International Review of Management and Marketing
Vol. 3, No. 4, 2013, pp.212-225
ISSN: 2146-4405
www.econjournals.com

Critical Success Factors for Six Sigma Implementation in Large-scale Turkish Construction Companies

Mehmet Tolga Taner
Uskudar University, Istanbul 34662, Turkey.
Email: mehmettolga.taner@uskudar.edu.tr

ABSTRACT: This paper aims to investigate the Critical Success Factors (CSFs) for the successful introduction of Six Sigma in large-scale Turkish construction companies. A survey-based approach is used in order to identify and understand the current quality practices. CSFs and impeding factors are identified and analysed. Involvement and commitment of top management, linking quality initiatives to customer and linking quality initiatives to supplier are found to be the most important CSFs to the construction companies. Leadership and commitment of top management, cross-functional teamwork and commitment of middle managers are found to be the most CSFs for successful introduction of Six Sigma, whereas lack of knowledge of the system to initiate and complacency are found to be hindering its implementation. High costs and high amount of waste are found to lower the performance of Turkish construction companies.

Keywords: Six Sigma; construction industry; large-scale companies; Turkey
JEL Classifications: L15; L74

1. Introduction

While driving economic activity and leading to wealth creation, construction industry has a major effect on every citizen on the planet. The role which it plays in many economies and its contribution to employment potential and Gross Domestic Product (GDP) should not be underestimated. Its contributions are estimated to be in the order of 7% of global employment, 10% of the world's GDP, 40% of global energy consumption and as much as 50% of global resource usage (Stewart and Spencer, 2006).

Being one of the major industries in Turkey, Turkish construction industry represents approximately 6% of Turkey's Gross National Product (GNP). From the end of 1950s, it evolved into its current format and represents approximately 6% of Turkey's GNP. Turkey started to export contracting services in 1972. Eight years later, a huge increase in the domestic market has accompanied a rising trend in the foreign markets (Kazaz and Ulubeyli, 2009). Ranking 2nd only to China in 2012, where Turkey's construction companies had carried out $206.4 billion worth of international projects in foreign countries mainly through construction and contracting activities, thirty-three of which were selected for the "Top 225 International Contractors List" as prepared by the Engineering News-Record (Engineering News-Record, 2012; Turkish Contractors Association, 2012). Undertaking all kinds of industrial and civil engineering projects, and taking high risks while using advanced marketing technologies, their ability to design, build and fulfill has made them a successful option in countries such as the Russian Federation, Middle East countries, Turkic Republics and North Africa.

The construction industry has continued to be a substantial industry in Turkey in spite of the global economic crisis in 2009. Arditi and Gunaydin (1997) argue that the drawbacks of small and medium Turkish construction companies are the inefficient use of money, resources (both human and material) combined with inadequate quality management procedures. In the absence of a clear standardized evaluation tool, this project based industry which comprises of many different organizations having diverse performance and quality approaches will remain difficult to evaluate. On the other hand, large-scale Turkish construction companies while showing some quality problems in terms of poor workmanship, quality problems in material utilized, error in design and lack of supervision, have nonetheless started to embrace the use of standardized quality systems such as ISO

9001 (Kazaz and Ulubeyli, 2009). Since the quality in construction projects is highly dependent on the abilities and commitments of the consultants and contractors involved, it is an area where a total quality approach in all construction projects with the aim of eliminating inefficiencies and waste might be successfully implemented (Pheng and Ke-Wei, 1996).

A number of sources such as Love (1996), and Hampson and Tatum (1997) allued to the fact that construction while dependent on complex communication between large number of individuals and interacting functions is replete with problems relating to variation, non-value adding activities and waste; the latter of which is considered to be the major source of financial loss within the industry. In addition to these, industry researchers and practitioners include wasteful activities during the design and construction process as well as time loss as other major cost factors.

Waste of materials is not the only source which contributes to financial loss in the construction process. Other factors such as reworks/repairs, defects, material waste, delays, waiting, poor material allocation, unnecessary material handling and material waste have been identified by Alarcon (1995), Alwi (1995), Koskela (1993), Robinson (1991), and Pheng and Hui (1999). Kaming et al. (1997) determined that lack of material, rework/repair, lack of equipment and supervision delays are the factors influencing productivity in the construction industry. Garas et al. (2001) defined construction waste using two main components as time wastes (e.g waiting periods, stoppages, clarifications, variation in information, rework, ineffective work, interaction between various specialists, delays in plan activities and abnormal wear of equipment) and material wastes (e.g. comprising over ordering, overproduction, wrong handling, wrong storage, manufacturing defects and theft or vandalism). Graham and Smithers (1996) chose to focus on constructional waste during different project phases such as design (e.g., plan errors, detail errors and design changes), procurement (e.g. shipping error and ordering error), materials handling (e.g. improper storage, deterioration and improper handling on and off site), operation (e.g. human error, trades person, labour, equipment error, accidents and weather), residual (e.g. leftover and unreclaimable non-consumables) and others (e.g. theft, vandals and clients actions). In addition, they identified the clients themselves as a possible source of waste through careless inspection procedures and variation orders during the process. Improper planning at the design stage may also lead to waste if the need for overorder to avoid shortage of materials on site becomes an issue.

