
Supply chain management—1	3	6	9	8	17	1
Supply chain management—2	2	6	3	11	22	
Optimize production system—1	3	4	13	9	11	4
Optimize production system—2	1	1	8	22	12	
Optimize production system—3	4	4	9	9	18	
Reduce process cycle time—1	6	3	7	11	17	
Reduce process cycle time—2	2	4	8	18	12	
Reduce process cycle time—3	7	3	9	18	6	1
Optimize work content	2	3	2	14	20	3
Standardization						
Visual management—1	2	4	5	13	20	
Visual management—2	1	5	12	10	14	2
Workplace organization	4	4	7	13	15	1
Defined work processes	4	7	6	15	11	1
Total	68	121	209	344	327	31

statistics for this test were found as 0.471 for the A^2 value and 0.234 for the P value. Because the P value (0.234) is larger than the α value (0.05), the distribution can be assumed to follow the normal distribution.

The t-test was applied to the data set to make some inferences for the whole population. For $v = 43$ $(44 - 1)$ and the 95% level of confidence ($\alpha/2 = 0.025$), $t_{0.025,43}$ was identified as 2.0174.

J. Manage. Eng., 2013, 29(3): 236-250

Table 5. Descriptive Statistics for Sample Lean Conformance

Measurement	Value
Minimum	34.40
Maximum	96.00
Mean ($\tilde{y}$)	72.35
Median	74.00
Mode	92.00
Standard deviation (s)	15.70
Kurtosis	−0.60
Skewness	−0.45

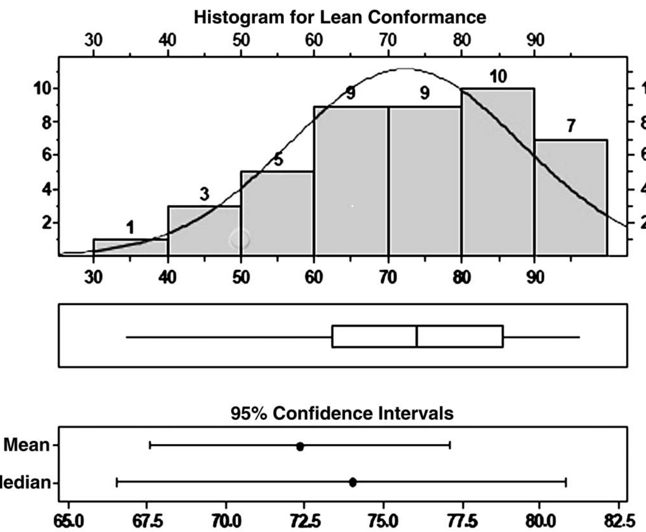

Fig. 3. Histogram for lean conformance values (percentage)

Therefore, the average (μ) lean conformance (percentage) of the contractors in Turkey with 95% confidence is $67.50\% \leq \mu \leq 77.19\%$. The summary descriptive statistics for each question are shown in Table 6.

The percent fulfillment for each subprinciple, which shows the real degree of realization for each subprinciple, can be calculated as follows:

$$\text{Percent difference}\,(\%) = \frac{\text{Real value} \times 100}{\text{Maximum possible value}} \qquad (2)$$

where maximum possible value = maximum possible lean conformance value; and real value = calculated mean value for corresponding subprinciple. The percent fulfillment for each of the main principles, calculated using Eq. (2), is shown in Fig. 4.

The participating companies were grouped by their average annual turnovers. Small companies (US\$1–US\$10 million turnover), medium–small companies (US\$10–US\$100 million turnover), medium–large companies (US\$1,000–US\$10,000 million turnover), and large companies (more than US\$1,000 million turnover). The percent fulfillment of each classified group is shown in Table 7.

An analysis for determining the statistically significant differences between the data groups is necessary. For this kind of an analysis, the ANOVA method was chosen. Because the data were grouped and analyzed by only one factor, one-way ANOVA between the groups was used to compare the mean (μ) lean conformance (percentage) values of the groups. In the ANOVA analysis, if the F_{test} value is smaller than the F_{critic} value, H_0, which is $\mu_1 = \mu_2$, is accepted. It means there is no significant difference between the two tested groups at the given confidence interval. The tested groups were formed by their average annual turnovers (in millions of U.S. dollars). The tested groups are shown in Table 8.

