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Investigation of Lean Production Knowledge among Employees in Building Inspection Organizations

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Abstract: Currently, lean construction has become very important, with lean manufacturing, a philosophy of production that in the most basic sense refers to the elimination of waste and tries to eliminate anything that does not add value to the product or service, emerging as a Japanese business pattern. The aim of this study was to determine the lean production knowledge among employees in building inspection organizations. To measure the level of awareness in construction inspection institutions, which are the leading entities in the construction sector, and the level of awareness on this issue, a survey was conducted through face-to-face meetings with engineering employees residing in Adana province. The results were converted into datasets in the appropriate Microsoft Excel format. With these datasets, the reliability level of the survey was measured using the SPSS program, and the data were analyzed using WEKA software. The study used association rule learning, a data mining method. According to the results, the number of employees who knew the definition of lean production was less than half, at 47%, while the number of those who knew about the concept of lean construction was 44%. The results obtained according to three different class labels were statistically interpreted, and it was determined that the employees lacked knowledge and sufficient awareness about the subject.

Keywords: lean construction; construction inspection organizations; waste; WEKA

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1. Introduction

Earthquakes were the starting point for building control systems being applied worldwide. Earthquakes can have similar negative results at different geographical locations. Although the main purpose of inspecting buildings is the same across the world, differences can be observed in how inspections are implemented. In Turkey, when structures damaged in past earthquakes were examined, it was seen that the main cause of the damage was the inappropriate construction of the buildings rather than the earthquake [1]. In this case, it is clear that controlling the structure is important during the construction phase.

Production can be defined as the transformation of certain inputs into a good or a service through certain some processes [2,3]. The new-generation production strategies that are effective and efficient come to the fore because these production systems can meet customer tastes and preferences in a short amount of time. The most important and successful of these production methods is "Lean Production" [4]. The word "lean" means less of many things, far from excess, plain, and purposeful. Being lean means less cost and waste, as well as more information flow and profit. Lean production, which adopts the highest level of importance in any organization, means no unnecessary steps in the production process, minimum cost, minimum error, zero stock, customer satisfaction, improvement, and repair.

When adopting the word "lean" as a concept, the primary goal is to stay away from all waste via the simplest way possible and to choose to reach the maximum via this way [5]. The diverse variety of lean tools provides answers to the most diverse challenges, and

companies are increasingly adopting processes that aim to progressively reduce waste and help their production paradigm to adapt to what the market requires [6].

Lean manufacturing emerged from the study of processes at Toyota and has been applied in industrial processes through the use of different systematics, such as 5S, total quality management-(TQM), and just in time-(JIT). In almost all these systematics, the main goal is to continuously improve different production processes. The lean methodology aims to reduce overall "waste" in eight categories: overproduction, waiting time, transportation, unnecessary procedures, tools and equipment, movements, defects, and lack of operator input to generate ideas that could improve processes [7].

The concept of "lean construction" was first mentioned at the International Group of Lean Construction (IGLC) meeting held in 1993, and it was seen as a system that includes architects, civil engineers, mechanical and electrical engineers, suppliers, contractor companies, owners, and inspection institutions as the target audience [8]. As in all production sectors, quality, time, and cost are the most well-known focal points in the construction process. It is necessary to eliminate waste to create a production process with activities that add the most economic value in the optimum amount of time. With the application of industrial manufacturing methodology, construction costs, materials, execution time, and waste are reduced, improving productivity, and resulting in more sustainable construction [7].

It is believed that there are deficiencies in lean production in Turkey. In this context, firstly, the awareness of the lean production concept and its content among employees in building inspection companies, which are a special branch of the construction sector, was investigated and unique results were obtained. As it is important to first create and use knowledge before it can be put into practice, it can be said that the results of this study are crucial and will help identify the losses in building inspection organizations that are within the scope of the control of construction companies. In addition, detecting losses and determining awareness in building inspection companies, which have an important function in construction inspection, will help to prevent losses.

The literature on the subject was examined, and it was determined that there are few studies on the construction sector. The application of lean manufacturing has transformed many industries today, and its application in construction is slowly beginning to show benefits. The concept of lean construction involves the application of lean thinking to the construction industry. Lean construction focuses on providing exactly what customers and end users want [9]. This highlights the importance of this issue for construction industry stakeholders, such as building inspection companies. Another study emphasized that the use of resources in the construction industry has become vital for the future of companies. In this study, the gains obtained from lean production practices at construction sites are presented in the results section [10]. This shows that lean production systematics can produce positive results in every branch of the construction industry.

Lean manufacturing in building inspection organizations is an untouched subject. However, considering that factors such as scheduling, material, and human resources are the basic building blocks in construction supervision, it can be said that this subject is open to development. In this respect, the basic points of lean production philosophy in building inspection organizations are summarized below:

- Time-schedule control;
- Material usage (waste) control;
- Budget control;
- Control of administrative processes;
- Optimization of human resources in production [11].

The motivation for this study stemmed from this. Although the above-mentioned basic points are critical for building inspection organizations, the absence of any studies on this subject and the lack of a systematic approach has led to serious losses that have gone noticed.

It is thought that reducing the lack of knowledge of the employees in building inspection organizations about lean production may facilitate a reflection on the improvements in

this regard to the sector. The main aim of this study was to determine the level of awareness on this issue. Then, in line with this purpose, solutions to this problem are presented. In this way, it is possible for employees in building inspection companies operating in the sector to apply lean production principles.

Simultaneously, reducing losses in the building construction process will contribute to the sustainability of building inspection companies. It is thought that the future of companies that excluded non-value-added processes will be brighter than that of others. This makes the original results of this study important.

In summary, the contributions of this study to the literature are as follows:

- This study is the first of its kind in the research literature that examines the lean production approach in construction inspection organizations;
- This research, which determines scientific awareness about this issue in the construction sector, is an original study;
- In light of the data collected as a result of the research, it has been determined that employees in the relevant sector are not conscious about this issue. These findings may serve as the starting point for future research;
- The fact that this study is the first in the construction industry to use data mining techniques to determine people's levels of awareness is another novel contribution to the field;
- Within the scope of the research findings, it has been clearly seen that there is a need to increase social-scale education activities on this issue in Turkey.

2. Materials and Methods

In this study, we first analyzed the studies on lean production in the construction sector in the literature. The recent ones have examined the lean production situation in practice [7,10,12]. One study examined the implementation of lean manufacturing and its impact on construction management by developing case studies on construction sites where these concepts are applied. In the study, it was recommended that construction companies develop knowledge about the lean building system and the tools used by this system [10]. Another study was on design for manufacture and assembly (DfMA) and suggested that the slow adoption of this system in Australia was due to the community mentality, government regulations, building codes, and finance and supply chain management [12]. Another study analyzed the use of materials, construction design, use of resources, and the application of lean tools in construction [7]. In a different study the impact of lean manufacturing in industry 4.0 was examined. It was emphasized that benefits such as simplifying production processes, following innovations, and reducing unnecessary wages in organizations could be achieved [13]. In a recent study, practical application of PDCA cycle as a problem-solving methodology in the company for production was presented. The aim was to ensure the sustainability of the production process and to increase efficiency with lean production tools. By applying the lean manufacturing and PDCA approach with the developed model, productivity performance was increased by 10.67% compared to before the process improvement [14]. Additionally, in another study, modular construction (MC) as a sustainable alternative offered many benefits related to waste reduction, shorter construction times, and increased quality. A qualitative study was conducted involving eight MC manufacturers from Germany, Austria, and Switzerland. Seven barrier sizes were defined with 21 subcategories. It was stated how the existing obstacles to the application of automation in prefabricated production could be overcome in the most effective way [15]. These current studies were exemplary for the methodology of our study.