Alarcon (1994) and Formoso et al. (1999) suggest that construction wastes can also result from activities such as overproduction, waiting time, material handling, processing, inventories and movement of workers. Alwi et al. (2002) proposes that identification of waste, non-value added activities, their causes and an assessment of their level of importance, can also provide valuable information to empower managers to be proactive and thus reduce negative effects in advance.

In addition to the waste problems, construction are also affected by other problems related to production, general quality of work, design changes, material quality and availability and capacity utilization (Akintoye, 1995). Koskela (1993), Alarcon (1993) and Chan et al. (1997) determined low productivity, poor safety, inferior working conditions and insufficient quality as recurring problems of construction. Lack of human resource development in additions to equipment shortages, inefficiencies in using materials, imbalances in organizational structure, unfair competition, limited funds and planning uncertainties have also been identified by Alwi et al. (2002). He concluded that issues such as disputes and litigations, delays in planned schedule, quality problems and cost overruns have also contributed to construction failures.

The products of construction are large in scale and very varied in kind. This variation is one of the critical problems within the construction process. Sources of variability may include late delivery of equipment and material, design errors, change orders, equipment breakdowns, tool malfunctions, improper crew utilization, labor strikes, environmental effects, poorly designed production systems, accidents and physical demands of work (Abdelhamid and Everett, 2002). These sources need to be reduced or totally removed in order to improve the performance. Schonberger (1986) suggests that reduced cycle times and increased productivity can be achieved by eliminating the root causes of variability. Koskela (1992) says that a decrease in the volume of non-value-adding activities coupled with increased customer satisfaction can be achieved by reducing process variability.

Egan (1998), in his report, listed criteria such as unacceptable level of defects, lack of predictability, lack of contractor profit, need for customer feedback, lack of investment in capital,

research, development and training and level of dissatisfaction amongst the industry's clients as being responsible for underachievement within the industry as a whole.

Arslan and Kivrak (2009) carried out among forty Turkish construction companies which are located in the northwest region of Turkey to investigate the critical factors leading to construction company success. They found that business management, financial conditions and owner-manager characteristics were identified as the most important main factors to success.

Clearly, the construction industry is plagued by problems which exacerbate each other. Therefore, elimination of these problems at project inception can only lead to greater efficiencies. Thus, the identification and elimination of waste in materials and time, and chronic construction problems in order to improve project performance, productivity, quality and customer satisfaction must be foremost in planning construction. In addition to this, sensitivity must be shown to the environment and resources in the industry. This, in turn, would lead to cost savings within the society (Düğme, 2008). The ability to meet the contractual goals is the benchmark of quality in the construction industry. This ability is also seen as a fundamental way of meeting customer needs as closely as possible. Customers are increasingly demanding in their expectations and customer satisfaction drives company policy and affects profitability within the industry (McCrary et al., 2006). However, Shammas-Toma et al. (1998) acknowledge the fact that variability in customer expectations cannot be totally eliminated.

In their attempts at customer satisfaction, construction companies have overlooked the criteria which contribute to inefficiencies, unreliable workflow and process variability (Tommelein, 2000; Hopp and Spearman, 2000; Howell et al., 2001; Thomas et al., 2002). Dugme (2008) pointed out that for being more competitive, the Turkish construction industry recognized the importance of quality, performance, productivity, achieving excellence and focusing on the customers' growing expectations in the last decade.

It is essential that through continuous reassessment, the Turkish construction industry should undertake measures for an improved outcome in keeping with ever changing expectations of quality and performance. To achieve this, there is a need to offer a more sophisticated and efficient quality management method for the Turkish construction industry. In order to maintain a higher standard quality level and eliminate waste in construction operations, Six Sigma Methodology can be employed in these companies. Therefore, this paper aims at understanding the needs of Turkish construction industry from process improvement perspectives and matches these needs with the expected outcomes of Six Sigma; and investigates the CSFs for the successful implementation of Six Sigma in large-scale Turkish construction companies.

2. Literature Review

Six Sigma, originally initiated by Motorola, Honeywell and General Electric, is a powerful performance improvement tool that is changing the face of modern industries today. It is a people-focused management system that works by involving all employees, top-to-bottom, as a structured team. It aims to continually increase customer satisfaction by reducing real costs through a reduction in variation and causes of poor quality or waste (Klefsjo et al., 2001).

Six Sigma recognizes that business quality is the highest when costs of delivering products and services to meet customer requirements are at the absolute lowest for both the producer and the consumer (Pheng and Hui, 2004). For the construction sector, Six Sigma improvement methods are not about being totally defect-free or having all processes and products at Six Sigma levels of performance (Linderman et al., 2003). Instead, the appropriate level will depend on the strategic importance of the process and the cost of its improvement relative to the benefit (Brue, 2002). Schonberger (2008) and Chakravorty (2009) have pointed out that the objective of Six Sigma is to create a higher perceived value of the company's products and services in the eyes of customers.