Table 6. Summary Descriptive Statistics for Each Question

	Summary descriptive statistics				
Type of question	Mean	Median	Mode	Standard deviation	Skewness
Culture/people					
People involvement	3.70	4.00	4.00	1.02	−0.99
Organizational commitment	3.54	4.00	5.00	1.37	−0.58
Training	3.45	4.00	5.00	1.38	−0.44
Continuous improvement/built-in quality					
Metrics—1	3.50	4.00	4.00	1.17	−0.18
Metrics—2	3.50	4.00	4.00	1.17	−0.63
Response to defects	3.95	4.00	5.00	1.05	−0.77
Error proofing	3.50	4.00	4.00	1.06	−0.42
Organizational learning	3.63	4.00	4.00	1.10	−0.63
Customer focus					
Flexible resources—1	3.34	4.00	4.00	1.43	−0.49
Flexible resources—2	3.38	4.00	4.00	1.12	−0.52
Optimize value—1	3.68	4.00	5.00	1.25	−0.69
Optimize value—2	3.16	3.00	3.00	1.44	−0.19
Eliminate waste					
Supply chain management—1	3.63	4.00	5.00	1.36	−0.55
Supply chain management—2	4.02	4.50	5.00	1.24	−1.09
Optimize production system—1	3.29	3.00	3.00	1.37	−0.33
Optimize production system—2	3.97	4.00	4.00	0.87	−1.04
Optimize production system—3	3.75	4.00	5.00	1.33	−0.75
Reduce process cycle time—1	3.68	4.00	5.00	1.41	−0.80
Reduce process cycle time—2	3.77	4.00	4.00	1.09	−0.85
Reduce process cycle time—3	3.25	4.00	4.00	1.31	−0.61
Optimize work content	3.93	4.00	5.00	1.35	−1.22
Standardization					
Visual management—1	4.02	4.00	5.00	1.17	−1.13
Visual management—2	3.61	4.00	5.00	1.24	−0.50
Workplace organization	3.65	4.00	5.00	1.34	−0.77
Defined work processes	3.45	4.00	5.00	1.33	−0.54

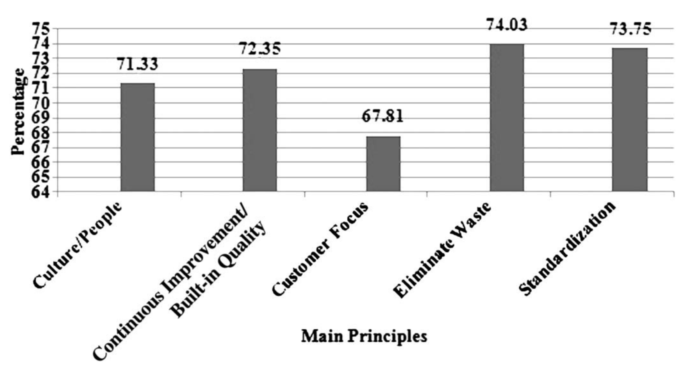

Fig. 4. Percent fulfillment for each main principle

J. Manage. Eng., 2013, 29(3): 236-250

Table 7. Percent Fulfillment of Classified Groups

Classified group (U.S. dollars)	Percent fulfillment				
	Culture/ people	Continuous improvement/ built-in quality	Customer focus	Elimination of waste	Standardization
Small companies ($1–$10 million)	67.62	68.00	61.43	67.78	67.50
Medium–small companies ($10–$100 million)	64.89	67.20	61.33	69.93	68.33
Medium–large companies ($100–$1,000 million)	82.78	79.67	78.75	82.41	85.42
Large companies (>$1,000 million)	75.56	89.33	86.67	90.37	83.33

Table 8. Groups by Average Annual Turnover

Average annual turnover (U.S. dollars)	Lean conformance (percentage)
$1–$10 million	76.8
	81.6
	65.6
	80.8
	51.2
	46.4
	60
	62.4
	91.2
	83.2
	62.4
	52.8
	55.2
	64.8
$10–$100 million	73.6
	46.4
	54.4
	66.4
	92
	63.2
	74.4
	86.4
	80.8
	88.8
	44
	34.4
	52
	68.8
	81.6
$100–$1,000 million	72.8
	91.2
	84
	68.8
	76
	92
	92
	95.2
	72
	86.4
	79.2
	72
>$1,000 million	88.8
	96
	75.2

The first ANOVA test was performed among the companies with average annual turnovers between US$1–US$10 million (the small companies) and US$10–US$100 million (the medium–small companies). The hypothesis test, with 95% confidence, is as follows:

$$H_0{:}\mu 1 = \mu 2; \qquad H_1{:}\mu 1 \neq \mu 2$$

The first ANOVA test results are shown in Table 9.