Our study aimed to measure the level of awareness among the employees of a building inspection company operating in Adana about the concept of waste, which is the focal point of lean construction. To achieve this, surveys were conducted with technical personnel involved in building inspection. In total, 343 questionnaires were administered. The interviews were conducted face-to-face. Microsoft Excel, SPSS, and WEKA software programs were used to analyze the data.

Within the scope of this study, the descriptive research model, accepted as a quantitative research method and used to clarify the existing phenomenon, was adopted. Data were usually collected by observation oriented face-to-face interviews, surveys, experiments, and literature reviews. In our study, the survey study, a quantitative data collection method, was chosen because it provides fast and relatively easy access to information [16]. In this framework, lean production awareness among the employees of building inspection companies that organize the control processes of construction in the private sector in Turkey was measured. It was anticipated that determining this will help eliminate many losses (in terms of material, equipment, time, etc.) that the sector is not aware of.

In the prepared questionnaire, the answers obtained as 1 (Yes), 2 (No), and 3 (I have no idea) were processed into the Excel program and converted into the formats required by the other analysis programs used and made ready for analysis.

WEKA, one of the software used, is a package program that is increasingly being used today [17]. The flow and accumulation of information, which is similar to the flow and accumulation of mineral deposits, has created a concept called data mining. Although its origins are based on different disciplines, such as artificial intelligence, machine learning, and statistics, data mining can be used in decision support systems and strategic planning studies [18]. In other words, the purpose of data mining is to find large amounts of data and previously unknown patterns in databases and use this information to create predictive models through computer programs, establishing meaningful and useful connections [19,20].

The biggest problem that complicates data analysis is that the data form a large- scale and complex structure. WEKA simplifies this structure. WEKA is Java-based software developed at the University of Waikato and was first used for agricultural analysis and later used for machine learning. It takes its name from the initials of "Waikato Environment Knowledge for Analysis" [17,21]. It is a popular program used in data mining because it is open-source software [22].

The WEKA program can perform operations such as classification, clustering, association, inference of association rule, preprocessing, and visualization on datasets. While performing data analysis, the WEKA program works in arff "Attribute Relationship File Format" [23] and keeps all operations included in the WEKA program in a text structure. The @relation, @attribute, and @data statements are used to determine the file structure. The @relation statement refers to the general purpose or name of the dataset, the @attribute statement refers to the feature names corresponding to the columns in the database, and the @data statement refers to the row where the raw data starts [24].

In this study, the data obtained were converted into arff files under the requirements of the data mining method to be used. Due to the mentioned reasons, it was decided that the WEKA program and algorithms were suitable for the datasets of this study. The fact that association rules work with a system that deals with the situation of other variables around a variable was also instrumental in this choice.

2.1. Questionnaire Design and Implementation

Prior to administering the questionnaires, the authors of this study received approval from the ATU Ethics Committee (Approval Date: 28 April 2021). The relevant board examined questions from both social and technical perspectives.

For the questionnaire used in the study, the opinions obtained by scanning existing studies on the subject were taken as a basis. Refs. [25,26] were a guide for creating the questionnaire used in this study. The literature review revealed that the subject of lean construction is a new branch of work in Turkey, and its examination in the building inspection sector can contribute to the literature. Both issues have been discussed separately, and examples have been presented in previous studies.

The applied questionnaire consisted of 28 questions in total with the first part consisting of 6 questions. The questions in this section were aimed at getting to know the employees of the building inspection company and were demographic questions that in-

cluded job descriptions within the company. The second part of the questionnaire contained 22 questions. In this section, the concepts of lean production, lean construction, and waste were discussed, along with the well-known benefits of these concepts. In the second part of the questionnaire, we tried to measure whether the employees within the scope of building inspection had an opinion on the specified issues and whether they were aware of the effects of the mentioned issues in the sector they were in.

2.2. Analysis Methods

SPSS was used to determine the reliability of the dataset obtained from the questionnaires, Microsoft Excel was used to create the statistical data accumulation obtained from the questionnaire, and WEKA was used to analyze the data obtained from the questionnaires. The association rule learning method, a data mining algorithm in the WEKA program, was used.

2.3. SPSS Reliability Analysis

SPSS is a software package and stands for the Statistical Package for the Social Sciences. Although it was initially used for social sciences, it can find a wider area of use today, and the reliability of the data set obtained as a result of the survey study can be examined. The alpha coefficient method, developed by Cronbach in 1951 to determine the reliability of the questionnaire, is an internal consistency estimation method used to determine the consistency of a test or a scale within itself.

Cronbach's alpha coefficient is a weighted standard change average calculated by dividing the sum of the variances in the k items in the scale or the test by the general variance. There may be a single α value determined for each item or an average α value for all items in the scale. The "α" value obtained for all items indicates the overall reliability of that questionnaire, and the general acceptance is that this value is 0.70 or greater. The commonly accepted alpha coefficient ranges are as follows:

$0.00 \leq \alpha < 0.40$: The scale is not reliable,
$0.40 \leq \alpha < 0.60$: The scale has low reliability,
$0.60 \leq \alpha < 0.80$: The scale is very reliable,
$0.80 \leq \alpha < 1.00$: The scale has high reliability [27].

2.4. Association Rules

Association rule is a data-mining method that examines the relationships between records in any database and attempts to identify which events can occur simultaneously. The association rule was first introduced by Agrawal and Srikant in 1994 [28]. The purpose of this data-mining method is to identify the association between the products purchased by customers during shopping and, thus, to determine the purchasing habits of the customer profile. Association rules are important for forming a basis for future research by analyzing past data and determining association behaviors in these data. Several algorithms have been developed for this purpose. The most well-known algorithm is Apriori, which was used in this study, to perform data analysis. The algorithm, which is one of the association rule algorithms that finds association relationships between large data sets, is a reliable and useful algorithm used to highlight the general trend in the data set. Each rule obtained by the study of the Apriori is expressed with support and confidence criteria. The support criterion expresses the frequency of association between items. Confidence criterion expresses the accuracy of these associations [29].

3. Results

This section presents the results of SPSS and WEKA in this study.

3.1. SPSS Reliability Analysis and Survey Main Results

The applied questionnaire data were subjected to reliability analysis according to Cronbach's alpha coefficient scale in the SPSS program and the value was determined to be

0.815. Because the coefficient value obtained was between 0.80 and 1.00, it can be concluded that our survey study is highly reliable. Table 1 presents the results of the analysis.

Table 1. Cronbach's Alpha Coefficient Obtained from Reliability Analysis.

		N	%
Cases	Used	343	100.0
	Excluded *	0	0.0
	Total	343	100.0
Reliability Statistics			
Cronbach's Alpha		Number of Items	
0.815		22	

* Scale: All Variables, Case Processing, Summary.

In this part of the study the data obtained from the surveys are shown in the form of pie charts with the help of the Microsoft Excel program.

The demographic characteristics of the participants were determined on the basis of the answers provided by the participants to the questions in the first part of the questionnaire. For example: it was concluded that the total number of technical personnel in the company where 66% of the participants, that is, 228 participants, worked, was 16 or more (Figure 1).