Yet, the implementation of Six Sigma has started to extend beyond the manufacturing and service industries (Antony et al., 2008; Kumar, 2007, Taner, 2012; Taner et al., 2012). The relevance of Six Sigma has been successfully proven across the industrial spectrum from shop floor personnel to senior management level in the organizations which have embraced it. The companies which have invested in and implemented Six Sigma (i.e. allocated a special budget to launch it and created a separate organizational culture), have been rewarded with reduced operational costs and defect rates, achieved high rates on business profits, increased employee morale, improved quality of final product.

In addition to these, customer loyalty and Return on Investment (ROI) have also shown measurable improvement (Kumar, 2007; Kumar and Antony, 2009; Snee, 2004).

Six Sigma has the potential to improve processes in the construction industry. Applying Six Sigma in construction may involve breaking down large tasks into smaller ones that can be re-engineered and improved. The structured and systematic framework of Six Sigma, combined with the employment of statistical techniques, can make it a robust tool for process diagnostics, which is an integral task of modern construction managers. High customer satisfaction and the discovery of essential factors for its improvement can be analyzed using the Six Sigma's DMAIC model. This model can be implemented to study the influences driving the construction process, affecting quality and then to design a technique aimed at correcting and improving these factors.

Very little research has been conducted on Six Sigma applications in construction operations so far. Abdelhamid (2003) was the first academician to suggest a Six Sigma application to reduce the variability in a construction process. Cha and O'Connor (2005) described the Six Sigma Methodology as one of forty-four state-of-the-practice tools for value management applicable to a construction project. Six Sigma principles were applied in residential construction (Abdelhamid and Thanveer, 2005; Shan and Li, 2013), concrete longitudinal beams construction (Stewart and Spencer, 2006), precast construction (Chang et al.), prefabricated composite construction (Tchidi, 2011), concrete panel production system (Celep et al., 2012) and the production of ready concrete mixture plant (Karakhan and Alsaffar, 2013).

Pheng and Hui (2004) identified management initiative and support, relevant training, appropriate selection of pilot projects and commitment by team members as crucial factors for successful implementation of Six Sigma in a construction company.

While Yilmaz (2012) and Tchidi et al. (2012) showed that Six Sigma principles was feasible in construction quality management. many researchers investigated the possibilities of integrating Lean and Six Sigma (Han et al., 2008; Shan and Li, 2013; Al-Aomar, 2013).

3. Methodology and Data

In this study, a survey-based approach is used to identify the Continuous Improvement (CI) initiatives commonly practised in large-scale Turkish construction companies as well as understanding the approach of these companies to Six Sigma. The 24-item questionnaire was tailored from Kumar and Antony (2009) and Dugme (2008) with the purpose of identifying the CSFs for implementing Six Sigma in these companies (see Appendix). In the context of Six Sigma implementation, CSFs are the essential ingredients without which company's performance stands little chance of success (Antony and Banuelas, 2002).

Survey was carried out among top-level managers and owners of the companies in 2012. They were selected for the interviews due to their knowledge about the organizational structure, culture and strategies. The questionnaire was emailed to 152 large-scale (i.e. recruiting more than 100 employees) companies operating in the construction industry. Seventy-one companies (46.71%) returned the questionnaire. Therefore, the sample size (n=71) is statistically called as large ($n \geq 30$) for representing the whole.

4. Analysis

The respondents of the survey consisted of forty-nine quality managers (69.02%), seventeen managing directors (23.94%) and five CEOs (7.04%). They were asked to rate the importance of the fifteen short-term strategic objectives for their companies. Then, they were asked to give information regarding the quality initiatives deployed in the past and present. Following this, they were asked to rate the importance of twenty-six CSFs necessary for and the five impeding factors that will be hindering the introduction of Six Sigma as a new quality initiative in their companies. Finally, they were asked to rate the thirteen possible reasons lowering the performance of their companies. The respondents made use of the likert scale of 1 to 5 while rating the importance of CSFs, e.g. rating as 1 corresponding to "not important at all", 2 corresponding to "not important", 3 corresponding to "neither important nor not important", 4 corresponding to "important" and 5 corresponding to "very important". Consequently, ratings are collected and averaged.

Table 1. Importance of the short-term strategic objectives of companies

Strategic Objective	Mean Rating	Standard Deviation	Rank
Profitability	4.750	0.440	1
Customer satisfaction	4.394	0.492	10
Quality	4.521	0.503	8
Creativity/Innovation/Aesthetics	4.197	0.401	12
Research and Development	4.197	0.401	12
Lower costs	4.732	0.446	2
Credibility	4.634	0.485	5
Higher market share/Higher competitive power	4.662	0.476	3
Reputation/Nice company image	4.437	0.499	9
Further growth	4.606	0.492	6
Social responsibility	3.789	1.094	15
Effective use of resources	4.648	0.481	4
More financial strength	4.577	0.497	7
Employee Satisfaction	3.831	0.654	14
Higher Technology	4.366	0.485	11
Benchmarking	2.986	0.621	16

Table 1 summarizes the factors defining the strategic objective(s) of the large-scale Turkish construction companies. Profitability (4.750), lower costs (4.732) and high market share/high competitive power (4.662) are found to be the three most important strategic objectives in short-term.