Because the F_{test} value (0.005) is smaller than the F_{critic} value (4.210), H_0 was accepted. No significant difference was found between the average lean conformance values of the small companies and the medium–small companies. The second ANOVA test was performed among the companies with average annual turnovers between US$1–US$10 million (the small companies) and US $100–US$1,000 million (the medium–large companies). The hypothesis test, with 95% confidence, is as follows:

$$H_0{:}\mu 1 = \mu 2; \qquad H_1{:}\mu 1 \neq \mu 2$$

The second ANOVA test results are shown in Table 10.

Because the F_{test} value (10.208) is larger than the F_{critic} value (4.260), H_0 was rejected. A significant difference was found between the mean lean conformance values of these groups.

The third ANOVA test was performed among the companies with average annual turnovers between US$10–US$100 million (the medium–small companies) and US$100–US$1,000 million (the medium–large companies). The hypothesis test, with 95% confidence, is as follows:

$$H_0{:}\mu 1 = \mu 2; \qquad H_1{:}\mu 1 \neq \mu 2$$

The third ANOVA test results are shown in Table 11.

Because the F_{test} value (6.651) is larger than the F_{critic} value (4.241), H_0 was rejected. A significant difference was found between the average lean conformance values of the medium–small companies and the medium–large companies.

No test was applied to the group with average annual turnover of more than US$1,000 million because its sample size is too small ($N = 3$) and its average lean conformance is 86.66%, by far the highest average of all groups.

Discussion of Results

The comparatively high values of the sample average lean conformance (72.35%) and median (74%) promise a strong base for further lean construction studies and the application of the lean methodologies/tools. Additionally, the population average (μ) of the contractors between 67.50 and 77.19%, with 95% confidence interval, indicates a sound potential for a lean character that is capable of realizing the major lean construction concepts and principles. The comparatively higher figures may imply that, perhaps unknowingly or using a different terminology, some lean production–like methods have already been in practice in some of these companies.

The figures are promising for the future development of lean construction in operations among the construction companies in Turkey. Lean thinking and lean construction can systematically be introduced to and developed with contractors. This foundation is open to development and can enable the contractors to benefit

J. Manage. Eng., 2013, 29(3): 236-250

Table 9. ANOVA Analysis between Small and Medium–Small Companies

Group	Average	Variance	Sum of squares	Degree of freedom	Mean square	F	P value	F_{critic}
Annual turnover (U.S. dollars)								
$1–$10 million	66.743	189.215						
$10–$100 million	67.147	314.008						
Source of variation								
Between groups			1.181	1.000	1.181	0.005	0.946	4.210
Within groups			6,855.912	27.000	253.923			

Table 10. ANOVA Analysis between Small and Medium–Large Companies

Group	Average	Variance	Sum of squares	Degree of freedom	Mean square	F	P value	F_{critic}
Annual turnover (U.S. dollars)								
$1–$10 million	67.147	314.008						
$100–$1,000 million	81.800	89.498						
Source of variation								
Between groups			1,464.944	1.000	1,464.944	10.208	0.004	4.260
Within groups			3,444.274	24.000	143.511			

Table 11. ANOVA Analysis between Medium–Small and Medium–Large Companies

Group	Average	Variance	Sum of squares	Degree of freedom	Mean square	F	P value	F_{critic}
Annual turnover (U.S. dollars)								
$10–$100 million	67.147	314.008						
$100–$1,000 million	81.800	89.498						
Source of variation								
Between groups			1,431.468	1.000	1,431.468	6.651	0.016	4.241
Within groups			5,380.597	25.000	215.223			

from lean construction. It was also observed that 95% percent of the contractors either had never heard of the term lean construction or had no specific idea about it yet, as identified in the first contact with the companies. A broader search initiative for companies of different sizes, including people from various levels of the supply chain and organizational positions, may be deployed for a more refined analysis of the lean conformance in the country.

Regarding the subprinciples, the customer focus and culture/people subprinciples yielded relatively lesser values in terms of percent fulfillment from Fig. 4. The culture/people subprinciple focuses on systematically educating employees, listening to their ideas, and committing to incorporating every employee into the lean movement in a company. The second optimize value question under the customer focus subprinciple got the highest number (7) of NA answers. This question inquires whether or not customer needs are understood and agreed on by everyone that is going to serve the customers. The somewhat terminological tongue of the question might have contributed to the number of NA answers. In summary, according to the research, customer focus and culture/people issues should get comparatively more attention by lean practitioners.

