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Optimizing Construction Projects: Leveraging Lean Management for Enhanced Efficiency and Waste Reduction

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Abstract: ***This study examines the use of Lean Construction in Turkey, by highlighting how main lean activities influence project results. A questionnaire survey was used to collect information from 269 professionals in the industry about their views on lean culture, focusing on people, continuous improvement, attention to customers, waste reduction and standardization. I relied on literature from experts to design the theoretical basis and structure of the survey instrument. According to the results, while every lean aspect is put into action, it turned out that standardization and efforts to minimize costs have the strongest impact on project success. On the other hand, a few culture - focused strategies and efforts at improvement were associated with negative effects when analyzed with other conditions, signaling that their implementation may be going off track. The outcomes were reviewed alongside literature, confirming that having clear standards, using KPIs guided by customers, engaging with key stakeholders and using feedback early on are essential. According to the research, Takt Time Planning, Work Standard Sheets and prefabrication play a key role in bringing lean methods closer to the goals of the project. The information gathered from the survey helps to build lean construction knowledge and provides better direction for people in the construction industry's aiming to improve in these areas.***

Keywords: Lean construction, project performance, standardization, waste elimination, continuous improvement

1. Introduction

Turkey's economy relies heavily on the construction industry which boosts its GDP and creates many jobs (Erol & Unal, 2015). Until recently Guide, (2025), the construction sector in Turkey was doing well, as there were great annual investments from both the public and private sectors. Because Turkey is focusing on big infrastructure plans for urban areas, the construction sector is now more vital than ever. The purpose of this research to quantify how core lean - management principles influence time, cost, and quality outcomes on Turkish construction projects. With difficulty affecting the economy due to the depreciation of the lira and political problems, the Turkish government is now placing greater emphasis on earning stable incomes from a wide variety of sectors. It has become a priority to build major infrastructure projects that are connected to Turkey's Vision 2023, as it marks the celebration of the centennial of the Republic (Yaldız, 2023). Some examples include work in transportation, energy, healthcare and urban areas. Examples include the building of the Istanbul New Airport, the Kanal Istanbul project and a number of city transformation programs in different parts of the country. While these projects are very large, Turkish constructors encounter major difficulties with delivering them, controlling total expenses and ensuring quality (Demirkesen & Tezel, 2022). In the Turkish construction sector, delays in projects often result in going over the planned budget and taking longer than initially expected. The construction of the Istanbul New Airport has been postponed and the budget has increased, showing that better project management methods are required (Eren, 2019). Furthermore, these projects are often blamed for their negative effect on the environment and for failing to meet certain quality expectations, putting people in danger and disappointing the public.

As a way to resolve these problems, people are focusing on the concept of lean construction. Adapted from manufacturing - based lean production, lean construction aims to avoid waste, deliver projects more efficiently and do so with better results (Garcés & Peña, 2023). Prioritizing efficiency and focus on creating value in building projects, lean construction helps save money and resources. In projects related to civil and infrastructure engineering, lean helps by influencing steps such as planning, purchase of materials, task schedules and their implementation. Reductions in extra orders, lowering downtime among tools and staff and aligning subcontractors can all help ensure less waste (Habibi Rad et al., 2022).

Nevertheless, Turkey is not using lean construction much, since the industry 's character and operating environment are unique (Tezel, & Nielsen, 2013). Approaches to lean construction that originated in the West may not suit all the problems encountered in Turkey. Many studies on lean construction are centered on Western nations and other parts of the world, leaving little research done in Turkey. Since Turkey is focusing on infrastructure and the construction industry holds great importance to the economy, we need to explore the use of lean construction principles there. This research may support the creation of specific frameworks for Turkey's construction industry which can make projects more sustainable, less wasteful and of better quality (Yıldırım et al., 2022). Above all, focusing on time and costs may stop the completion of construction projects. Because infrastructure projects involve dozens of companies and many activities, some tasks and procedures might be overlooked during their

planning and implementation. So, teams end up completing their work late, use more funds than planned and are disorganized. The problem of exceeding the estimated budget is reported in more than 76.3% of construction projects (Yang, & Chen 2015). If costs increase and people become suspicious, they may postpone their payments and even start considering the project's abandonment. Highways that are part of large civil engineering projects for the public are difficult for the government to stop which causes more of its funds to be used until the project is finished. To do a highway project requires understanding logistics for long routes, focusing on the design and construction of key structures, as well as meeting strict deadlines. Increasing the time for work will raise the need for more people, equipment, fuel, as well as costs to operate (Garcés & Peña, 2023).