Table 2. History of quality initiatives in companies (n=71)

Quality Initiatives Undertaken/Accredited	Frequency	%
ISO 9001 Quality management systems : Requirements	69	97.18
ISO 14001: Environmental Management Standard	51	71.83
OHSAS 18001: Occupational Health and Safety Assessment	46	64.79

The results show that all companies under study have quality departments and that their employees are trained for quality. It is revealed that most large-scale Turkish construction companies (69 out of 71, i.e. 97.18%) are ISO 9001-certified and added that 71.83% and 64.79% of them have also undertaken ISO 14001 and OHSAS 18001, respectively (Table 2).

Companies were asked to identify the inhibiting factor that was felt to be barriers to quality initiative implementation. As shown in Table 3, 36.62% of the responding enterprises stated that poor employee participation was the most common factor in the companies. This was followed by lack of knowledge and internal resistance.

It is crucial to understand the perception of Six Sigma and factors preventing its implementation from the companies' perspective. Companies were asked to state the reasons for not implementing Six Sigma as an initiative to drive CI effort within their enterprises. Table 4 shows that 42.25% of the companies were discouraged to implement Six Sigma due to lack of knowledge of the system to start the initiative. This was followed by complacency (32.39%) and other competing quality initiatives such as ISO (21.13%).

Table 3. Barrier to implementation of a new quality improvement initiative in construction companies

Reasons for not implementing quality initiatives	Frequency	%	Rank
Internal resistance	15	21.13	3
Lack of knowledge	18	25.25	2
Lack of top management commitment	12	16.90	4
Unavailability of resources	0	0	5
Changing business focus	0	0	5
Inadequate process control techniques	0	0	5
Poor employee participation	26	36.62	1
Lack of training	0	0	5

Table 4. Reason for not implementing Six Sigma in companies

Reasons for not implementing Six Sigma	Frequency	%	Rank
Lack of knowledge of the system to initiate	30	42.25	1
Complacency/ People prefer status quo	23	32.39	2
Availability of Staff/Time for Projects	0	0	5
Other competing quality initiatives such as ISO	15	21.13	3
Cost	3	4.23	4

CSFs, their mean importance and standard deviation are given in Table 5. All of the mean ratings are above 3.750. Therefore, the majority of the respondents have rated the importance of the CSF to company as above average (3.750 › 2.500). The three most important CSFs cited across the companies are found to be involvement and commitment of top management (4.746), linking quality initiatives to customer (4.732) and linking quality initiatives to supplier (4.662), respectively. The CSF with the least variation is found to be linking quality initiatives to employee. The three most common important CSFs cited across the companies for successful introduction of Six Sigma are found to be leadership and commitment of top management (4.875), cross-functional teamwork (4.761) and commitment of middle managers (4.718), respectively.

Table 5. CSFs and Mean Ratings of Importance

Question	CSF	Mean Rating	Standard Deviation	Rank	Cronbach's alpha
Importance of CSF to company	Involvement and commitment of top management	4.746	0.438	1	0.71
	Organizational infrastructure	4.394	0.492	10	0.68
	Vision and Planning	4.521	0.503	8	0.74
	Linking Quality Initiatives to Employee	4.197	0.401	11	0.72
	Linking Quality Initiatives to Customer	4.732	0.446	2	0.73
	Linking Quality Initiatives to Business	4.634	0.485	5	0.70
	Linking Quality Initiatives to Supplier	4.662	0.476	3	0.73
	Project selection	4.437	0.499	9	0.71
	Project management skills	4.606	0.547	6	0.76
	Information Technology and innovation	3.789	1.094	14	0.69
	Communication	4.648	0.481	4	0.75
	Teamwork	4.577	0.497	7	0.73
	Cultural change	3.831	0.654	13	0.73
	Education and training	4.155	0.856	12	0.71
CSFs for successful introduction of Six Sigma as a quality initiative in company	Leadership and Commitment of top management	4.875	0.355	1	0.75
	Strategic vision	4.592	0.485	8	0.74
	Change management	4.225	0.513	11	0.72
	Commitment of middle managers	4.718	0.484	3	0.72
	Funds	2.577	0.552	12	0.73
	Education and training	4.535	0.502	9	0.74
	Empowerment of employees	4.549	0.501	7	0.76
	Communication	4.690	0.466	4	0.71
	Cross-functional teamwork	4.761	0.430	2	0.73
	Data collection and measurement	4.634	0.567	5	0.72
	Process documentation	4.451	0.501	10	0.72
	Regular audits	4.634	0.514	5	0.75
	Lack of a well-implemented customer management system	4.718	0.453	3	0.76
	Lack of a well-developed supplier management system	4.690	0.466	4	0.75
	Lack of a well-developed	3.451	0.983	12	0.71