The ANOVA applied between the classified companies (except for the largest company group) indicates that there is no significant difference between the small and medium–small companies in terms of their average lean conformance values. Conversely, it was found that the medium–large companies have a significant difference from both the small and medium–small companies in terms of their average lean conformance values. The larger companies were observed to have higher average lean conformance values. It can be inferred from the analysis that the medium–large and large companies can more easily adapt to the lean construction methodologies/tools, possibly owing to, for example, higher customer expectations, complex projects, economy of scale, more resources available for training and operational improvements, diverse and skilled workforce, stronger supplier and subcontractor relations, and consultancy. Thus, a lean construction dissemination effort can be first initiated from these kinds of larger companies. The question that comes to mind, of course, is the scope of this imitation and whether or not it is economically practical and rational, especially for the smaller construction companies, to embark on a lean construction journey. Being smaller, these companies can more flexibly choose among the lean construction methods and adapt with less effort.

According to the research, the small and medium–small companies have the lowest percentage of fulfillment in the customer focus and culture/people subprinciples. The medium–large companies, conversely, have the lowest percentage of fulfillment in the customer focus and continuous improvement/built-in quality subprinciples. The continuous improvement/built-in quality subprinciple is related to making quality inherent in projects. Partially, this means to have metrics to measure quality, to take proactive actions to prevent defective construction in the first place, to implement organizational learning and quality at the source, and to have a clear roadmap in case of under-quality production. The large companies have the lowest percentage of fulfillment in the culture/people and the standardization subprinciples. The standardization subprinciple primarily contains management with visual assistance (e.g., graphs, illustrations); workplace organization as a reflection of 5S methodology (short for *seiri*, *seiton*, *seiso*, *seiketsu*, *shitsuke*, 5S refers to a systematic housekeeping methodology); a construction site populated with other visual devices (e.g., production control using signals, cards, or in-station quality-control boards); and the standardization of, for instance, work procedures, work instructions, or checklists. All of the companies have comparatively high percentages of fulfillment in the subprinciple for the elimination of waste.

J. Manage. Eng., 2013, 29(3): 236-250

Table 12. Bottom Five Parameters for Different Company Groups

Rank	Overall	Small companies	Medium–small companies	Medium–large companies	Large companies
1	Optimize value—2 (3.16)	Optimize value—2 (3.16)	Flexible resources—1 (2.80)	Organizational learning (3.50)	Organizational commitment (3.67)
2	Reduce process cycle time—3 (3.25)	Metrics—2 (2.93)	Error proofing (2.93)	Optimize value—2 (3.58)	Training (3.67)
3	Optimize production system—1 (3.29)	Reduce process cycle time—3 (2.93)	Optimize value—2 (2.93)	Optimize production system—1 (3.67)	Optimize production system—2 (3.67)
4	Flexible resources—1 (3.34)	Training (3.00)	Reduce process cycle time—3 (2.93)	Reduce process cycle time—3 (3.75)	People involvement (4.00)
5	Flexible resources—2 (3.38)	Reduce process cycle time—1 (3.00)	Flexible resources—2 (3.00)	Flexible resources—2 (3.83)	Organizational learning (4.00)

This seems logical because the reduction of waste directly reduces the cost of a production process; therefore, it is subject to prioritized attention from the management.

Considering the questions that have the five lowest average values among all of the companies (overall), as shown in Table 12 (second column), the second optimize value, third reduce process cycle time, first optimize production system, first flexible resources, and second flexible resources questions got the lowest mean values. The second optimize value question relates to understanding and clarifying the value that is created through any project. This understanding should be realized and shared with employees and customers. The third reduce process cycle time question investigates whether or not some risk-management techniques are utilized. The first optimize production system question focuses on the level of continuous flow in a production unit. The idea of flow (see Koskela 2000) seems alien to the companies. The first flexible resources question corresponds to how customer focused and flexible the companies are to comply with the changing customer expectations. The second flexible resources question focuses on the degree of flexibility of a company, primarily toward environmental changes.

The small companies have the lowest average values (Table 12, third column) at the second optimize value, second metrics, third reduce process cycle time, training, first reduce process cycle time, optimize work content, defined work processes, first flexible resources, first optimize value, and first optimize production system questions. The second metrics question focuses on the existence of some objective metrics about construction processes. The training question investigates whether or not the companies allocate resources for the training of their employees. The first reduce process cycle time question relates to whether or not the projects are evaluated in terms of their constructability in addition to their costs and conformities to the present codes and specifications. The optimize work content question measures the degree of utilization of standard, prefabricated, preassembled, and repetitively usable construction elements. The defined work processes question deals with whether or not the work processes are systematically mapped. The first optimize value question deals with systematic investigation of the customer needs throughout a project. These specified points seem to demand the most attention from the small companies.