In situations where there are several contractors, suppliers and government agencies, those using TQM struggle to succeed in high - complexity work environments. Hence, using the "Lean Management" method is considered a better way to handle construction and infrastructure engineering projects. A lean management system is based on analyzing whether each process truly benefits the final work. In civil engineering, waste may happen as extra work due to poor results, surplus materials, transferring and moving labor and tools unnecessarily or wasting time waiting for work. These problems can be addressed using lean systems such as the Last Planner System (LPS), Just - In - Time (JIT) delivery, prefabrication and visual management (Garcés & Peña, 2023). When highway and infrastructure projects use these methods, managing the schedule becomes simpler, the time needed is often less, larger equipment is used better and less clutter and waste is seen on the site. All tasks and procedures concerning the supply chain are interpreted through a project perspective, allowing for a quick response to problems and a successful outcome that meets what clients and green requirements need. This study looks into using lean management approaches in engineering and construction processes to improve efficiency and reduce wastage. It is well known that the construction industry involves many details and needs much effort which can lead to slipping deadlines, going over budget and squandered resources. The research is aimed at solving these problems by emphasizing lean construction principles and making efforts to make projects more efficient and waste - free in infrastructure and civil engineering.

Studying this area is important as it can result in significant progress within construction. Projects in engineering and construction contribute greatly to helping economies grow, infrastructure improve and towns or cities expand. In addition, not eliminating inefficiencies in construction projects can cost the economy, pollute the environment and decrease people's trust in the company. Studying lean construction guides us to use improved techniques for finishing projects on time, maximizing available resources, avoiding waste, time delays and making construction less harmful to the environment. Moreover, using lean techniques helps companies adapt to changes in the industry that focus on sustainability, new ideas and performing better. Because cost - saving, excellent results and environmental sustainability matter more, organizations must turn to lean management. The findings of this study will support the growth of special frameworks in Turkey that support continuous improvement, unite all involved parties and increase the strength of civil and infrastructure projects.

2. Definition of Lean Construction

In the last few years, there have been setbacks, unnecessary costs and inefficiency on many construction projects. Therefore, a variety of methods aimed at enhancing these projects' results have been created. At the moment, lean construction is increasingly involved in the construction business. Lean construction uses lean principles associated with manufacturing and applies them to the construction industry for more efficient project management (Gerber, Becerik - Gerber, & Kunz, 2010). Even so, implementing lean construction is not like lean production using typical current practices. The goal for delivery in construction is easily defined, unlike in manufacturing. The main goal of construction management is to enhance the project's performance by managing all the processes during its entire duration. Also, construction managers develop the plan and the product side by side (Hirota, Lantelme, & Formoso, 1999).

Lean construction is a system that focuses on delivering value to customers quickly and reliably (Forbes & Ahmed, 2010). Lean aims to finish the project with respect for resources, while making everything as valuable and as close to perfect as possible. To put it simply, the leading purpose of lean construction is to eliminate any waste in building construction and related activities (Gerber et al., 2010). Taking Albalkhy & Sweis, (2022) into account, lean construction is about minimizing waste, ensuring quality and making sure all productivity is used effectively. These strategies involve producing consistently, reducing wastes and using several different methods at once. Table 1 shows examples of other descriptions of lean construction.

Table 1: Definition of Lean Construction

Author (Year)	Definition
Oudshoorn, & Pinch (2005)	Lean construction is a construction system all about handling projects by focusing on reliable and quick delivery of the project's value. We want to make sure the project delivers the best value, with minimum waste and strives for perfection, all so that every stakeholder can sell what the customer wants profitably.
Ellis et al., (2024)	Lean construction is a belief system formed on the ideas of lean manufacturing. It involves guiding how a building project advances, so the required features are delivered at the best profit.
(El - Kourd, 2009)	Added value is given to lean construction when useless space, resources and productivity are removed.
Diekmann et al. (2004) in Gresh (2011)	To follow lean construction, you should lessen or remove waste, satisfy and exceed all clients' expectations, handle the entire value stream and always aim for perfection during construction.
Hamzeh et al., (2016)	Eliminating waste in building construction

Koskela et al. (2002)	Lean construction tries to supervise the progress and benefits gained from all the steps in the project life cycle.
Gao, & Low, (2014)	Lean Construction is based on the principles of a Lean production system—add value and eliminate waste—and makes use of those principles in building a new process for project delivery.
Marhani et al., (2013)	Lean construction is focused on handling and improving the construction process to ensure the customer's needs are met financially.
Koskela (1992)	In Lean Construction, working with a set of related principles and applying them all together results in expected success.
(Pillai, Shukla, & Magar, 2016)	Lean construction means always working to reduce waste, meet all customers' needs, consider the complete process and strive for perfection in executing the project tasks.
(Somani & Minde, 2017)	Lean construction includes using a broad and integrated approach to design and build facilities so that all project stakeholders can get the most value from systematic, coordinated and continuous enhancements in the project's rules and procedures, planning, how construction is carried out, supply chain and site operation reliability.