Factors lowering company's performance	benchmarking system				
	Lack of a well-developed strategic planning system	3.676	0.907	11	0.70
	Lack of a well-developed human resource management system/ Lack of qualified personnel	4.634	0.485	5	0.72
	Lack of cross-functional teamwork	4.394	0.492	6	0.75
	Lack of quality management	3.930	1.060	8	0.69
	High amount of waste	4.775	0.421	2	0.73
	High costs	4.789	0.411	1	0.73
	Lack of financial resources	3.732	0.827	10	0.74
	Incompetency within organizational structure	2.887	0.785	13	0.71
	Incompetency with new technologies	3.746	1.143	9	0.70
	Legal procedures and obligations	4.014	0.978	7	0.71

The three most important CSFs lowering the performance of companies are found to be high costs (4.789), high amount of waste (4.775) and lack of a well-implemented customer management system (4.718), respectively. To test the internal consistency, Cronbach's alpha values were calculated for each performance measure. All the Cronbach's alpha values showed satisfactory levels (above 0.68).

Table 6. Capacity of the companies

Capacity usage per annum	Frequency	%	Rank
81%-100%	32	45.07	2
61%-80%	47	66.20	1
31%-60%	2	2.83	3
Below 30%	0	0	4

The respondents were asked about the annual capacity usage rate of their company (Table 6) and to shorlist the factors that can increase their company's performance and capacity by lowering company's process inefficiencies. Table 7 shows that reduction in waste; cost and customer complaints are the top three factors that can improve the performance and capacity of companies.

Table 7. Factors to increase the company's performance and capacity by lowering its process inefficiencies

Factors	Frequency	%	Rank
Reduction in waste	71	100	1
Reduction of costs	71	100	1
Improved sales	1	1.41	9
Reduction of customer complaints	26	36.62	3
Reduction in cycle time	14	19.72	4
Increase in profitability	2	2.82	8
Reduction in delivery time	12	16.90	5
Reduction of employee complaints (return rate)	5	7.04	7
Increase in productivity	11	15.49	6

According to the 67.6% of the respondents, the use of ISO certification can be beneficial to large-scale Turkish construction companies before embarking on Six Sigma (Table 8).

Table 8. Benefit of ISO certification before embarking Six Sigma

	Frequency	%
Yes	48	67.60
No	16	22.54
Not sure	7	9.86

5. Conclusion

This paper analyzes the importance of CSFs for the successful introduction of Six Sigma to the large-scale Turkish construction companies. Involvement and commitment of top management, linking quality initiatives to customer and linking quality initiatives to supplier are found to be the most important CSFs to the companies. Leadership and commitment of top management, cross-functional teamwork and commitment of middle managers are found to be the most CSFs for successful introduction of Six Sigma, whereas lack of knowledge of the system to initiate and complacency are found to be hindering its implementation. High costs and high amount of waste are found to lower the performance of the companies. Therefore, Six Sigma can be useful for Turkish construction companies since it promises products with lower rates of faults and waste, reduced costs, higher efficiency and higher customer satisfaction.

This study shows that the majority (97.18%) of the large-scale Turkish construction companies have successfully implemented ISO. However, it appears that they have a long way to go before they can embed Six Sigma into the fabric of their companies.

Before embarking on Six Sigma, it is imperative for large-scale Turkish construction companies to have a strong management involvement and commitment, and strong bonds between quality initiatives and customers as well as suppliers. In order for these companies to go through the route of Six Sigma, major changes in company's organizational culture are required. Top management is in a key position in the company to introduce and support the Six Sigma principles. Strong linkages between company's strategic objective(s) and Six Sigma implementation need also to be developed. Cross-functional teamwork as well as empowerment of middle managers are necessary to enhance company's network, capabilities and performance.

The complacency results show that companies are prejudiced on Six Sigma. Knowledge transfer on Six Sigma from local and foreign universities or external consultants will be helpful for its acceptance as a new quality system within the company.

Undoubtedly, Six Sigma can help Turkish large-scale construction companies maintain the highest quality of thought. By integrating to existing management procedures of companies, Six Sigma can help to fight and control variation from construction process with the help of its tools such as DOE (Design of Experiments), regression, correlation and hypothesis testing. Thus, by providing a broader quality concept, detailed performance measurement, coordinated and repeatable process/performance improvement to these companies, it can increase quality directly or indirectly, and positively affect productivity. Therefore, Six Sigma has a lot to offer to large-scale Turkish construction companies in order to improve operations and strategic performance metrics.

References

Abdelhamid, T.S., Everett, J.G. (2002), Physical demands of construction work: A source of workflow unreliability, Proceedings of the 10th Annual Conference of the International Group for Lean Construction, Gramado, Brazil.

Abdelhamid, T.S. (2003), Six-sigma in Lean construction systems: Opportunities and challenges, Proceedings of 11th Annual Conference of the International Group for Lean Construction, Blacksburg, Virginia, USA.

Abdelhamid, T., Thanveer, B. (2005), Production Planning Process in Residential Construction using Lean Construction and Six Sigma Principles, Construction Research Congress, San Diego, CA.

Akintoye, A. (1995), Just-in-Time application and implementation for building material management, Journal of Construction Management and Economics, 13, 105-113.