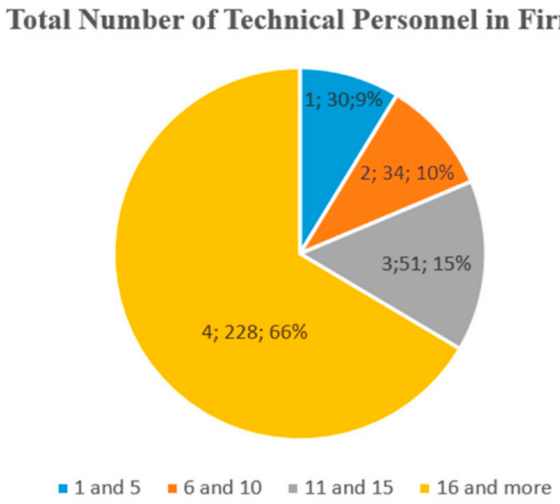

Figure 1. Profile of the Total Number of Technical Personnel in a Sample Firm—results of the survey.

As seen in Figure 2, a total of 156 participants (46%) worked with the title of engineer–inspector–architect. As shown in Figure 3, 54% were engineers and 16% were architects.

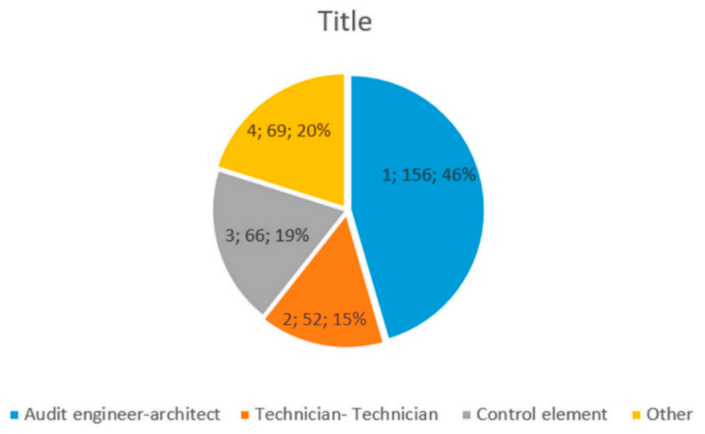

Figure 2. Sample Title Profile—results of the survey.

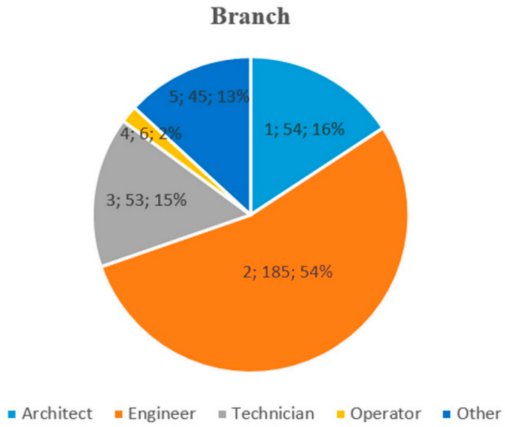

Figure 3. Sample Branch Profile—results of the survey.

According to the data obtained from the answer to the seventh question in the second part of the questionnaire on awareness about the concept of lean production, it was concluded that 47% of the participants (160 people) knew about the concept of lean production (Figure 4.)

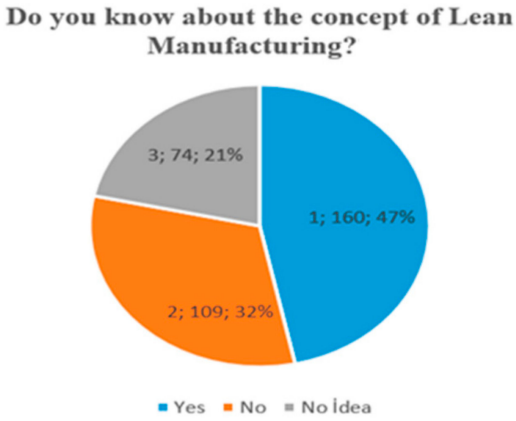

Figure 4. Awareness of the Lean Production Concept—results of the survey.

In the answers to the 14th question in the second part of the questionnaire, on the state of wastage due to application errors, 75% of the participants (256 people) selected yes, 20% of the participants (70 people) selected no, and the remaining 5% (17 people) had no idea (Figure 5).

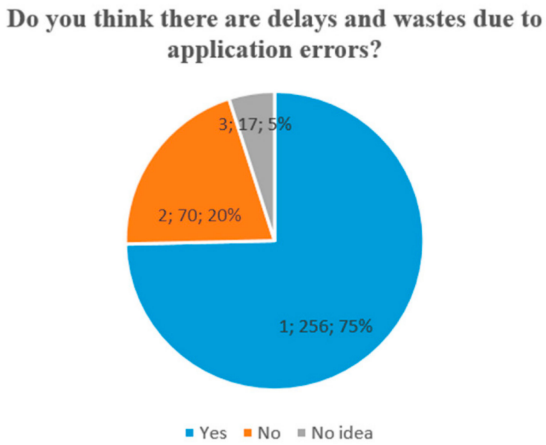

Figure 5. Waste Realization Due to Implementation Errors—results of the survey.

In the answers to the eighth question in the second part of the questionnaire, about whether the technical personnel knew about the concept of lean construction, 44% (150 people) selected yes, 33% (114 people) chose no, and 23% (79 people) had no idea. The related graphs are shown in Figure 6.

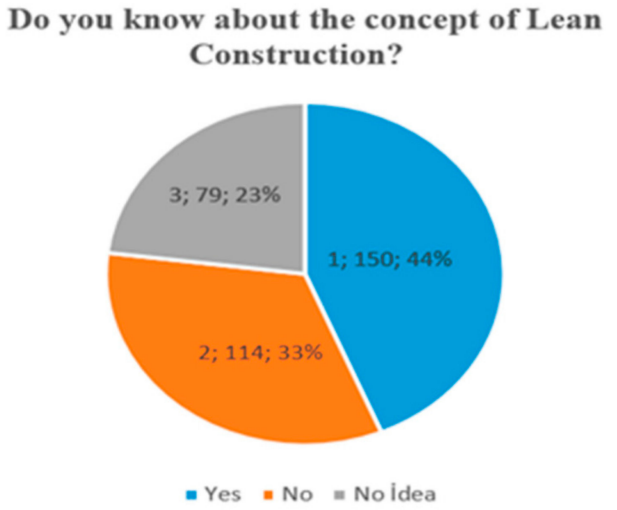

Figure 6. Awareness of the Lean Construction Concept—results of the survey.

3.2. WEKA Analysis Results

The WEKA program, which includes various methods, was used to analyze the data obtained as a result of the survey study. The concept is associated with whether a study is in a reliable range is called confidence. As this value approaches 1.00, the reliability rate of the study increases [29–31].

The questions specified in the questionnaires were chosen as class labels. While choosing among the questions, those that could reflect the purpose of the study were considered. In this study, the following three questions were used as class labels:

- The construction process based on applications that aim at a lower cost, a higher efficiency, and less waste is defined as "lean construction". "Do you have any information about the defined system?" (Question 8 of the survey);
- "Do you think that the lack of information about the Law on Construction Supervision No. 4708 and the relevant legislation can cause waste?" (Question 21 of the survey);
- "Do you think that raising awareness on lean construction and waste issues and increasing its practices will make positive contributions to the sector?" (Question 28 of the survey).