There are differences between lean construction and how construction is practiced now. Today, construction is guided by using construction management that deals with contracts and outlines goals that all parties agree on. The focal point leads the way in determining the setup of activities in a given order, as well as when each one will begin (Manrodt, Vitasek, & Thompson, 2008). Within the process, there are opportunities for mistakes, paying for things and gaining experience. Making projects faster and more streamlined or changing the process to allow for overlapping actions, helps lower the construction cost. In this way, waste is seen as any expenses that could have been avoided during the construction processes (Neve et al., 2021). On the other hand, lean construction works as an entirely different method. Steps in construction are managed to ensure each activity adds something unique for the customer. Cost and time are essential elements in the way the project is built. Under the construction system, the project budget and completion time are emphasized over the cost or time it takes for each step. Controlling the details of the work is done by the central schedule which means the project is coordinated by those who co - operate and help achieve the goals (Gao & Low, 2014). The main purposes of the system are satisfying customers, moving information and moving materials. Currently, construction work focuses on reducing waste and accelerating accomplishment of what the customer needs.

Lean construction goes through different stages during the process. Project definition, lean design, lean supply, lean assembly and basic use are part of the process (Bamana et al., (2019) (See Figure 1). Ballard and Howell point out that project definition should cover the purposes, the design criteria, design concepts, a budget estimate, a timeline for completion and work with the customer and all stakeholders. In lean design phase, engineers shift the conceptual design from the project outline to how the manufacturing process and product will be designed. LPS is brought into play during the design of the product by using technology such as 3D computer programs and software used by a group. At this point, accurate engineering work for the project needs to be done before the order, construction and shipment of the materials to the site can take place. The primary purpose of the process is to lower the number of needed inventories on site. It should all be done to ensure customers get the most value. Only after all the resources are delivered is the Lean Assembly phase initiated; it concludes after all the works are given to the client. Efficient handling of continuous flow process is required at this phase (Ballard, & Tommelein, 2021).

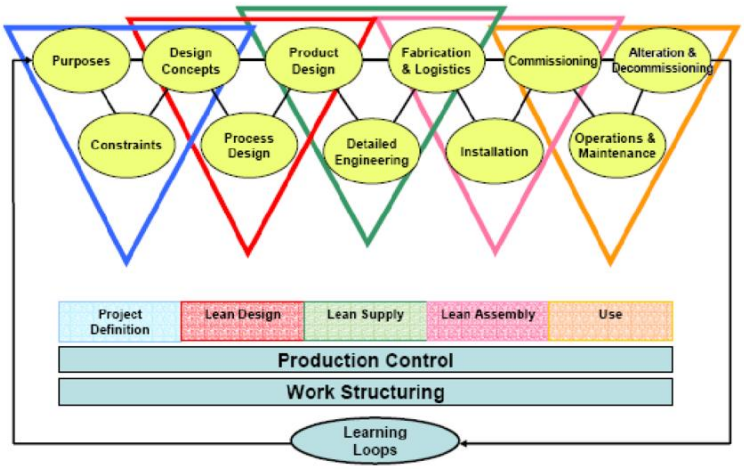

Figure 1: Lean Project Delivery System (Ballard, 2008; Construction Industry Institute (CII), 2007)

2.1. Lean Management for Civil and Construction Projects in Turkey

Working in construction helps build up the nation, since the industry accounts for a big part of the country's GDP and employs many people. Still, inefficiencies like delays on projects, overspending on work, extra material waste and a decrease in productivity are common in the construction industry. In the past few years, people have looked to Lean Management in Turkey's civil and construction projects as a way to perform better, be more efficient and offer more value to clients. Lean construction in Turkey is only beginning to take shape and is understood only by a few stakeholders. Despite the fact that several large construction companies

have started using Lean techniques, the industry as a whole is not using them consistently (Tezel, & Nielsen, 2013). Usually, only certain phases or individuals are affected by agile; it is not seen as a company - wide practice. Vaziri et al. (2015) found that Turkish contractors notice issues with their speed, but they still prefer using conventional methods of project management. A limited understanding, lack of training and no explicit Lean guidelines for the local industry is causing the progress to Lean thinking to be much slower. Many elements prevent Lean construction from being properly implemented in Turkey. Most Turkish construction enterprises organize in ways that see decisions made quickly by senior staff. This cultural system is different from the Lean approach, where decisions are made collaboratively by everyone (Alarcón et al., 2023). Because not many managers and engineers have access to education and training on Lean, they find it hard to use the Lean tools successfully (Deniz, & Tükenmez, 2024). Few Adamses Construction is not able to rely on Lean approaches to delivery like Just - In - Time supply because the supply chain is not properly connected. Since many infrastructure projects are complex and involve several people, the Lean approach often needs to be adjusted to handle the uncertainty (Tetik et al., 2019). Using Lean Management helps improve the productivity and sustainability of projects in the civil and construction sector in Turkey. Although adoption of Genomics is still just beginning, educating people, raising awareness and involving organizations can help deal with any problems that come up. With the right approach, Lean will help Turkey's construction sector become more efficient, produce better results and compete well in the world market.