The medium–small companies have the lowest average values (Table 12, fourth column) at the first flexible resources, error proofing, second optimize value, third reduce process cycle time, second flexible resources, first optimize production system, first metrics, defined work processes, organizational commitment, and training questions. The error proofing question investigates the existence of proactive measures and mistake-proofing devices against defects at a company. The first metrics question focuses on the existence of some objective metrics regarding material waste. The defined work processes question focuses on whether or not the processes are systematically mapped. The organizational commitment question deals with how open and committed upper management is to change.

The medium–large companies have the five lowest average values at the organizational learning, second optimize value, first optimize production system, third reduce process cycle time, and second flexible resources questions. The organizational learning question deals with capturing, analyzing, and distributing both implicit and explicit data from the projects and making inferences from these data.

The large companies have the lowest average values at the organizational commitment, training, second optimize production system, people involvement, organizational learning, second

J. Manage. Eng., 2013, 29(3): 236-250

Table 13. Average Lean Conformance Values by Operational Duration

Number of companies	Operational duration (years)	Average lean conformance (percentage)[a]	Average				
			Culture/ people	Continuous improvement	Customer focus	Elimination of waste	Standardization
31	>20	74.7 (15.77)	8.49	14.86	11.45	27.71	12.18
4	10–15	66.8 (17.10)	8.8	12.2	9.8	24.6	11.4
5	5–10	63.2 (17.57)	8.16	13.92	8	21.44	11.68
4	0–5	71 (9.93)	9.4	14.4	10.8	27	9.4

[a]Values in parentheses are corresponding standard deviation values.

flexible resources, second optimize value, first supply chain management, first optimize production system, second visual management, and defined work processes questions (Table 12). The second optimize production system question measures the degree of flexibility of the workforce. The people involvement question investigates whether or not the employees' experiences and ideas are utilized. This can be harder for the larger companies because of their sizes. The first supply chain management question focuses on the existence of just-in-time delivery, which may be highly affected by external factors. The second visual management question focuses on how up to date the visual management tools (boards) are. Although the sample size of the large companies is small in this paper, it can be said that the number of the larger companies in the whole population is also minor. Therefore, some inferences can be made from the present sample. The bottom five parameters (with average values) for the company groups and the overall results that have been explained in this section are shown in Table 12.

When the companies were clustered by their operational durations and the main lean conformance principles (see Table 13), it was observed that the oldest companies (more than 20 years in operation) have the highest average lean conformance value (the corresponding standard deviation values are shown in brackets in Table 13). Interestingly, the youngest company cluster (0–5 years in operation) yields the second-best average lean aptitude value. The figures suggest that a successful lean dissemination effort can be ideally started at either a relatively older or younger company, perhaps by using different systems and implementation methods. To make a more robust conclusion, more data from the companies operating for less than 20 years may be necessary, because the current data predominantly represent the older companies.

Conclusion and Recommendations

The lean construction concept, which has been promoted as an alternative approach for improving the performance of the construction industry, has not yet been adopted and is not yet known adequately by the construction companies operating in Turkey. The prevalent lack of awareness of lean construction in Turkey is concurrent with the findings of Johansen et al. (2002), Johansen and Walter (2007), and Senaratne and Wijesiri (2008) for other countries. Although lean construction might be alien to the companies, it was found that they possess a relatively high readiness for, approval of, and conformance to the lean construction practices

Culture/ People		
	People Involvement	
Employees do not share their ideas/point of views in the name of improving the company's operations.	1 | 2 | 3 | 4 | 5 | N/A ☐ ☐ ☐ ☐ ☐ ☐	Employees share their ideas/point of views to improve the company's processes and to reduce the waste. The company has some mechanisms to provide this.
	Organizational Commitment	
Upper-level management seems satisfied with the status quo.	1 | 2 | 3 | 4 | 5 | N/A ☐ ☐ ☐ ☐ ☐ ☐	Upper-level management endeavours to change the company's culture in the name of increasing organizational effectiveness.
	Training	
The company does not allocate time and money for the activities (seminars, educational meetings etc.) that enrich employees' present knowledge and capabilities.	1 | 2 | 3 | 4 | 5 | N/A ☐ ☐ ☐ ☐ ☐ ☐	The company, consciously and systematically, sustains activities that enrich employees' present knowledge and capabilities for the changing needs.

