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Article

Determination of the importance of material management activities in construction works in terms of their contribution to productivity

Serkan Yildiz

Department of Real Estate Development and Management, Ankara University, Ankara 06590, Turkey; syildiz58@yahoo.com

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Abstract: In a construction project, a significant part of the costs and construction process is controlled by materials. It is possible to significantly increase productivity at the construction site with successful material management. In this study, first, a comprehensive literature review on material management processes was conducted and how material planning, material procurement, material acceptance and inspection, storage and inventory control, material handling and productivity issues were discussed in the literature was reviewed. Then, the contribution of nine criteria regarding material management to productivity was evaluated through surveys conducted at different construction sites. The study revealed that there were significant differences between the participants' evaluations according to their gender, education level, profession and construction site size. However, according to general evaluations, the most important criteria were found to be proper storage of materials, identification of critical materials and proper handling of materials. It is evaluated that the study will be a guide for stakeholders in the establishment of material management processes.

Keywords: material management; procurement; storage; handling; relative importance

1. Introduction

Materials constitute the basic components of construction works together with labour and low productivity is one of the most important problems of the construction industry [1,2]. Therefore, the achievement of cost, time and quality targets of a construction project is closely related to materials management, and it is important for the sector to examine the relationship between materials management processes and productivity. The first activity that the contractor initiates in parallel with the site preparations is to make subcontracts for different parts of the work and to place purchase orders for the materials to be used. All activities related to building materials during construction, from determining the building materials and quantities required for construction to the treatment of waste materials, are referred to as materials management.

Research shows that materials account for approximately 50%–60% of the construction cost, depending on the type of building, and that materials control 80% of the project schedule from the procurement of initial materials to the delivery of the final product [3]. Since construction tenders are procurement systems that reward the lowest bidder, often resulting in contractors running the project with little profit [4], success in materials management is crucial. Poor materials management leads to many problems such as inaccurate warehouse records, over-ordering and large material surpluses at the end of the project, poor field storage practices, materials that should have gone into production but cannot be found on site, delayed deliveries, nonstandard materials and cash flow problems. Rahman et al. [5] discovered that late, irregular, or incorrect delivery of construction materials affects the efficient operation of labor and machinery, which constitute the second main part of the cost of construction work. While there are many studies in the literature showing that problems with construction materials lead to poor project performance, on the contrary, good materials management plays an important role in the success of construction projects, and that efficient management can lead to significant savings in project costs [6–12].

The purpose of materials management is to ensure that the right materials are in the right place, in the right quantities, when needed. In this respect, the materials management system in any project ensures that the right quality and quantity of materials are appropriately selected, efficiently procured, properly delivered and safely put into production on-site on time and at a reasonable cost [13]. Thus, with good materials management, construction cost overruns can be avoided, profits can be made even with low bids, and various bad practices can be avoided [4]. All this has made materials management a critical part of a successful construction management process over the years. However, materials management has often been a neglected area by construction industry stakeholders and academics [14–16].

In this study, first of all, a comprehensive literature review was conducted to form the basis of the quantitative study to be conducted. Then, a quantitative study was conducted to determine how important each material management activity is in terms of productivity at the construction site for sector employees at different levels. Since there are employees with different demographic characteristics such as gender, age, education level, work experience and profession at construction sites, it is important to see whether the opinions of the employees differ according to these characteristics. In this respect, various hypotheses such as "there is no difference between the opinions of the employees according to their gender" were tested with the study. Another issue that was thought to have an effect on material management is the size of the construction site. Therefore, the study also aimed to investigate the effect of the size of the construction site. The financial size of the project and the number of employees were used as indicators of the size of the construction site, and the hypotheses "There is no difference between the opinions of the participants in terms of the financial size of the ongoing project" and "There is no difference between the opinions of the participants in terms of the number of employees at the construction site" were also tested.

Last goal of the study was to determine the relative importance of different material management activities in terms of their contribution to productivity. In this way, it was possible to make clear which material management activities contractors and people responsible for material management should focus more on.

2. Literature review

Kanimozhi and Latha [13] defined materials management as the coordination function responsible for planning and controlling the flow of materials, and introduced its management processes as planning, procurement, logistics, processing, and waste control. In another way, it may be defined as a combination of planning, identification, inventory control, receiving and distribution, material handling and storage of materials [17,18].