2.2. Waste Reduction in civil and construction projects

Viana, Formoso and Kalsaas (2012) say that dealing with construction waste in the construction industry is something most people do not yet understand. As a consequence, though understanding this concept lowers the obstacles to better performance (Koskela, Sacks, & Rooke, 2012), construction waste is not understood in the same way by all members of the construction industry (Koskela, 2018). At the same time, various types of waste are found in construction and I will discuss them below. **Overproduction** is considered waste if things are made in excess during the manufacturing process. Part of it could also be the preliminary installation or construction of materials. We also consider overproducing construction records as a form of waste (Koskela et al., 2020). Sometimes, the design architecture develops methods that exceed only meeting required standards and what the client wants. It may also involve changes resulting from speculation or anticipated alterations in the economy. Growing your inventory takes time and resources (Koskela, Bølviken, & Rooke, 2013). If you want to reduce overproduction, concentrate on the following (Decker et al., 2016): **Waiting** in any process of construction that wastes time leads to waiting waste. Any time all activities in construction stop, waiting waste takes place (Nikakhtar et al., 2015). Inventory built up hits both the goods and the workers negatively. Completing the work can take quite some time. Instead, an ideal state should not require waiting, but ensure the processes are handled quickly. The lost time is actually useful for training and upkeep of materials, along with other important tasks, since this prevents extra production (Ali, 2012). Akhir, (2015) indicated that among all types of waste, waiting happens most commonly in Indonesian and Australian construction projects. Mulders, (2013) found instances of waiting construction wastes in the Netherlands. To solve waiting wastes in the construction processes, activity mapping is the preferred lean construction tool. This approach can increase understanding of the process so that waiting waste is avoided (Olugboyega, 2015).

Inventory is the part of the process where operations and supplies provided by the supply chain combine. In most cases, making too much inventory is a result of procedures that take a long time (Koskela et al., 2013). Additional and unnecessary inventory can increase the delay in the process and makes it hard to instantly find problems which requires more space. Therefore, people are discouraged from interacting with each other. As a result, Sarhan et al. (2017) concluded that inventories mask or hide, problems. Before problems can be corrected, the issues need to be found and this becomes possible when inventory is reduced. As well as this, having too much stock is costly for companies, reducing their advantage in the market. Using the 5S system is the best approach to cut down on excess inventory (Hines & Rich, 1997). In these steps, sorting wastes away, then put side all those things you take; and ensure the workspace is clean and neat. If something needs to be fixed and more time is required to do so, correctional waste and rework must be done. It includes reviewing and adjusting sections with mistakes and replacing materials to keep up with any changes in the design (Vivekananthamoorthy, & Sankar, 2011). In their work, Lapinski et al. suggest using the perfection tool to avoid any unnecessary errors and reworks in regular activities. The process calls for an understanding of the procedures and what the customers require before anything is done. Taking advantage of checklists and standardized work plans will show results (Vivekananthamoorthy, & Sankar, 2011).

Unneeded movement of products and items under development does not improve the process. The focus of lean construction is to reduce or eliminate movements that are not needed (Koskela et al., 2013). During construction, things need to move around; yet, material movement on the construction site is regarded as solid waste by Ward, & Sobek (2014). Therefore, the key is to move needed materials more gradually than all at once. Likewise, double working on the material and extra work stages frequently lead to damage and wear out the goods. When there is a large distance to cover for communication, it takes longer for news to reach the employee which often results in poor quality reports followed by no substantial action (Ward, & Sobek, 2014). This process eliminates pointless activities, makes some sections easier by uniting them and aims to change the order of some activities to decrease waste. Prepare several ways to improve the process and pick the most practical one for putting into action.

This refers to mishaps that happen when construction workers need to walk or bend too far due to the setting of the worksite. Sometimes, unneeded motion occurs when tools, fixtures or inventory parts are designed poorly and it involves workers who have to move and pick things that could be handled without stretching or lifting. Such waste tires employees and results in decreased productivity and quality (Ward, & Sobek, 2014). To eliminate motion waste, the 5Ss (Zaporowska, &

Szczepański, 2022) are the easiest lean construction tool, as they motivate the project team to review and improve every part of their work. Additionally, the team would not need to spend any money on the tool. Any unproductive activities or useless processes produce waste too. There may be waste in the organization caused by past reasons and the company's unwillingness to improve successful methods. If we focus on manufacturability and keeping things in good shape, most of the waste will disappear. Sometimes, processing waste involves polishing or finishing unimportant details past what the client requests. There are times when complex actions are performed in areas that could just as well be handled simply (Viana et al., 2012). People who follow lean construction promote the use of cost - effective and straightforward systems and machines (Koskela et al., 2013). It would be best if the machines were made small so they create the proper quality. They should be put as close as possible to the next operations (Hines & Rich, 1997). Each activity should be reported with the number of miles driven, the time spent and the individuals onboard. Taking the approach will allow for the removal of unnecessary work and the simplification of the rest, resulting in less waste.