The reason for selecting these questions as class labels is that they could determine the awareness of employees on the subject. The answers to the other questions associated with these three questions were obtained for the association rules and are shared in this section.

3.2.1. The First Situation: "Do You Know about the Concept of Lean Construction?" Determined as the Class Label

In this case, the eighth question in the questionnaire was determined as the class label. It tried to find how often the answers given to the other questions were seen together on the question axis, which is the class label. The values in the table are the encodings used for the conversion to the arff file format required for WEKA. Lean Production = 1 means that the concept of lean production is known, Is there a Benefit of Lean Construction = 1, Lean construction concept is found to be useful, Bureaucratic Waste = 1, Excess bureaucratic or official correspondence is wasteful. The first ten association rules from the results are listed in Table 2.

Table 2. Results of Class Label 1.

Rules No.	Association Rules			Reliability Value
	Properties of the Rules	⇒	**Class Label Attribute**	
1	Lean Manufacturing = 1, Lean Construction Beneficial = 1, Bureaucratic Waste = 1	⇒	Lean Construction = 1	conf:(1)
2	Lean Manufacturing = 1, Lean Construction Beneficial = 1, Bureaucratic Waste = 1, Sectoral Contribution = 1	⇒	Lean Construction = 1	conf:(1)
3	Lean Manufacturing = 1, Lean Construction Beneficial = 1, Project Process = 1	⇒	Lean Construction = 1	conf:(0.98)
4	Lean Manufacturing = 1, Lean Construction Beneficial = 1, Project Process = 1, Sectoral Contribution = 1	⇒	Lean Construction = 1	conf:(0.98)
5	Lean Manufacturing = 1, Lean Construction Beneficial = 1, Bureaucratic Waste = 1, Using Lean Construction = 1	⇒	Lean Construction = 1	conf:(0.98)
6	Lean Manufacturing = 1, Lean Construction Beneficial = 1, Efficient Process = 1	⇒	Lean Construction = 1	conf:(0.98)
7	Lean Manufacturing = 1, Lean Construction Beneficial = 1, Efficient Process = 1, Sectoral Contribution = 1	⇒	Lean Construction = 1	conf:(0.98)
8	Lean manufacturing = 1, Lean Construction Beneficial = 1, Bureaucratic Waste = 1, 4708 Law = 1	⇒	Lean Construction = 1	conf:(0.98)
9	Lean Manufacturing = 1, Lean Construction Beneficial = 1, Bureaucratic Waste = 1, Qualified Personnel = 1	⇒	Lean Construction = 1	conf:(0.97)
10	Lean Manufacturing = 1, Lean Construction Beneficial = 1, Project Process = 1, App Waste = 1	⇒	Lean Construction = 1	conf:(0.97)

It can be observed that each line has association rules. In the applied survey, we asked:
"Do you know about the concept of lean construction?"
"Do you know the benefits of lean production?"
"Are you aware of its contribution to the project processes?"
"Do you think there are bureaucratic wastes?"
"Do you have any information about the Law No. 4708?"

The participants had to choose from options 1 (yes), 2 (no), and 3 (no idea). The first rule stated that people who knew about the concept of lean production, who found the concept of lean construction useful, and who thought that excessive bureaucratic work or official correspondence was wasteful knew about the concept of lean construction at a 100% confidence level. Similarly, in rule 2 in Table 2, those who knew about the concept of lean production found the concept of lean construction useful, found that excessive bureaucratic work or official correspondence was wasteful, believed that increasing lean construction practices by raising awareness about lean construction would make positive contributions to the sector, and had knowledge of the concept of lean construction. This confidence rate was 1.

Other rules presented in Table 2 were also evaluated within this framework in terms of their confidence rates (0.98–0.97). Table 3 explains all the attributes used in association rule extraction in Table 2.

Table 3. Definitions of Features of Class Label 1.

Features of Association Rules	Definitions of Features
Lean Manufacturing = 1	The concept of lean production is known.
Lean Construction Beneficial = 1	The concept of lean construction is found to be useful.
Bureaucratic Waste = 1	Excessive bureaucratic work is thought to be wasteful.
Sectoral Contribution = 1	It is believed that an increase in lean construction practices will make positive contributions to the sector.
Project Process = 1	It is thought that wastes occur in all processes of work from the project preparation stage to the delivery.
Using Lean Construction = 1	Using the concept of lean structure in practice is considered.
Efficient Process = 1	The process considered efficient in the construction process is thought to account for only 43% of the entire process.
4708 Law = 1	It is thought that there is a lack of information about the Building Inspection Law No. 4708.
Qualified Employee = 1	Wastage is thought to be due to unskilled employees.
App Waste = 1	Delays due to application errors are defined as waste.

Figure 7 shows the distribution of the other questions according to the class label question (the eighth question of the questionnaire).

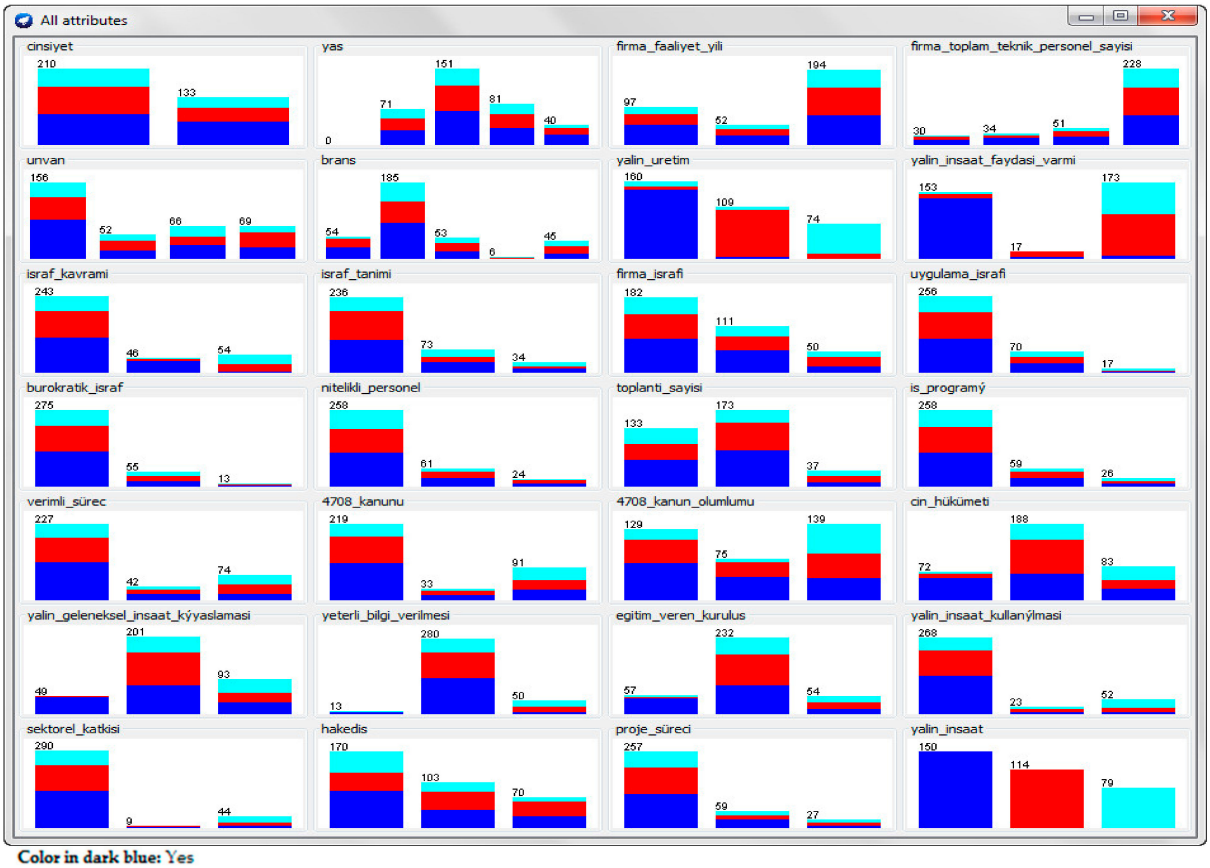

Figure 7. Distribution of Other Questions by the Class Label "Do you know any information about the concept of lean construction?".