Fig. 5. Culture/people

J. Manage. Eng., 2013, 29(3): 236-250

in their operations. Admittedly, some findings may be the reflection of the positive wishes of the managers (with too optimistic, rather than realistic, views of their companies), yet they also shows an approval of the core lean construction concepts, at least at a conceptual level. This conformance/approval can be exploited to build up, refine, and disseminate the lean construction concept among the companies in the country. The large and/or older companies may present the initial ground for this kind of dissemination because they seem to have the highest average conformance scores comparatively, which is a statistically meaningful positive difference from the rest in terms of lean conformance. Expectedly, these companies also have access to more resources to deploy for this kind of an initiative. However, a smaller and younger company can offer some flexibility in application and experience a quick return on investment. Additionally, some weak points for each group of companies in different sizes were identified to form a basis for

Continuous Improvement/ Built – in – Quality		
	Metrics- 1	
Unused and/or unnecessarily purchased materials and tools are frequently put aside. These materials and tools are either wasted or returned to the supplier at the end of the job.	1 | 2 | 3 | 4 | 5 | N/A ☐ ☐ ☐ ☐ ☐ ☐	There is a concrete system in the company that measures and evaluates the quantity of unused and/or unnecessarily purchased materials and tools.
	Metrics- 2	
Some metrics about production (Worker – machine productivity, production defect ratios, material waste ratios, the ratio of real time – cost performance to the planned figures and so on.) are not clearly, systematically and objectively measured.	1 | 2 | 3 | 4 | 5 | N/A ☐ ☐ ☐ ☐ ☐ ☐	Some metrics about production are clearly, systematically and objectively measured, recorded and analyzed. These standard measures are taken into account while evaluating project successes.
	Response to Defects	
Production defects are usually identified randomly. The decision of whether production will be stopped or not, after the identification of production defects, are completely left to the will of the crew that is responsible for that production.	1 | 2 | 3 | 4 | 5 | N/A ☐ ☐ ☐ ☐ ☐ ☐	In the identification of defects, there is a guiding quality plan that defines the duties and the responsibilities of people within any project. Crews and individuals behave according to this quality plan in case of a production defect.
	Error Proofing	
The precautions against production defects are limited to defect correctors that are put into application after the occurrence of any defect. These precautions have a reactive nature.	1 | 2 | 3 | 4 | 5 | N/A ☐ ☐ ☐ ☐ ☐ ☐	The precautions against production defects are preventive measures that are put into application before the occurrence of any defect. These precautions have a proactive nature.
	Organizational Learning	
Each project is evaluated separately. An effective database, created from the objective and the subjective data of the past projects, has not been constituted. Some inferences are not driven from the past projects to use for the future projects.	1 | 2 | 3 | 4 | 5 | N/A ☐ ☐ ☐ ☐ ☐ ☐	For the company, effectively recording project data, employees' knowledge and ideas, analyzing these data, presenting these data to the related departments on time and applying necessary change by the inferences driven from these data are among priorities. During the realization of any future project, these data are extensively utilized.

Fig. 6. Continuous improvement/built-in quality

J. Manage. Eng., 2013, 29(3): 236-250

future research and development efforts within the lean construction concept.

A broader research initiative without some of the limitations of this research effort needs to be conducted for a better understanding of lean construction conformance at construction companies in Turkey. Possibly with the help of governmental and nongovernmental organizations, a similar research effort can be repeated with a larger and more evenly distributed data set for diverse comparison and analysis opportunities. For instance, out of 44 companies studied in this research, 31 have more than 20 years of operational duration. The remaining 13 companies are distributed among the three other data groups representing the operational duration parameter. The unevenness in the data set obstructs a comparative analysis among the companies on the basis of their operational durations and many other parameters.

In-depth studies are necessary to check the validity of the findings presented in this paper and to identify the differences between the managerial understanding of a good practice in reality and its definition in theory—for instance, how well the definition of waste in the lean production literature, which in essence is quite broad, overlaps with managerial understanding of waste remains unidentified. It is suggested that all poor operational practices identified in Table 12 from the lean construction point of view should be investigated carefully, regardless of the size of the construction companies. It is also advised that a similar study be repeated with selected companies and management teams that are informed about