2.3. Relationship between dependent and independent variables

Figure 2 illustrates the components of lean construction. Each component is explained below.

2.3.1. Culture/People in Lean Construction

In lean construction, the success of the work depends on its people and culture. For lean initiatives to succeed, everyone from top managers to workers on the site must have the right mindset and behave correctly. This means there should be commitment from leaders, an attitude to accept change, successful teamwork and removing the habit of blaming (Koskela et al., 2010). Since Turkish organizations rely on traditional ways and resist progress, applying lean practices can be challenging. To support a lean culture, employees should be trained, different groups should work together and employees should actively participate (Emuze & Smallwood, 2013; Jiang et al., 2019). Managers should give their teams the freedom to address issues and make sure all team members share information.

2.3.2. Eliminate Waste in Lean Construction

In lean thinking, getting rid of waste is the main purpose. Waste is evident in construction for several reasons: delays, extra production, fixing mistakes, extra motions, unnecessary stockpiles and poor work (Ohno, 2019). There are often issues with using too many materials, delays in scheduling and ineffective logistics during the large - scale public projects found in Turkey (Gunduz & AbuHassan, 2016). To address waste, companies can put Value Stream Mapping (VSM), 5S and the Last Planner System (LPS) into use. Therefore, more can be done with less effort, at a lower cost and projects are delivered faster.

2.3.3. Continuous Improvement in Lean Construction

The lean construction philosophy relies on continuous improvement. It requires users to frequently discover ways to do things better, slowly introduce new ideas and make use of experience from past work (Liker, 2004). While accepted practice treats delays and extra work as something you can't avoid, lean insists on always improving the team's knowledge, identifying the causes of problems and using feedback constantly. Using the PDCA cycle, analyzing projects afterward and tracking results can encourage people in civil projects to improve. It allows engineers to update plans in long - term projects such as roads, tunnels or water infrastructure as the project's conditions continuously change.

2.3.4. Customer Focus in Lean Construction

The key in lean construction is to ensure that the client receives the value they expect. Traditionally, design was centered only on the finished product, but with lean, focus includes usability, usefulness and personal feelings. For infrastructure, it consists of being safe, strong, attractive, cost efficient over time and open to everyone's use (Koskela et al., 2013). A lot of infrastructure projects in Turkey receive money from the state, leaving public officials and people as the main stakeholders. Collaborating at the start, conducting value engineering and introducing performance - centered metrics can ensure that both stakeholders and investor satisfaction rise and ROI improves.

2.3.5. Standardization in Lean Construction

When something is standardized, the same high - quality method can be repeated on several projects. In this industry, it makes use of prefabrication, modular designs, standard ways of working and templates. Thus, they become more reliable, happen faster and prevent mistakes that can happen with human tasks (Koskela et al., 2013). Using the same components for concrete, drainage designs and barriers on highways and bridges in Turkey helps make the work faster and cheaper. Lean suggests structuring work to be flexible about certain areas, so the project succeeds.

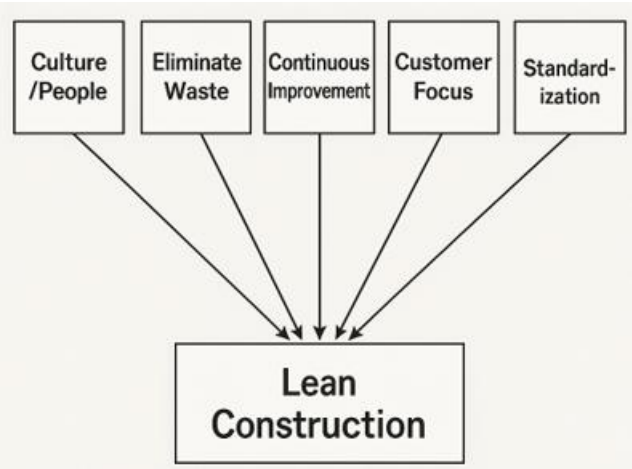

Figure 2: Research Model [Source: Abdullahi, C. M., & Tembo, M (2023)]

3. Methodology

3.1. Research Design

The focus of the study is on providing numerical information obtained through a quantitative research design. One advantage of quantitative methods is that it allows for easier study of relationships and testing of hypotheses methodically. This study is founded on a philosophical theory known as

positivism the process makes it possible to collect reliable data from people in the construction sector on the impact of LC. Using a survey - based approach allows the researcher to get input from various individuals, making the findings more widely applicable. Using outcomes such as delays in completion, excess spending and repeated corrections, the analysis examines if lean approaches are beneficial in projects.