Proper material management has benefits such as lower total material costs, better material handling, reduction in duplicate orders, availability of material on site when needed and in the required quantity, improvement in labor productivity, improvement in project scheduling, quality control, better material control on site and better relationships with suppliers [19,20].

The materials management process can be examined in the bidding, procurement, construction, and post-construction phases [17]. In the bidding phase, all the conventional and special materials needed and their quantities are determined and demand lists are prepared. The procurement phase is the process of keeping the desired material at the construction site in the desired amount and at the desired time according to the prepared demand schedules. The construction phase includes receiving, storing, distributing and manufacturing the materials on site. The post-construction phase involves storing the remaining materials to be used in other projects and disposing of material waste. It should be kept in mind that each of these phases requires individual attention, and errors and omissions can lead to negative consequences such as project delays, cost overruns, low productivity and waste [21,22]. How the various stages of materials management that are presented in **Figure 1** are addressed in the literature is examined below.

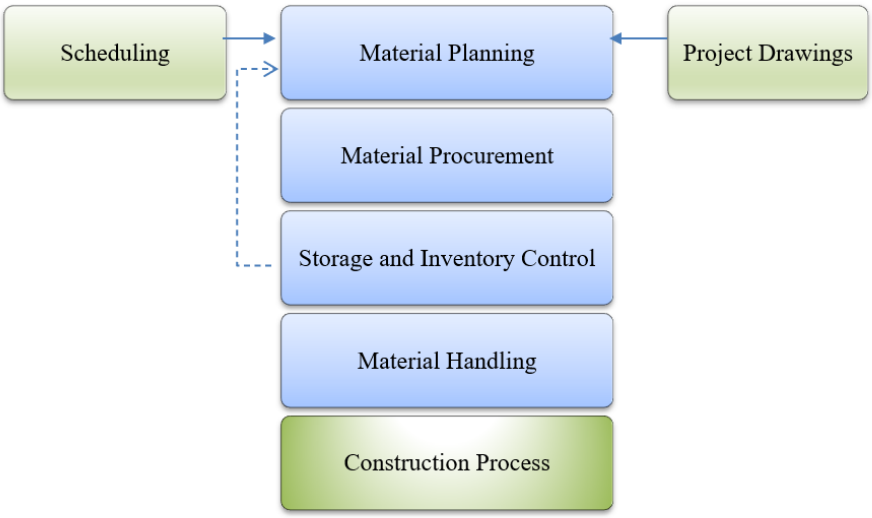

Figure 1. Stages of material management.

2.1. Material planning

In any industry, having the right material at the right time and in the right quantity is critical to the smooth running of production. The purpose of the material requirements plan is to determine which components are required to meet the main production schedule and to calculate the time when the components should be ready depending on the delivery time. This includes what to order, how much to order, when to order and when to schedule delivery [23]. All this makes materials management planning both the first and a very important step of materials management process [9,18]. To improve productivity, it is always recommended that the project management team plan ahead to ensure that critical materials are identified, procured and available on site [24]. Nasir [25] argues that identifying critical materials is a materials management best practice to increase productivity in infrastructure projects.

The first step in a construction project regarding materials, including critical ones, is to identify what is needed. In addition to identifying and determining the required materials, the planning process also includes the tasks of creating and maintaining material records, setting target inventory levels, logistics planning, and determining delivery frequency [3,26]. Considering the difficulty of the process and the importance of materials planning for materials management, it would be useful to consider a number of issues that can contribute to improving planning, such as spending more time for planning, the relationship between different parties, alternative plans and sufficient time, control time and revision interval [27].