Alarcon, L.F. (1993), Modeling waste and performance in construction, in: L. Alarcon, (Ed.) Lean Construction, A.A. Balkema, Netherlands.

Alarcon, L.F. (1994), *Tools for the identification and reduction waste in construction projects*, in: L. Alarcon, (Ed.) Lean Construction, A.A. Balkema, Netherlands.

Al-Aomar, R. (2012), *A Lean construction framework with Six Sigma rating*, International Journal of Lean Six Sigma, 3(4), 299-314.

Alwi, S., Hampson, K., Mohamed, S. (2002), Non-value-adding activities: A comparative study of Indonesian and Australian construction projects, Proceedings of the 10th Annual Conference of the International Group for Lean Construction, Gramado, Brazil.

Antony, J., Banuelas, R. (2002), *Key ingredients for the effective implementation of Six Sigma program*, Measuring Business Excellence, 6(4), 20-27.

Antony, J., Kumar, M., Labib, A. (2008), *Gearing Six Sigma into UK Manufacturing SMEs: An Empirical assessment of Critical Success Factors, impediments and viewpoints of Six Sigma implementation in SMEs*, Journal of Operations Research Society, 59(4), 482-493.

Arditi, D., Günaydın, H.M. (1997), *Total quality management in the construction process*, International Journal of Project Management, 15(4), 235-243.

Arslan, G., Kıvrak S. (2009), *Critical Factors to company success in the construction industry*, International Journal of Human and Social Sciences, 4(8), 561-564.

Brue, G. (2002), *Six Sigma for managers*, New York: McGraw-Hill.

Celep, O., Kim, Y.W., Hutchison, J., Han, S. (2012), Implementing Lean Six Sigma: A case study in concrete panel production, Proceedings for the 20th Annual Conference of the International Group for Lean Construction, San Diego, USA.

Chakravorty, S.S. (2009), *Six Sigma programs: An implementation model*, International Journal of Production Economics, 119(1), 1–16.

Cha, H.S., O'Connor, J.T. (2005), *Optimizing implementation of value management processes for capital projects*, Journal of Construction Engineering and Management, 131(2), 239–251.

Chan, A.P.C., Chan, F.T.S., Yeong, A.M.C (1997), Process improvement for construction, Proceedings of the International Conference on Construction Process Re-engineering, Gold Coast, 213-221.

Chang, L.M., Chao, C.H., Lin, Y.H., The application of Six Sigma approach in construction: A case study for improving precast production management, Accessed from http://management.kochi-tech.ac.jp/ssms_papers/sms129979_dfbfdcdc4799458bbc835d4a465fa59f.pdf [Accessed on 24th September, 2012]

Dugme, F.Z. (2008), *A guide for construction companies to apply Lean Six Sigma Methodology*, MSc. Thesis, Middle East Technical University, Ankara, Turkey.

Engineering News Record (2012), The Top 225 International Contractors in 2012, Accessed from http://enr.construction.com/toplists/Top-International-Contractors/201-300.asp [Accessed on November 1st, 2012]

Formoso, C.T., Isatto, E.L, Hirota, E.H. (1999), Method for waste control in the building industry, Proceedings of the 7th Annual Conference of the International Group for Lean Construction, Berkeley, USA.

Garas, G., Anis, A.R., El Gammal, A. (2001), Materials waste in the Egyptian construction industry, Proceedings of the 9th Annual Conference of the International Group for Lean Construction, Singapore.

Graham, P., Smithers, G. (1996), *Construction waste minimization for Australian residential development*, Asia Pacific Building and Construction Management Journal, 2(1), 14-19.

Hampson, K., Tatum, C.B. (1997), *Technology strategy and competitive performance in bridge construction*, Journal of Construction Engineering and Management, 123(2), 153-161.

Han, S.H., Chae, M.J., Im, K.S., Ryu, H.D. (2008), *Six Sigma-based approach to improve performance in construction operations*, Journal of Management in Engineering, January, 21-31.

Hopp, W.J., Spearman M.L. (2000), *Factory physics*, New York: McGraw-Hill.

Howell, G. (1999), What is Lean construction?, Proceedings of the 7th Annual Conference of the International Group for Lean Construction, Berkeley, USA.

Kaming, P.F., Olomolaiye, P.O., Holt, G.D., Harris, F.C. (1997), *Factors influencing construction time and cost overruns on high-rise projects in Indonesia*, Construction Management and Economics, 15, 83-94.

Karakhan, A.A., Alsaffar, A.E. (2013), *Measure and analyze the problems of concrete mixture production via Six Sigma DMAIC tools: Central concrete mix plant as a case study*, Advanced Materials Research, 622-623, 472-477.

Kazaz, A., Ulubeyli, S. (2009), *Strategic management practices in Turkish construction firms*, Journal of Management in Engineering, October, 185-194.

Klefsjo, B., Wiklund, H., Edgman, R. (2001), *Six Sigma seen as a methodology for total quality management*, Measuring Business Excellence, 5(1), 31–35.