3.2. Source of Data (Primary and Secondary)

The data used in this study is collected using a combination of primary and secondary methods, helping to understand Lean Construction (LC) in the Turkish construction industry fully. Both the conceptual and the statistical aspects of the research problem can be better examined using both types of data. All other data draw from the main empirical data, known as primary data. The data was gathered using a planned questionnaire given to people engaged in project management and lean implementation in several areas of Turkey. The respondents came from various areas such as project management, site engineering, corporate lean consulting and key roles on construction sites. The questionnaire helped obtain quantitative data on how lean is followed, the use of key lean principles (eliminating waste, strengthening teams, setting standards, etc.) and the effects of all these practices on aspects such as cost, quality, safety and time outcomes.

3.3. Population and Sampling

Participants are being selected from experts and others who contribute to managing projects in the Turkish construction industry such as project managers, site engineers, lean experts, supply chain coordinators and contractors. A purposive method was used to select people who had firsthand knowledge or experience with lean in construction. This was done to ensure answers were carefully considered and meaningful related to lean management concepts. The study tried to include a sample size that allowed for differences to be recognized statistically. According to construction research, the minimum number of respondents targeted was at least 300. The approach is consistent with similar studies and ensures the results have an acceptable degree of assurance and a low margin of error.

3.4. Data Collection

Through a questionnaire survey, we gathered information about how LC principles have been used in the construction industry in Turkey. It was determined that this method could collect the same kind of information about construction sector professionals from various regions effectively. The method of conducting a survey cited here is practical for reaching a wide range of construction workers and managers, allowing them to provide valuable tips on lean construction. Email, LinkedIn and some construction industry forums were used to carry out the survey and ensure a large audience took part. The decision to use these platforms was made to contact career professionals and high - level employees with insights from their actual field experiences. More than 90 percent of those who were surveyed filled out the questionnaire which is more than what was expected for a questionnaire of this type. Because so many were involved, the study is more credible and its data holds more power. Participants were asked to respond to the questionnaire using a 5 - point Likert scale starting at 1 (Strongly Disagree) and ending at 5 (Strongly Agree). The scale made it possible for respondents to reveal the levels of agreement they had with statements about lean thinking, cultural conditioning, waste reduction plans, as well as their effects on cost, time, quality and safety. The use of a Likert scale led to several benefits: it gathered subtle views and opinions, permitted the summarization of data and guaranteed uniform answers from many participants. Also, this measurement tool made it possible to identify both the positive and negative sides of lean implementation, thanks to its analysis of agreement between respondents. The results of the data collection were trusted and helpful because targeted distribution and a structured Likert scale were used. The information received gives a strong basis for understanding the research goals and monitoring the prevalence of lean construction in Turkey.

3.5. Data Analysis

When the data was retrieved, it was checked and coded in software such as SPSS to be examined. Data analysis was done in two steps.

- Descriptive Statistics: The use of descriptive statistics shows how results are spread, calculates average scores for the lean topics and discovers the general trend of applying lean in the industry.
- Inferential Statistics: Researchers focused on correlations and applied linear regression models to analyze how the lean principles impacted project outcomes. Regression analysis gave numbers that made it possible to identify and measure the strength of the connections.

4. Results

4.1. Demographic Variables

Table 2 lists the results of respondent rate by gender and age. Among the 269 participants in the study, 59.1% were male and 40.9% were female, indicating higher male participation. Together, these two groups account for the full sample. While there are more men, the gender distribution still shows a substantial representation of women. In terms of age, the majority of respondents were between 26 and 35 years old. Younger adults aged 18 to 25 made up 26.0%, followed by 17.8% in the 36–45 age group. Those aged 46 to 55 represented 12.6%, while only 4% were between 56 and 59. Most participants were therefore young or middle - aged, with a significant portion under 35. Educationally, the largest group (33.1%) held a Master's degree. M. Phil. holders comprised 26.0% of the sample, closely followed by those with a Bachelor's degree at 25.3%. Around 15% held a Ph. D., showing that most participants had completed postgraduate education, with 84.4% holding degrees below M. Phil. Overall, the sample reflects a highly educated population.