3.2.2. The Second Situation: "Do You Think That the Lack of Information about the Law on Construction Supervision No. 4708 and the Related Legislation May Cause Waste?" Determined as the Class Label

The 21st question of the questionnaire set the second-class label, and attempts were made to determine how often the answers to other questions were seen around this axis. The 10 association rules from these findings are listed in Table 4.

Table 4. Results of Class Label 2.

Rules No.	Association Rules			Reliability Value
	Properties of the Rules	⇒	Class Label Attribute	
1	Qualified Employee = 1, 4708 Law Positive Effect = 1, Sectoral Contribution = 1	⇒	4708 Law = 1	conf:(0.89)
2	Qualified Employee = 1, 4708 Law Positive Effect = 1	⇒	4708 Law = 1	conf:(0.88)
3	Bureaucratic Waste = 1, 4708 Law Positive Effect = 1, Providing Adequate Information = 2	⇒	4708 Law = 1	conf:(0.87)
4	Waste Definition = 1, Implementation Waste = 1, Bureaucratic Waste = 1, Efficient Process = 1, Providing Adequate Information = 2, Sectoral Contribution = 1	⇒	4708 Law = 1	conf:(0.86)
5	Waste Definition = 1, Implementation Waste = 1, Efficient Process = 1, Providing Adequate Information = 2, Sectoral Contribution = 1	⇒	4708 Law = 1	conf:(0.86)
6	4708 Law Positive Effect = 1, Providing Adequate Information = 2, Sectoral Contribution = 1	⇒	4708 Law = 1	conf:(0.86)
7	Waste Definition = 1, Qualified Employee = 1, Efficient Process = 1, Providing Adequate Information = 2, Sectoral Contribution = 1	⇒	4708 Law = 1	conf:(0.86)
8	4708 Law Positive Effect = 1, Providing Adequate Information = 2	⇒	4708 Law = 1	conf:(0.85)
9	Waste Definition = 1, Qualified Employee = 1, Efficient Process = 1, Providing Adequate Information = 2, Using Lean Construction = 1	⇒	4708 Law = 1	conf:(0.85)
10	4708 Law Positive Effect = 1, Providing Adequate Information = 2, Using Lean Construction = 1	⇒	4708 Law = 1	conf:(0.85)

The first rule created by this class label was that people who thought that there was waste due to unqualified personnel, that the Law on Construction Supervision No. 4708 had contributed positively to the construction process, and that an increase in lean construction practices by raising awareness about lean construction would make positive contributions in the sector had a lack of knowledge about the relevant legislation and the law. The confidence rate was 89%. Similarly, in rule 2 in Table 4, those who thought that there was wastage due to unskilled workers with a lack of knowledge on this subject also thought that the Law on Construction Supervision No. 4708 made a positive contribution to the construction process. This confidence rate was 0.88.

Other rules presented in Table 4 were also evaluated within this framework in terms of their confidence rates (0.87–0.85). Table 5 explains all the attributes used in association rule extraction in Table 4.

Table 5. Definitions of Features of Class Label 2.

Features of Association Rules	Definitions of Features
Qualified Employee = 1	It is thought that there is wastage due to unskilled employees.
4708 Law Positive Effect = 1	Building Control Law No. 4708 is thought to contribute positively to the construction process.
Sectoral Contribution = 1	It is believed that an increase in lean construction practices will make positive contributions to the sector.
Bureaucratic Waste = 1	Excessive bureaucratic work is thought to be wasteful.
Providing Adequate Information = 2	It is thought that sufficient information is not given about lean structure concepts.
Waste Definition = 1	The definition "waste is anything that does not contribute to the production process" is correct.
Implementation Waste = 1	Delays and disruptions caused by application errors are considered a waste.
Efficient Process = 1	The process considered efficient in the construction process is thought to account for only 43% of the entire process.
Using Lean Construction = 1	It is thought that the concept of lean construction should be used in practice.

Figure 8 presents the distribution of the survey questions according to the 21st question of the survey, a class label question.