<table>
<tr><th colspan="3"><u>Customer Focus</u></th></tr>
<tr><th colspan="3"><u>Flexible Resources- 1</u></th></tr>
<tr><td>Working by customer focus is not explicitly stated among the strategic goals. The features of the main resources, such as material, tools and man power, are in a static nature and predominantly determined by the management.</td><td>1 | 2 | 3 | 4 | 5 | N/A
☐ ☐ ☐ ☐ ☐ ☐</td><td>Being customer focused is one of the strategic goals. The features of the main resources, such as material, tools and man power and the elements, like the employed technology and the organizational structure within the, are in a dynamic nature and in a change according to the expectations of customers.</td></tr>
<tr><th colspan="3"><u>Flexible Resources- 2</u></th></tr>
<tr><td>The company has to consume substantial amount of resources in order to comply to the environmental change, such as changing customer needs.</td><td>1 | 2 | 3 | 4 | 5 | N/A
☐ ☐ ☐ ☐ ☐ ☐</td><td>The company has a flexible nature. It can adapt to the environmental change with consuming relatively lesser amount of resources.</td></tr>
<tr><th colspan="3"><u>Response to Defects</u></th></tr>
<tr><td>Production defects are usually identified randomly. The decision of whether production will be stopped or not, after the identification of production defects, are completely left to the will of the crew that is responsible for that production.</td><td>1 | 2 | 3 | 4 | 5 | N/A
☐ ☐ ☐ ☐ ☐ ☐</td><td>In the identification of defects, there is a guiding quality plan that defines the duties and the responsibilities of people within any project. Crews and individuals behave according to this quality plan in case of a production defect.</td></tr>
<tr><th colspan="3"><u>Optimize Value- 1</u></th></tr>
<tr><td>Some problems are experienced about studying the customer needs throughout a project, understanding them correctly and constructing by these needs.</td><td>1 | 2 | 3 | 4 | 5 | N/A
☐ ☐ ☐ ☐ ☐ ☐</td><td>It can be said that the customer needs are studied throughout a project, understood correctly and the necessary construction is executed by these needs.</td></tr>
<tr><th colspan="3"><u>Optimize Value- 2</u></th></tr>
<tr><td>The value created by means of a project is defined separately by each and every party involved.</td><td>1 | 2 | 3 | 4 | 5 | N/A
☐ ☐ ☐ ☐ ☐ ☐</td><td>The value created by means of a project is defined with the customer and for the whole of a project. It is ensured that this value is understood by every party involved.</td></tr>
</table>

Fig. 7. Customer focus

J. Manage. Eng., 2013, 29(3): 236-250

Eliminate Waste		
Supply Chain Management- 1		
Materials, prior to their use, are stored in somewhere near the construction site.	1 | 2 | 3 | 4 | 5 | N/A ☐ ☐ ☐ ☐ ☐ ☐	Materials predominantly arrive to the construction site just before their use. Storage is at its minimum.
Supply Chain Management- 2		
Materials stay at a specific place, no matter where their location of use is on the construction site.	1 | 2 | 3 | 4 | 5 | N/A ☐ ☐ ☐ ☐ ☐ ☐	Materials stay at the possible closest place to their location of use on the construction site.
Optimize Production System- 1		
The output of a production unit gets into its successor production unit as an input, either in huge amounts or being totally completed. The production chain is discontinuous.	1 | 2 | 3 | 4 | 5 | N/A ☐ ☐ ☐ ☐ ☐ ☐	The output of a production unit gets into its successor production unit as an input, in a continuous manner and in lesser amounts.
Optimize Production System- 2		
The number of employees in a production unit at the construction site is not changed. There is only one production unit for each individual, in which they can work efficiently.	1 | 2 | 3 | 4 | 5 | N/A ☐ ☐ ☐ ☐ ☐ ☐	The number of employees in a production unit at the construction site can be changed depending on the needs of their successor production units. Each individual can work in more than one production unit efficiently.
Optimize Production System- 3		
There is no planning and control department in the company.	1 | 2 | 3 | 4 | 5 | N/A ☐ ☐ ☐ ☐ ☐ ☐	There is a planning and control department in the company, with its authority and responsibilities clearly defined. This department is efficiently utilized.
Reduce Process Cycle Time- 1		
Projects, prior to their starts, are evaluated according to their approximate costs and their conformances to the related codes and specifications.	1 | 2 | 3 | 4 | 5 | N/A ☐ ☐ ☐ ☐ ☐ ☐	Projects, in addition to their approximate costs and conformances to the related codes and specifications, are evaluated also according to their constructability. The points, that are believed to cause waste of resources and some discontinuity in the production line and that are believed not to contribute to meeting customer needs, are tried to be changed.
Reduce Process Cycle Time- 2		
The departments (Civil, mechanical, electrical, architectural, environmental etc.) operate in their areas of responsibility. There is no intensive connection between each other.	1 | 2 | 3 | 4 | 5 | N/A ☐ ☐ ☐ ☐ ☐ ☐	Coordination and cooperation between the departments (Civil, mechanical, electrical, architectural, environmental etc.) are intensive
Reduce Process Cycle Time- 3		
Risk management techniques are not utilized within projects.	1 | 2 | 3 | 4 | 5 | N/A ☐ ☐ ☐ ☐ ☐ ☐	Risk management techniques, according to the features of projects, are always utilized with different methods and scales.
Optimize Work Content		
Standard, pre-fabricated, pre-assembled, repetitively usable construction elements have very rarely or never been used.	1 | 2 | 3 | 4 | 5 | N/A ☐ ☐ ☐ ☐ ☐ ☐	Standard, pre-fabricated, pre-assembled, repetitively usable construction elements have been consciously preferred. The company desires and works for the wider standardization of their use.