Table 2: Respondent rate by gender

Variable		Frequency	Percent
Gender	Male	159	59.1
	Female	110	40.9
	Total	269	100.0
Age	18 – 25	70	26.0
	26 – 35	104	38.7
	36 – 45	48	17.8
	46 – 55	34	12.6
	56 – 59	13	4.8
	Total	269	100.0
Education	Bachelor	68	25.3
	Master's	89	33.1
	M. Phil.	70	26.0
	Ph. D.	42	15.6
	Total	269	100.0

4.2. Descriptive Statistics

Results from descriptive statistics, as shown in Table 3, indicate that participants agreed to a moderate extent (between 3.46 and 3.54) with all the questions on the scale. Individuals in this group scored their cultural influence as 3.5130 on average, with a standard deviation of 0.84171, meaning some diversity exists in their answers and the level of cultural influence is close to medium. Researchers observed that Continuous Improvement was strongly agreed upon by participants, as the average score was 3.5190 and the standard deviation was 0.56049.

"Customer Focus" had a mean of 3.5008 and standard deviation of 0.58987, indicating that, on average, respondents still supported customer efforts but saw them as slightly below average. Respondents showed the most variation in their ratings for waste elimination, as the mean was 3.4881 and the standard deviation was 0.86481. The average score for standardization was 3.5361 and its standard deviation was 0.82521, so companies practice it, but not strongly and people have diverse opinions. The average respondent rated "Project Outcomes" as 3.4693, indicating that projects were mostly successful but with visible differences between those involved. While every main Lean Construction practice was widely present in the projects, people differed in how they saw things, considering "Continuous Improvement" to be the most recognized.

Table 3: Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Culture People	269	1.00	5.00	3.5130	.84171
Continuous Improvement	269	1.00	5.00	3.5190	.56049
Customer Focus	269	1.00	5.00	3.5008	.58987
Eliminate Waste	269	1.00	5.00	3.4881	.86481
Standardization	269	1.00	5.00	3.5361	.82521
Project Outcomes	269	1.00	5.00	3.4693	.82647
Valid N (listwise)	269				

4.3. Correlations

Pearson correlation analysis studies the connection between Culture/People, Continuous Improvement, Customer Focus, Eliminate Waste, Standardization and the final results of the projects are shown in Table 4.

Table 4: Correlation

		Culture People	Continuous Improvement	Customer Focus	Eliminate Waste	Standardization	Project Outcomes
Culture People	Pearson Correlation	1	.562**	.890**	.991**	.928**	.947**
	Sig. (2 - tailed)		.000	.000	.000	.000	.000
	N	269	269	269	269	269	269
Continuous Improvement	Pearson Correlation	.562**	1	.649**	.531**	.694**	.631**
	Sig. (2 - tailed)	.000		.000	.000	.000	.000
	N	269	269	269	269	269	269
Customer Focus	Pearson Correlation	.890**	.649**	1	.873**	.893**	.900**
	Sig. (2 - tailed)	.000	.000		.000	.000	.000
	N	269	269	269	269	269	269
Eliminate Waste	Pearson Correlation	.991**	.531**	.873**	1	.906**	.939**
	Sig. (2 - tailed)	.000	.000	.000		.000	.000
	N	269	269	269	269	269	269
Standardization	Pearson Correlation	.928**	.694**	.893**	.906**	1	.981**
	Sig. (2 - tailed)	.000	.000	.000	.000		.000
	N	269	269	269	269	269	269
Project Outcomes	Pearson Correlation	.947**	.631**	.900**	.939**	.981**	1
	Sig. (2 - tailed)	.000	.000	.000	.000	.000	
	N	269	269	269	269	269	269

**. Correlation is significant at the 0.01 level (2 - tailed).

4.4. Regression

The summary of the regression model, as shown in Table 5, demonstrates that R values very close to 1 indicating that the independent and dependent variables are strongly related. Since 98.1% of the change in Project Outcomes is explained by the model, the fit of this model is considered excellent. Even after considering all the predictors, the adjusted R

Square shows that the model remains exceptionally strong. Since the Standard Error of the Estimate is 0.11468, we can see that predicted values are in good agreement with the actual observed values. The statistic Durbin - Watson turns out to be 2.135 and since it is close to 2, we can say there is no significant autocorrelation in the errors, so the regression assumptions are met.

Table 5: Regression Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin - Watson
1	.991[a]	.981	.981	.11468	2.135
a. Predictors: (Constant), Standardization, Continuous Improvement, Customer Focus, Eliminate Waste, Culture People					
b. Dependent Variable: Project Outcomes					

The model used by the analysis, as seen in Table 6, shows that the regression model is of statistical significance. We found that F - value = 2731.333, suggesting that the entire model is very significant at a critical level of 0.01. So, the presence of independent variables (Culture, People, Continuous Improvement, Customer Focus, Eliminate Waste and Standardization) helps to predict Project Outcomes. A lot of how Project Outcomes vary can be attributed to the model, since the Regression Sum of Squares is 179.601 and much larger than Residual Sum of Squares which is 3.459. This corroborates the findings from the R - Square value which concluded that the data fits the model very well.