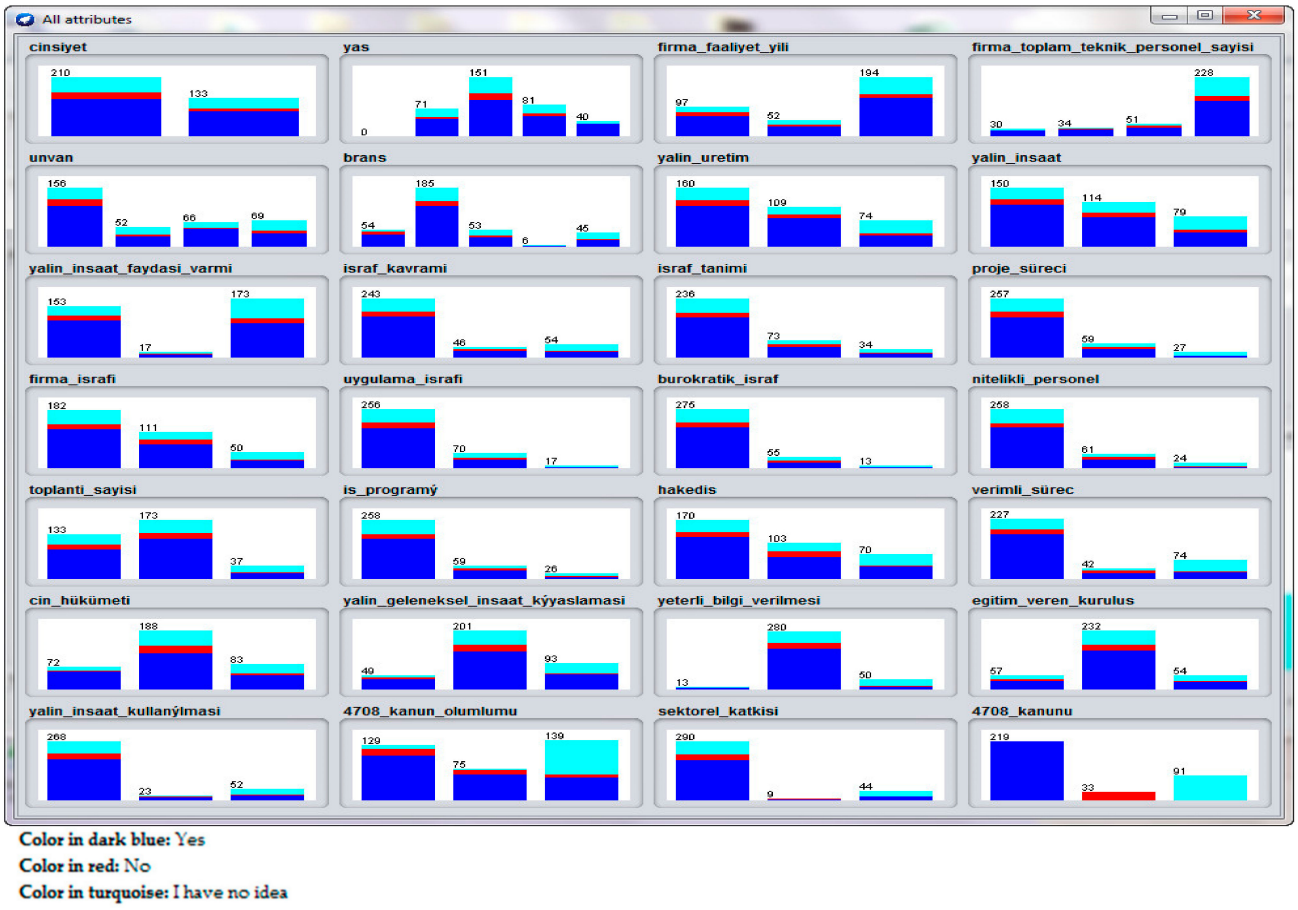

Figure 8. Distribution of Other Questions by the Class Label "Do you think that the lack of information about the Law on Construction Supervision No. 4708 and the related legislation may cause waste?".

3.2.3. The Third Situation: "Do You Think That Raising Awareness on Lean Construction and Waste Issues and Increasing Its Practices Will Make Positive Contributions to the Sector?" Determined as the Class Label

The 28th question of the questionnaire set the third-class label, and we tried to determine how often the answers to other questions were seen around this axis. Table 6 lists the 10 association rules from these findings.

Table 6. Results of Class Label 3.

Rules No.	Association Rules			Reliability Value
	Properties of the Rules	⇒	**Class Label Attribute**	
1	Project process = 1, Work Program = 1, Providing Adequate Information = 2, Using Lean Construction = 1	⇒	Sectoral Contribution = 1	conf:(0.99)
2	Work Program = 1, Providing Adequate information = 2, Using Lean Construction = 1	⇒	Sectoral Contribution = 1	conf:(0.99)
3	Waste Concept = 1, Providing Adequate Information = 2, Using Lean Construction = 1	⇒	Sectoral Contribution = 1	conf:(0.99)
4	Efficient Process = 1, Providing Adequate Information = 2, Using Lean Construction = 1	⇒	Sectoral Contribution = 1	conf:(0.99)
5	Bureaucratic Waste = 1, Work Schedule = 1, Providing Adequate Information = 2, Using Lean Construction = 1	⇒	Sectoral Contribution = 1	conf:(0.99)
6	Waste Concept = 1, Efficient Process = 1, Using Lean Construction = 1	⇒	Sectoral Contribution = 1	conf:(0.99)
7	Work Program = 1, Efficient Process = 1, Using Lean Construction = 1	⇒	Sectoral Contribution = 1	conf:(0.99)
8	Waste Concept = 1, Bureaucratic Waste = 1, Providing Adequate Information = 2, Using Lean Construction = 1	⇒	Sectoral Contribution = 1	conf:(0.98)
9	Bureaucratic Waste = 1, Efficient Process = 1, Providing Adequate Information = 2, Using Lean Construction = 1	⇒	Sectoral Contribution = 1	conf:(0.98)
10	Efficient Process = 1, Using Lean Construction = 1	⇒	Sectoral Contribution = 1	conf:(0.98)

The first rule in Table 6 was about raising awareness about the wastages in terms of money, time, labor, etc., in the processes from the project preparation stage to the delivery of the work because of the deficiencies in the work program. The authorized institutions did not provide sufficient information about the mentioned concepts, considering the use of these concepts in practice. It was seen that people who thought that the increase in lean construction practices would make positive contributions in the sectoral sense, at a 99% confidence interval, thought that these concepts would make positive contributions to the sectoral sense.

Similarly, in rule 2 in Table 6, people who experienced wastage due to the deficiencies in the work program, did not think that enough information was given about the concepts of lean construction and waste, thought about using these concepts in practice, believed that they would contribute positively to the sector if used thought that the increase in lean construction applications would make positive contributions to the sector by raising awareness about lean construction. This confidence rate was 0.99.

Other rules presented in Table 6 were also evaluated within this framework in terms of their confidence rates (0.99–0.98). Table 7 explains all the attributes used in association rule extraction in Table 6.

Table 7. Definitions of Features of Class Label 3.

Features of Association Rules	Definitions of Features
Project Process = 1	Wastes are thought to occur in all processes from the project preparation stage to the delivery of work.
Work Program = 1	It is believed that there are losses, for example, in resources, time, and materials due to deficiencies in the work schedule.
Providing Adequate Information = 2	It is thought that sufficient information is not given about lean structure concepts.
Using Lean Construction = 1	It is thought that the concept of lean construction should be used in practice.
Waste Concept = 1	It is thought that "the most emphasized issue in the concept of lean construction is waste."
Bureaucratic Waste = 1	Excessive bureaucratic work is thought to be wasteful.
Efficient Process = 1	The process considered efficient in the construction process is thought to account only for 43% of the entire process.

Figure 9 shows the distribution of the other questions according to the 28th question of the survey, a class label question.