Koskela, L. (1992), Application of the new production philosophy to construction, Technical Report No. 72, Center for Integrated Facility Engineering, Department of Civil Engineering, Stanford University.

Kumar, M. (2007), *Success factors and hurdles to Six Sigma implementation: The case of a UK manufacturing SME*, International Journal of Six Sigma and Competitive Advantage, 3(4), 333-351.

Kumar, M., Antony, J. (2009), *Investigating the quality management practices in Six Sigma against Non-Six Sigma UK manufacturing SMEs: Key findings from multiple case studies*, Journal of Engineering Manufacture, IMECH E Part B, 223(7), 925-934.

Lindermann, K., Schroeder, R.G., Zaheer, S., Choo, A.S. (2003), *Six Sigma: A goal-theoretic perspective*, Journal of Operations Management, 21, 193–203.

Love, P.E.D. (1996), Toward concurrency and integration in the construction industry, Proceedings of the 3rd ISPE International Conference on Current Engineering, Canada.

McCrary, S.W., Smith, R.R., Callahan, R.N. (2006), *Comparative analysis between manufacturing and construction enterprises on the use of formalized quality management systems*, Journal of Industrial Technology, 22(3), 1-8.

Pheng, L.S., Hui, M.S. (2004), *Implementing and applying Six Sigma in construction*, Journal of Construction Engineering and Management, July/August, 482-489.

Pheng, L.S., Ke-Wei, P. (1996), *A framework for implementing TQM in construction*, The TQM Magazine, 8(5), 39-46.

Schonberger, R.J. (1986), *World class manufacturing*, New York: The Free Press.

Schonberger, R.J. (2008), *Best practices in Lean Six Sigma process improvement*, New York: John Wiley and Sons.

Shammas-Toma, M., Seymour, D., Clark, L. (1998), *Obstacles to implementing total quality management in the UK construction industry*, Construction Management and Economics, 16, 177–192.

Shan, Y., Li, Z. (2013), Integration and application of Lean principles and Six Sigma in residential construction, Proceedings of 3rd International Asia Conference on Industrial Engineering and Management Innovation, Part 1, Chapter 25, 245-252.

Snee, R.D. (2004), *Six Sigma: The evolution of 100 years of business improvement methodology*, International Journal of Six Sigma and Competitive Advantage, 1(1), 4-20.

Stewart, R.A., Spencer, C.A. (2006), *Six Sigma as a strategy for process improvement on construction projects: A case study*, Construction Management and Economics, 24(4), 339-348.

Taner, M.T. (2012), *A feasibility study for Six Sigma implementation in Turkish textile SMEs*, South East European Journal of Economics and Business, 7(1), 63-72.

Taner, M.T., Sezen, B., Atwat, K.M. (2012), *Application of Six Sigma Methodology to a diagnostic imaging process*, International Journal of Health Care Quality Assurance, 25(4), 274-290.

Tchidi, M.F. (2011), *Lean Six Sigma research application in construction industry*, PhD Thesis, Tianjin University, China.

Tchidi, M.F., He, Z., Li, Y.B. (2012), *Process and quality improvement using Six Sigma in construction industry*, Journal of Civil Engineering and Management, 18(2), 158-172.

Thomas, H.R., Horman, M.J., Souze, U.E., Zavrski, I. (2002), *Reducing variability to improve performance as a Lean construction principle*, Journal of Construction Engineering and Management, 128(2), 144–154.

Tommelein, I. D. (2000), Impact of variability and uncertainty on product and process development, Proceedings of the 6th Construction Congress, ASCE, Reston, Virginia, USA, 969–976.

Turkish Contractors Association, Available from http://www.tmb.org.tr, [Accessed on 24th September, 2012]

Yilmaz, M.F. (2012), *Six Sigma within construction context as a quality initiative, performance indicator/improver, management strategy*, MSc. Thesis, KTH Department of Real Estate and Construction Management, Real Estate Development and Financial Services, Architectural Design and Construction Management, Stockholm, Sweden.

Appendix

The questionnaire used in the study is given below.

1. Company name:
2. What type of projects does your company undertake? Please state the ones applicable.
   a. Infrastructure
   b. Industrial
   c. Building
   d. Housing
   e. Rehabilitation
   f. Highway
   g. Public works
3. How important is the following strategic objective for your company? Please rate from 1 to 5.
   a. Profitability
   b. Customer satisfaction
   c. Quality
   d. Creativity/Innovation/Aesthetics
   e. Lower costs
   f. Credibility
   g. Higher market share/Higher competitive power
   h. Reputation/Nice company image
   i. Further growth
   j. Social responsibility
   k. Effective use of resources
   l. More financial strength
   m. Employee Satisfaction
   n. Higher technology
   o. Benchmarking
   p. Research and Development
4. How many employees are working in your company? Please state.
5. What percentage of your work is self-performed in contrast to sub-contracting?
   a. 0-10%
   b. 10-25%
   c. 25-50%
   d. 50-75%
   e. 75-100%
6. How many engineers are employed in your company? Please state.
7. Is there any quality department in your company? Yes/No
8. Are the employees trained for quality? Yes/No
9. For how many years has your company been operating in the construction sector?
   a. 1-5 years
   b. 6-10 years
   c. 11-20 years
   d. Over 20 years
10. What is the average annual income of your company?
11. Does your company measure, check and control the variations and failures in the following concepts? Please state the ones applicable.
   a. Cost
   b. Time
   c. Quality
   d. Earned Value
   e. Material Flow
   f. Process Flow
   g. Labor Productivity
   h. Company performance
   i. Customer Satisfaction
   j. Employee Complaints
   k. Supplier performance
   l. Subcontractor performance
   m. Wastage