Table 6: ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	179.601	5	35.920	2731.333	.000[b]
	Residual	3.459	263	.013		
	Total	183.059	268			
a. Dependent Variable: Project Outcomes						
b. Predictors: (Constant), Standardization, Continuous Improvement, Customer Focus, Eliminate Waste, Culture People						

The coefficients Table 7 reveals how each input factor influences the outcome of the project. Since p is high (0.754) and the model has constant value 0.017, having all the other variables at zero won't make a noticeable difference. Of all independent variables, the factor of Culture People gives a negative unstandardized coefficient (B = –0.546) and a significant p - value (0.000). We find that, surprisingly, promoting practices that are culturally focused on individuals may lead to poorer outcomes in a Project. The connection between Continuous Improvement and Project Outcomes is also negative, but not as much as for other aspects (B = –0.085, p = 0.000).

Customer Focus has a positive relationship with Project Outcomes; however, the strength of this link is low (B = 0.114, p = 0.000). Putting more focus on what customers require helps improve the outcomes of any project. Eliminate Waste and Standardization play the biggest roles in enhancing Lean. The Higher the Effectiveness score for eliminating waste, the better the project outcome due to the positive correlation (B = 0.659, Beta = 0.690). Standardization has the strongest influence on the outcome, as its unstandardized and standardized coefficients are both 0.841 and 0.840. Since the significance level (p = 0.000) is very low, we can say implementation of standardized processes contributes a lot to a project's success. In conclusion, using standard processes and removing waste is key for accomplishing a project successfully. At the same time, some cultural and continuous improvement practices may not guarantee better results when other elements are present. All these practices should be carefully brought together and lined up to help a project succeed.

Table 7: Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.017	.054		.314	.754
	Culture People	- .546	.076	- .557	- 7.212	.000
	Continuous Improvement	- .085	.019	- .058	- 4.516	.000
	Customer Focus	.114	.029	.081	3.900	.000
	Eliminate Waste	.659	.064	.690	10.275	.000
	Standardization	.841	.029	.840	29.260	.000
a. Dependent Variable: Project Outcomes						

5. Discussion and Conclusion

This study explores how key Lean Construction (LC) principles relate to project outcomes in Turkey, drawing on responses from 269 professionals with Lean - related experience. Findings reveal that *Standardization* is the most influential factor, with a strong correlation (r = 0.981) and a high standardized beta coefficient (β = 0.840), suggesting that consistent processes greatly enhance performance. Closely following is *Eliminate Waste* (β = 0.690, r = 0.939), which confirms that removing inefficiencies like delays, overproduction, and unused resources significantly improves project delivery.

Surprisingly, *Culture/People* and *Continuous Improvement*—despite high correlations—showed negative regression effects (β = –0.546 and β = –0.085, respectively). This may indicate that while these concepts are acknowledged, they are not yet effectively integrated into daily operations or supported by aligned systems. *Customer Focus* had a mildly

positive influence (β = 0.081, r = 0.900), suggesting that although companies understand the importance of client satisfaction, they still lack tools and processes to fully act on customer input.

Theoretically, the results highlight that Lean practices must be tailored to the specific conditions of emerging markets. In Turkey's construction sector, operational efficiency through standardization and waste reduction currently yields better results than softer aspects like culture or improvement initiatives. This supports earlier research by Salem et al., Ballard & Howell, and Formoso, reinforcing that standardized workflows and reduced variability enhance quality and timeliness. It also aligns with Womack and Jones's and Koskela's emphasis on waste elimination as a core Lean goal.

Although Culture/People and Continuous Improvement are central to Lean philosophy, their lack of immediate impact here may stem from poor implementation, insufficient integration with daily routines, or a gap between policy and practice. These observations resonate with Sarhan et al. 's findings on slow cultural transformation in construction environments. Similarly, limited effectiveness in Customer Focus echoes the challenges noted by Aziz and Hafez regarding hierarchical structures and weak communication in developing markets.

Overall, the model explains 98.1% of the variation in project performance using Lean principles, confirming their collective value. Yet the mixed effects—especially negative ones for soft practices—indicate that successful Lean adoption depends on strategic alignment, implementation maturity, and local context. Practically, this suggests that firms should prioritize standardizing procedures and eliminating waste before investing heavily in cultural transformation or continuous improvement. Policymakers and industry leaders should provide practical support through training, toolkits, and performance benchmarks to enable better execution of Lean strategies.

While the study delivers valuable insights, it is based on self - reported data and focused solely on Turkey, limiting its generalizability. Future research should explore these findings over time, across different regions, and investigate in - depth why softer Lean elements may underperform. Investigating Lean maturity levels and firm size could also offer deeper understanding into how Lean practices yield benefits.

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