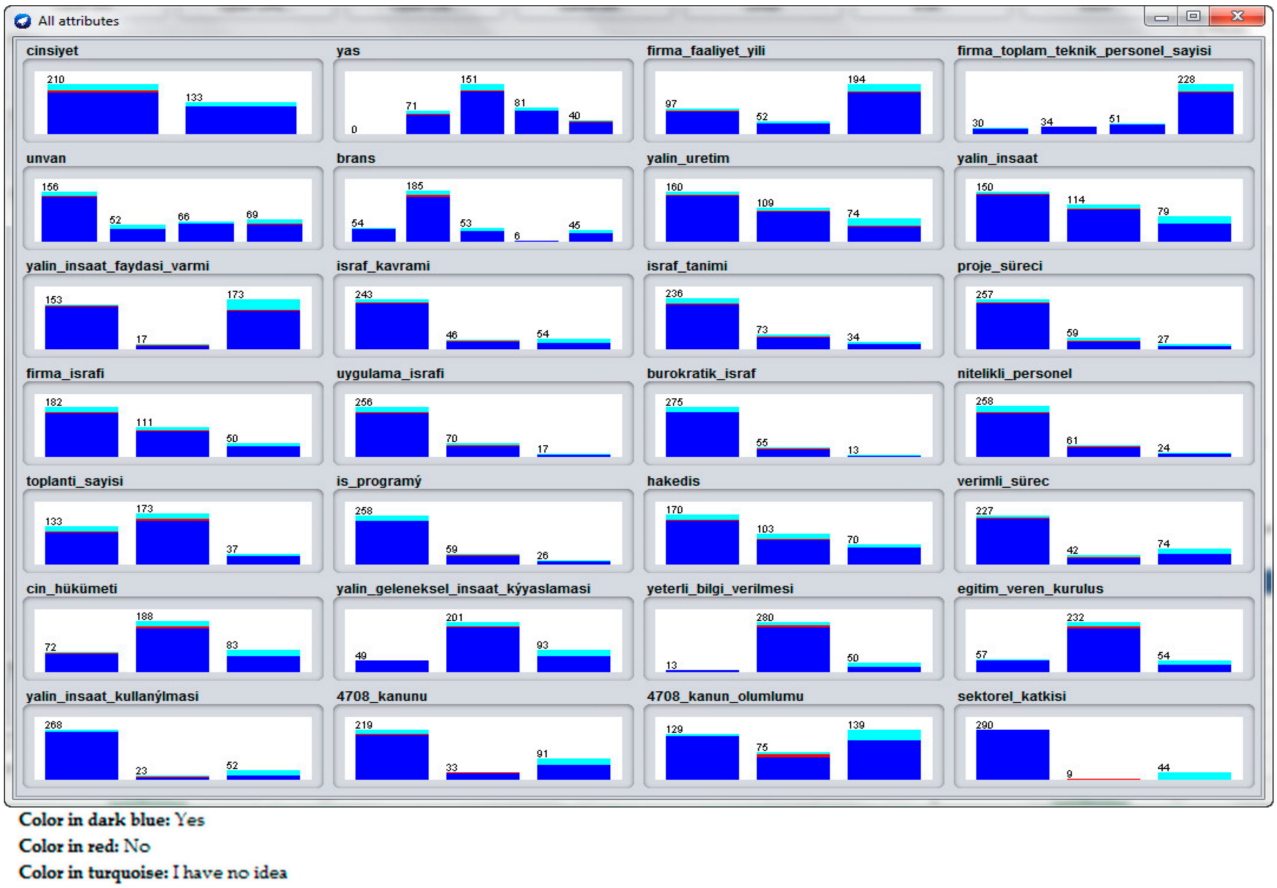

Figure 9. Distribution of Other Questions by the Class Label "Do you think that raising awareness on lean construction and waste issues and increasing its practices will make positive contributions to the sector?".

The findings led to the conclusion that the majority of those working in construction inspection firms (more than half of all analyzed questions) were unaware of concepts such as lean production, losses, and wastage in construction work.

4. Discussion

In this part of the study, the results of the data analysis are discussed. At the beginning of the study's analyses, Cronbach's alpha coefficient was found, and the reliability of the study was questioned. On the basis of the value found, statistical data containing the answers to the demographic questions in the survey, graphics, and data analysis results obtained by using WEKA and SPSS programs were divided into subgroups.

This study aimed to measure the awareness of the concepts of lean production, lean construction, and waste. A survey consisting of 28 questions was conducted among 343 technical employees working in building inspection companies operating within the provincial borders of Turkey. The results were expected to contribute to the literature and the construction sector. The reasons for this are as follows:

- In the construction industry, lean manufacturing is a relatively new topic;
- Although there are many researchers in different sectors working in this field [5,6,26], etc., the construction sector is still untouched. There are studies on lean production in the construction sector [9–15,31] (albeit fewer than in industries such as industry, medicine, and economy). However, there has been no study (except for a study by authors) on lean production in inspection institutions in the construction sector [11] which is a sub-branch of the sector and important for the inspection mechanism. In this study, answers were sought to determine whether there was awareness of this subject and the extent of the awareness of scientific facts. This study is unique in this respect. Issues such as waste, losses, and inefficient work are important in the construction industry, where production is based on limited resources. One of the aims of this study was to draw attention to these issues;
- This study primarily aimed to measure the level of awareness of lean production. Analyzing the current situation is important for understanding the benefits of this concept;
- It is clear that there is insufficient awareness of lean production among the employees of building inspection companies in Turkey. However, as can be seen in Figure 9, employees believed that some of the waste was due to bureaucratic obstacles (in the opinion of 275/343 participants). These and similar cases show that authorized institutions have important duties in this regard;
- In one of the studies in the literature [10], it was stated that there was a lack of information on this subject. This result indicates a lack of education, which was among the findings of this study;
- The proposal by a study in [12] to develop a community mindset, which is among the challenges in implementing DfMA in Australia, is in line with the results of this study. The importance of community development on the subject was emphasized in the implementation of lean construction. Similarly, in another study [7], the importance of reducing losses by applying lean production was explained and it was stated that the level of knowledge on this subject should be increased. The results of all these studies on lean production in the construction sector are compatible with the results of this study, which is the first study to measure the knowledge of lean production among building inspection employees;
- Both the contribution of lean production in Industry 4.0 [13] and the use of PDCA cycle with lean production [14] studies emphasized the application of lean production in companies for process improvement and sustainability. Considering the importance of raising awareness and education in the application of lean production, the results of these studies are also in line with the results of the study;
- The limitations of this study are as follows: it was carried out only in Adana, there was difficulty in establishing a systematic method due to the high turnover rate of the employees of the building inspection companies, the building inspection companies have to inspect different construction companies, and no comparison could be made because there is no other similar study in the literature. It is recommended to pay attention to these points in future studies.

5. Conclusions

In this study, we determined the extent to which the technical personnel working in the construction inspection sector dominated lean construction, whether they had sufficient knowledge about these subjects, their perspectives on the concept of waste based on the institutions they work for, and the level of desire and demand for the use of all these subjects in practice. In total, 343 participants were included in the survey. Participants were questioned about their awareness of the lean construction concept, and it was determined that 44% of the participants knew but 56% did not know. This situation gives an idea about the awareness of the concept of lean construction among technical personnel in Adana, Turkey. When questioned about whether there was any waste in the processes from the project preparation stage to the delivery of work, 75% of the participants thought that waste occurred and the remaining 25% did not.

Participants were asked whether the lack of information about the Law on Construction Supervision No. 4708 would cause waste. The majority of the participants (64%) thought that there would be waste due to a lack of information, while 36% did not think that it would create waste. Asked about the contribution of the Law on Construction Supervision No. 4708 to the lean construction process 38% of the participants found it useful, 22% did not find it useful, and the remaining 40% did not have any idea.

When asked whether the increase in lean construction practices would positively contribute in the sectoral sense, 84% of the respondents thought that it would make a positive contribution, whereas 16% did not think that it would make a positive contribution. During the face-to-face interviews, it was observed that the participants did not have a full grasp of the concepts mentioned. There was not enough awareness of how they could use these concepts and how they could gain benefits if they used the concepts.

Presenting the original results of this study to society and construction industry employees is critical for raising awareness about this issue. In terms of sustainability, it is crucial for the employees in building inspection companies to be aware of loss reduction and the concept of waste. In this respect, it is critical that all stakeholders, especially universities, other educational institutions, and public institutions, cooperate. It is thought that this study is the first on its subject, can be a reference for future studies, and can help to eliminate the scientific deficiency in this subject.

Some suggestions for implementing lean manufacturing principles in building inspection organizations are listed as follows:

- The building inspection staff should be educated on these topics. The training should clearly state the concept of lean manufacturing, its content, and how it will be implemented;
- Efforts should be made to reduce all waste by making applications on the basis of units;
- Those responsible for lean production processes should be identified, and controls should be created at all stages of implementation. Corrective-preventive actions should be carried out in parts that do not comply with the planning;
- All these processes should be recorded and reported, and improvements should be standardized. In addition, in-house training periods should be determined;
- In summary, it is necessary to ensure full participation of all stakeholders in order to make the application of lean production principles an organizational culture in building inspection organizations.