2.2. Material procurement

From the contractors' point of view the purpose of the procurement process is to provide materials at the right time, right place, right quality and within the agreed budget [28]. This process is carried out by creating a purchase requisition; evaluating and selecting suppliers; negotiating price and terms; creating a purchase order; receiving and inspecting the material; matching; approving and paying the invoice; and record keeping [29]. It is clear that the first factor in material procurement is cost. The total cost of materials includes major cost categories such as purchase cost, storage cost, ordering cost, unavailability cost and opportunity cost due to capital tied up in material stocks. Therefore, there must be a trade-off between these cost categories to procure materials at a reasonable cost [30,31]. Dynamic nature of construction projects makes sometimes to receive the material on time, and often the reliability of the supplier more important than the cost. In this respect, it is critical to evaluate suppliers on criteria such as price, quality, delivery time, inventory held by suppliers and flexibility [9,32]. It can be said that it is impossible for contractors to place material purchase orders for the right quantity of materials at the right quality, at the lowest cost and without any delay without establishing appropriate methods and procedures [33]. In material ordering, it is important not to order more or less material than needed. Under-ordering causes program disruption and over-ordering causes additional cost. Onabule [34] refers to the difference between the materials delivered to the construction site and those used for construction work as construction materials waste. To avoid waste, rational management of materials, including material procurement, is important. As a part of procurement, delivery of the materials to a construction site is also important. In the delivery of construction materials, problems such as materials arriving at the site at the wrong time; the wrong quantity of materials arriving; material specifications not matching those on the purchase order; storage space not being planned for materials on site are common problems [10]. Therefore, the delivery process also needs to be well managed. Material brought to site is usually received by the site supervisor or his/her deputy. On delivery, the quality and quantity of the material should be checked. With the acceptance of the delivered goods comes the acceptance of "responsibility for the care, custody and control" of the equipment and materials received and inspected. Another point to be considered in material delivery is the fact that improper unloading and handling processes cause damage and waste of a large amount of material [35].

2.3. Storage and inventory control

Proper storage at the construction site is necessary to prevent waste, loss and damage to materials, which are often caused by scattered stock, misclassification, misallocation and misstacking [36]. Storage conditions of equipment and materials should be defined before shipment. Problems often arise during material procurement due to improper storage, causing delays and affecting the work schedule [35]. Previous studies have identified that construction materials often require a large storage capacity, which is rarely available on site [37]. The timing of the initial purchase, historical knowledge and experience should be taken into account when planning storage space [38]. Industrial guidelines for stacking and storing certain materials should be considered [12]. Materials should be stored appropriately, protected from contamination or atmospheric effects, locked against theft, accessible for handling, stored in the most suitable locations close to their place of use, and precautions should be taken against tripping, fire, explosion, pests, etc. in the storage area [39]. Inventory control of stored materials is also a critical task. Inventory control is the technique that ensures that all items such as raw materials, processed materials, assembly components, consumables, general supplies, maintenance materials and spare parts, products in progress and finished are available when needed [40]. The overall objective of inventory control is to minimize the total cost of holding inventory while choosing between the major cost categories of (1) purchase cost, (2) ordering cost, (3) holding cost, and (4) non-finding cost. The main objective of inventory control is to prevent material shortages and surpluses on construction sites [10,18] and is also related to the handling, distribution, and use of materials [41,42]. Effective construction site inventory control provides significant benefits for a construction business.

2.4. Material handling

Effective material handling is defined as using the right method to provide the right material in the right quantity, at the right place, at the right time and sequence, right location, right condition and right cost [43]. Material handling, optimizing the location of service roads and determining crane location are problems in materials management that need to be solved with a realistic analysis [14]. The importance of proper material handling is due to the fact that it is an expensive process and requires critical decisions. Material handling costs are known to be an important part of total construction costs [43,44]. Material handling forms part of the logistics management of a project. Materials can be handled on site by hand, as well as by hydraulic excavators, telehandlers, cranes, forklifts, lifting devices and conveyor systems. The selection of material handling equipment is an important function as it can improve the production process, ensure efficient use of manpower, increase production and improve system flexibility [45]. It is important that everyone on site knows how the system works because safety is the top priority when dealing with materials on site. Neitzel et al. [46] suggested that approximately 6% of total construction costs are due to construction accidents and that one third of all fatalities on construction and maintenance sites are caused by cranes and material handling equipment. Shepherd et al. [47] estimated that approximately 25–33% of losses in construction activities are caused by crane accidents. Thus, while designing a material handling system for a construction project, considering worker health and safety as the primary objective, standardizing methods and processes, reducing or eliminating unnecessary use or movement and keeping the construction site safe, clean, and easy to navigate are important issues [39,48].