Fig. 8. Elimination of waste

J. Manage. Eng., 2013, 29(3): 236-250

lean construction. A case study or ethnographic research study in which researchers work more closely with construction companies will be useful for providing a complete picture of lean conformance and checking the validity of the findings of this research. Additionally, future lean conformance research can be designed to extend into construction sites, incorporating construction site managers, foremen, and construction workers in the research effort. This study is missing valuable perceptions of and information from such operational people on the lean conformance of their companies.

The relatively higher conformance values can be the leverage in the introduction of new concepts. The apparent lack of awareness of lean construction in Turkey calls for different channels of dissemination (e.g., university curricula; consultancy; workshops; governmental programs; and individual, organizational, or national initiatives). There can also be some lean construction–like methods in place that have been developed through logic and common sense at the companies unaware of lean construction. Those lean construction–like practices and the conceptual approval (or positively biased view) of the managers of lean construction possibly contribute to the relatively higher lean conformance value. Proven benefits achieved through adopting lean construction and the existence of some local benchmark companies will be useful for the industry to take an interest in lean construction. Nevertheless, this study may be understood as part of an initial step for lean construction application and research in the Turkish construction industry, which is an important portion of the country's economy.

Similar research of this nature can be repeated in different countries to compare the lean conformance values and characters. A similar longitudinal study, which covers a longer time period to evaluate an initiated lean construction program, can also contribute to demonstrating the benefits gained from the lean construction concepts at different construction companies. By presenting one of the first comprehensive research efforts on lean construction in Turkey, hopefully this paper will help raise the awareness of lean construction in the country.

Appendix. Questionnaire Contents

Figs. 5–9 present the questions answered by company managers to identify the lean conformance levels at their companies.

Standardization		
	Visual Management- 1	
Some visual tools, that inform employees about the matters like the production condition, schedule, safety, productivity, level of production quality and so on, have not been used.	1 | 2 | 3 | 4 | 5 | N/A ☐ ☐ ☐ ☐ ☐ ☐	Some visual tools, such as documents and pictures, about the matters like the production condition, schedule, safety, level of production quality and so on, have been used and are accessible to anyone at the offices and on the construction sites.
	Visual Management- 2	
The informative tools are updated at different intervals. These updates are sometimes frequent and sometimes seldom.	1 | 2 | 3 | 4 | 5 | N/A ☐ ☐ ☐ ☐ ☐ ☐	The informative tools are updated frequently and prepared to be understandable for everyone.
	Workplace Organization	
There is no pre - defined order at the offices and the construction sites. The order and the cleaning at these places, depending on the conditions, are at the personal initiatives of the office and the site managers.	1 | 2 | 3 | 4 | 5 | N/A ☐ ☐ ☐ ☐ ☐ ☐	The firm systematically pays attention to keeping the offices and the construction sites clean, materials and tools sorted orderly by their types and places of usage. There are company – wide standards in order to keep this system running. Chaos and dirt are never allowed.
	Defined Work Processes	
There is no study on work processes on a company-wide scale. Employees, within their responsibilities, are expected to manage their own work processes.	1 | 2 | 3 | 4 | 5 | N/A ☐ ☐ ☐ ☐ ☐ ☐	Work processes are systematically, consciously and continuously monitored. The visual maps of these processes, that show the flow of materials, equipments, man power and financial resources, are uncovered. Processes are identified.

Fig. 9. Standardization

J. Manage. Eng., 2013, 29(3): 236-250

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J. Manage. Eng., 2013, 29(3): 236-250