12. How do you measure customer satisfaction in your company?
    a. Not measured
    b. Questionnaire survey
    c. Face-to-face interview
    d. By the number of complaints
    e. Follow-up reports
13. Which quality initiative(s) has your company implemented in the past and present? Please state the ones applicable.
    a. Six Sigma
    b. Total Quality Management
    c. ISO 9001:2008 - Quality Management System accredited
    d. In the process of obtaining ISO accreditation
    e. In-house quality system
    f. ISO 14001:2004 - Environmental Management Systemi
    g. OHSAS 18001:2007 – Occupational Health and Safety Management System
    h. ISO 10002:2004 - The Customer Satisfaction standard
    i. No initiative undertaken
    j. Undertook no initiative yet but would like to be informed about Six Sigma.
    k. The company is ISO-certified and would like to be informed about Six Sigma.
14. How often does the top management provide the employees essential training opportunities to match their competencies with the company?
    a. No training
    b. Monthly
    c. Semi annually
    d. Annually
15. Which of the following training is given to employees in your company? Please state the ones applicable.
    a. Process management
    b. ISO 9000
    c. TQM
    d. Six Sigma
    e. Lean Construction
    f. Graphical and statistical analysis
    g. Total productivity maintenance
    h. Labor law
    i. Quality circles
    j. Quality improvement team Methodology
    k. Environmental management system
    l. Suggestion system
    m. Problem solving techniques
    n. Management improvement program
    o. Benchmarking
    p. Accounting economics
16. In your opinion, how important is the following CSF to your company? Please rate from 1 to 5.
    a. Involvement and commitment of top management
    b. Organizational infrastructure
    c. Vision and Planning
    d. Linking Quality Initiatives to Employee
    e. Linking Quality Initiatives to Customer
    f. Linking Quality Initiatives to Business
    g. Linking Quality Initiatives to Supplier
    h. Project selection
    i. Project management skills
    j. Information Technology and innovation
    k. Communication
    l. Teamwork
    m. Cultural change
    n. Education and training

17. Which is the most applicable factor that will hinder the implementation of a new quality initiative in your company?
    a. Availability of resources
    b. Lack of knowledge
    c. Lack of training
    d. Internal resistance
    e. Poor employee participation
    f. Inadequate process control techniques
    g. Changing business focus
    h. Lack of top management commitment

18. How important will the following factor be for successful introduction of Six Sigma in your company? Please rate from 1 to 5.
    a. Leadership and Commitment of top management
    b. Strategic vision
    c. Change management
    d. Commitment of middle managers
    e. Funds and Resources
    f. Education and training
    g. Empowerment of employees
    h. Communication
    i. Cross-functional teamwork
    j. Data collection and measurement
    k. Process documentation
    l. Regular audits

19. In your opinion, which of the following factors will hinder the implementation of Six Sigma in your company the most? Please choose the most applicable one.
    a. Lack of knowledge of the system to initiate
    b. Complacency/ People prefer status quo
    c. Availability of Staff/Time for Projects
    d. Other competing quality initiatives such as ISO
    e. Cost

20. What's your company's annual capacity usage rate?
    a. Below 30%
    b. 31%-60%
    c. 61%-80%
    d. 81%-100%

21. In your opinion, how important and effective are the following factors in lowering the performance of your company? Please rate from 1 to 5.
    a. Lack of a well-implemented customer management system
    b. Lack of a well-developed supplier management system
    c. Lack of a well-developed benchmarking system
    d. Lack of a well-developed strategic planning system
    e. Lack of a well-developed human resource management system/ Lack of qualified personnel
    f. Lack of cross-functional teamwork
    g. Lack of quality management
    h. High amount of waste
    i. High costs
    j. Lack of financial resources
    k. Incompetency with the organizational structure
    l. Incompetency with new technologies
    m. Legal procedures and obligations (bureaucracy, taxes, etc.)

22. In your opinion, which of the following factors can increase your company's performance and capacity by lowering the inefficiencies in your company? Please state the most important three.
    a. Reduction in waste
    b. Increase in productivity
    c. Improved sales
    d. Reduction of customer complaints
    e. Reduction in cycle time
    f. Increase in profitability
    g. Reduction in delivery time
    h. Reduction of employee complaints (return rate)
    i. Reduction of costs
23. In your opinion, can the use of ISO certification in your company be beneficial to your company for successful introduction of Six Sigma?
    a. Yes
    b. No
    c. Not sure
24. Please list the current inefficiencies in your company.