2.5. Productivity

Productivity is a concept that is seen as the basis for rising living standards. In economic terms, productivity is the ratio of output per unit of input. Creating more output in terms of quantity and quality for a given input means a higher standard of living in economic terms [49]. Prokopenko [50] divided productivity factors into external (uncontrollable) and internal (controllable) factors. Internal factors are hard factors, those related to products, plant and equipment, technology, materials and energy) and soft factors those related to people, organization and systems, working methods and management styles. Significant changes in materials technology were found to experience significantly larger improvements in both labor and partial factor productivity in the long run [51]. In the Loera et al. [52] study, one of the productivity focus areas was administrative factors that affect labor productivity by facilitating the management of materials and equipment during operations. Abdul Kadir et al. [24] identified material shortage as the first of the five most important factors causing inefficiency at the construction site. The most important factors affecting construction productivity were identified as lack of materials, rework, lack of equipment, inspection delays, absenteeism and interference [53,54]. Similarly, studies conducted in Australia, Iran, Indonesia and Thailand have also revealed that material shortages affect construction productivity [55–58]. Lack of materials has been identified as the main factor leading to low productivity in terms of lost time and frequency of occurrence [59]. Moreover, the availability of materials and equipment motivates employees to increase work productivity [4]. Poor materials management is known to cause labor inefficiency, and it has been found that failures in materials management lead to a 9% loss in labor productivity [16,60]. Improper material storage has been found to cause workers to need more time and effort to retrieve materials, thereby wasting their energy and causing physical fatigue [61]. On the contrary, with proper storage, workers' energy is used efficiently, while efficient yard layout makes material movement efficient and handling times shorter [12,62]. Choi and Chan [63] found that 32% of the causes of tower crane idling on Hong Kong construction sites were preventable, of which a significant proportion was due to inconsistent material flow.

3. Research methodology

In this study, the scales used in the studies [64–66] that investigated the effect of materials management on construction site productivity were revised and used. It was observed that two of these studies [64,65] addressed the protection and maintenance of the received materials as a criterion, but none of the studies directly included issues related to the storage and handling of materials. On the other hand, as discussed in the literature section, these issues are critical for materials management. The reason for not including criteria related to material storage and handling in these studies conducted in Australia is that contractors in Australia prefer materials to be brought to construction sites when needed and placed close to the installation area [66]. This can be confirmed by Polat and Arditi's [67] finding that in material procurement, contractors in developing countries stockpile excess materials just in case, while the trend in developed countries is to deliver materials just in time. Supply chain uncertainty, variability and uncertainty in the production process, unavailability of materials in the local market, high inflation rates, price discounts for large material orders and early orders make Just in Time (JIT) less advantageous, especially for developing countries. Thus, in this study determination of storage space on site, proper storage and handling of materials criteria were added to the scale and the evaluation was based on nine criteria.

The target population for of this study is construction site workers between the ages of 20–60. In such studies, workers have various concerns about giving their opinions about an ongoing project and therefore conducting a survey is a difficult process in terms of finding respondent. Therefore, the minimum sample size was taken as a basis and the minimum sample size was determined as 45 based on the 5:1 criterion, which considers at least 5 participants for each question [68]. Each construction site was visited separately, the workers interviewed face to face were informed that their identities would never be disclosed, and each survey form was filled out individually and by hand.

The survey was composed of two parts. In the first part, participants were asked for their personal information such as gender, age, education. The financial size of the ongoing project and the number of current employees is asked also in this part.