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References

1. Bayram, S.; Aydınlı, S.; Budak, A.; Oral, E. Ethical problems in the production and inspection of construction in Turkey. *Pamukkale Univ. J. Eng. Sci.* **2018**, *24*, 461–467. [CrossRef]
2. Womack, J.; Jones, D. *The Evolution of Lean Thinking and Practice*, 1st ed.; Netland, T.H., Powell, D.J., Eds.; The Routledge Companion to Lean Management: New York, NY, USA, 2016; p. 6.
3. Apilioğulları, L. *Yalın Dönüşüm Verimliliğin Şifresi*, 1st ed.; Aura Books: Istanbul, Turkey, 2010.
4. Kara, Y. New Models for U-Type Assembly Line Balancing Problems and an Application in Automotive Supply Industry. Ph.D. Thesis, Selcuk University Institute of Social Sciences, Konya, Turkey, 2004.
5. Can, G.; Taş, E.F. Analysis of non-physical waste causes affecting the construction process. *J. Fac. Eng. Archit. Gazi Univ.* **2021**, *36*, 655–668. [CrossRef]
6. Pinto, C.M.A.; Mendonça, J.; Babo, L.; Silva, F.J.G.; Fernandes, J.L.R. Analyzing the Implementation of Lean Methodologies and Practices in the Portuguese Industry: A Survey. *Sustainability* **2022**, *14*, 1929. [CrossRef]
7. Awad, T.; Guardiola, J.; Fraíz, D. Sustainable Construction: Improving Productivity through Lean Construction. *Sustainability* **2021**, *13*, 13877. [CrossRef]
8. Gleeson, F.; Townend, J. *Lean Construction in the Corporate World of the UK Construction Industry*; University of Manchester, School of Mechanical, Aerospace, Civil and Construction Engineering: Manchester, UK, 2007.
9. Harsha, N.; Suresh, A.V.; Nagaraj, N. Implementation of Lean Concepts in the Construction Engineering Project. *Int. J. Eng. Res. Technol.* **2013**, *2*, 1078–1095.
10. Aureliano, F.; Costa, A.A.F.; Junior, I.F.; Rodrigues, R.A. Application of lean manufacturing in construction management. *Procedia Manuf.* **2019**, *38*, 241–247. [CrossRef]
11. Keleş, A.E.; Yılmaz, H.K. *A Study for the Awareness of Lean Construction in Building Inspection Firms*, 1st ed.; Lambert Academic Publishing: Chisinau, Moldova, 2021.
12. Langston, C.; Zhang, W. DfMA: Towards an Integrated Strategy for a More Productive and Sustainable Construction Industry in Australia. *Sustainability* **2021**, *13*, 9219. [CrossRef]
13. Singh, K.; Jha, S. Lean Manufacturing—An analytical approach towards Industry 4.0. In Proceedings of the 2nd International Conference on Smart Electronics and Communication (ICOSEC), Trichy, India, 7–9 October 2021; pp. 1690–1695. [CrossRef]
14. Milosevic, M.; Djapan, M.; D'Amato, R.; Ungureanu, N.; Ruggiero, A. *Sustainability of the Production Process by Applying Lean Manufacturing Through the PDCA Cycle—A Case Study in the Machinery Industry. Advances in Manufacturing Engineering and Materials II. ICMEM 2021. Lecture Notes in Mechanical Engineering*; Springer: Cham, Switzerland, 2021. [CrossRef]
15. Feldmann, F.G. Towards Lean Automation in Construction—Exploring Barriers to Implementing Automation in Prefabrication. *Sustainability* **2022**, *14*, 12944. [CrossRef]
16. Üzgeç, M. A Study to Determine the Occupational Safety Awareness of Employees in a Corporate Company. Master's Thesis, Çukurova University Graduate School of Natural and Applied Sciences, Adana, Turkey, 2018; p. 107.
17. Keleş, A.E.; Önen, E.; Górecki, J. Determination of Green Building Awareness: A Study in Turkey. *Sustainability* **2022**, *14*, 11943. [CrossRef]
18. Irmak, S.K.; Köksal, C.D.; Asilkan, Ö. Estimating the future patient densities of hospitals with data mining methods. *Int. J. Alanya Bus. Fac.* **2012**, *4*, 101–114.
19. Bhatla, N.; Jyoti, K. An analysis of heart disease prediction using different data mining techniques. *Int. J. Eng. Res. Technol.* **2012**, *1*, 1–4. Available online: https://www.ijert.org/research/an-analysis-of-heart-disease-prediction-using-different-data-mining-techniques-IJERTV1IS8282.pdf (accessed on 2 March 2021).
20. Savaş, S.; Topaloğlu, N.; Yılmaz, M. Data mining and application examples in Turkey. *Istanb. Commer. Univ. J. Sci.* **2012**, *11*, 1–23.
21. Garner, S.R. Weka: The Waikato Environment for Knowledge Analysis. Proc New Zealand Computer Science Research Students Conference. 1995, pp. 57–64. Available online: https://www.cs.waikato.ac.nz/~{}ml/publications/1995/Garner95-WEKA.pdf (accessed on 17 February 2021).
22. Zupan, B.; Demsar, J. Open-source tools for data mining. *Clin. Lab. Med.* **2008**, *28*, 37–54. Available online: http://eprints.fri.uni-lj.si/893/1/2008-OpenSourceDataMining.pdf (accessed on 26 February 2021). [CrossRef]
23. Keleş, M.K. Breast cancer prediction and detection using data mining classification algorithms: A comparative study. *Teh. Vjesn.* **2019**, *26*, 149–155. [CrossRef]
24. Keleş, A.E.; Kaya Keleş, M. Adana İnşaat Sektörü Çalışanlarının Verimlilikleri Üzerine Bir Araştırma. *El-Jazari J. Sci. Eng.* **2018**, *5*, 605–609. [CrossRef]
25. Bajjou, M.S.; Chafi, A. Barriers of lean construction implementation in the Moroccan construction industry. *AIP Conf. Proc.* **2018**, *1952*, 1. [CrossRef]
26. Yağız, S. Türkiye'de yapı Denetim Uygulaması ve Konut Niteliğine Etkisi: Bursa Alan Çalışması. Master's Thesis, Bursa Uludağ University Institute of Science and Technology, Bursa, Turkey, 2019.
27. Özdamar, K. *Statistical Data Analysis with Package Programs*, 4th ed.; Kaan Publishing: Eskisehir, Turkey, 2004; pp. 279–340.

28. Agrawal, R.; Srikant, R. Fast algorithms for mining association rules in large databases. In Proceedings of the 20th International Conference on Very Large Data Bases, San Francisco, CA, USA, 12–15 September 1994; pp. 487–499.
29. Kaya, M.; Keleş, A.E.; Oral, E.L. Construction crew productivity prediction by using data mining methods. *Procedia-Soc. Behav. Sci.* **2014**, *141*, 1249–1253. [CrossRef]
30. Memon, A.; Akhund, M.; Laghari, A.; Imad, H.; Bhangwar, S. Adoptability of lean construction techniques in Pakistan's construction industry. *Civ. Eng. J.* **2018**, *4*, 2328–2337. [CrossRef]
31. Eriksson, P.E. Improving construction supply chain collaboration and performance: A lean construction pilot project. *Supply Chain. Manag.* **2010**, *15*, 394–403. [CrossRef]