In the second part, respondents were asked to rate the contribution of these criteria to productivity on the construction site on a 5-point Likert scale ranging from 1—not important, 2—less important, 3—moderately important, 4—very important and 5—absolutely very important. The survey was conducted with 70 participants with different demographic characteristics who continue to work at different construction sites, and the collected data were analyzed with SPSS 29.0 (Statistical Package for Social Sciences) [69]. In this context, firstly, descriptive analyses of the participants and reliability analysis of the scale were performed. Descriptive statistics are summary statistics that describe or summarize basic but important features of a quantitative data set [70]. Common descriptive statistics are percentages and means. It is necessary also to test whether the scale is reliable, that is, whether the scale items are internally consistent, and the most commonly used test for this is Cronbach's alpha coefficient [71]. In such a study where respondents with different demographic characteristics participate, it is necessary to test whether there are differences between the opinions of the participants to see whether the results are generalizable. Inferential analyses are performed for this purpose. Inferential analysis methods to be applied for parametric or nonparametric data are different from each other. Therefore, normality tests should be performed first. Although there are different normality tests in the literature, checking the skewness and kurtosis values is one of the most used methods [72]. The most common statistical methods used in hypothesis testing to compare means in the case of normal distribution of data are Student's t test (t test) and analysis of variance (ANOVA). While Student's t test is used to compare means between two groups, ANOVA is used to compare means between three or more groups. In the t test, the null hypothesis states that both means are statistically equal, while the alternative hypothesis states that both means are not statistically equal, that is, they are statistically different from each other. The ANOVA test is a statistical technique used to compare means between three or more groups. A significant *P* value indicates that there is at least one pair where the mean difference is statistically significant [73]. To analyze the order of importance of variables, the relative value of each variable perceived by the participants is expressed by the relative importance index (RII) [74]. RII is a widely used method because it has a high accuracy rate when rating variables obtained using a questionnaire [75].

4. Data analysis, findings and results

4.1. Findings about demographic characteristics of participants and construction sites

Table 1. Demographic data of the participants.

Variable	*N*	%
Gender		
Male	54	77.1
Female	16	22.9
Age Group		
20–29	15	21.4
30–39	15	21.4
40–49	26	37.1
50 and higher	14	20.0
Educational Status		
High school and below	28	40.0
University	38	54.3
Master's Degree—PhD.	4	5.7
Work Experience Duration		
5 and below	14	20.0
6–10 Years	19	27.1
11–15 Years	12	17.1
16–20 Years	13	18.6
21 Years and above	12	17.1
Profession		
Craftsman/worker	15	21.4
Technician	15	21.4
Civil Engineer	26	37.1
Other Engineers	14	20.0
Total	70	100.0

The demographic data of the participants were obtained through descriptive analysis. Descriptive analysis expresses and summarizes a data set that is in the form of quantitative numerical values or counting or ranking values in quantitative or graphic form [70]. Demographic data of the participants are presented in **Table 1**. 37% of the participants were civil engineers, while the rest were other engineers, technicians and craftsman/workers.

The surveys were conducted at six different construction sites. The largest of the construction sites where the survey was carried out is the stadium construction in Ankara capital city of Turkey. The project covers the construction with conventional formwork system of a stadium with 1 basement floor + ground floor and 5 normal floors, with a capacity of 45,000 spectators, with a building diameter of 250 m and a height of 65.5 m in elliptical form (390 m × 260 m) with a membrane roof. At the time of the site visit, 35% of the work had been completed and rough construction was in progress. The other construction site where the survey was conducted is the construction site of a 5000 m^3 capacity water reservoir being constructed by Ankara Water and Sewerage Administration in Mamak District. At the time of the study, rough construction was in progress and the project was at the level of 50 per cent. The research was conducted also in four different residential construction sites with reinforced concrete structural system in Çankaya district of Ankara, which are continuing at rough and fine construction levels. The smallest of them is a 2-storey, 6 + 1 villa project with a building session area of 190 m^2 and a land area of 660 m^2. The other construction site is a residential project on a plot of 5246 m^2 with 16 apartments of 4 + 1 and 5 + 1 in 4 blocks of four stories. The other project is the construction of 24 apartments on a 6-storey single block on a plot of 2400 m^2. The last project is the construction of an 8 two-storey 4 + 1 villas with a net size of 220 m^2 on a plot of 3450 m^2.

Since the size of the construction site is considered to have an impact on materials management activities, data on the number of employees and the budget of the work in progress were also collected from the respondents and the results are presented in **Table 2**. Accordingly, more than half of the surveys were conducted at construction sites with more than 200 employees and a budget size of more than 100 million TL.

Table 2. Data about construction sites.

Variable	***N***	**%**
Number of Employees		
Less than 10	6	10.0
10–50	10	14.3
51–100	14	20.0
101–200	2	2.9
More than 200	37	52.9
Project Size		
Less than 5 million TL	3	4.3
5–20 million TL	20	28.6
20–50 million TL	7	10.0
More than 100 million TL	40	57.1
Total	70	100.0

4.2. Descriptive statistics and reliability analysis of the scale

Table 3 presents the mean and standard deviation data for the 9 criteria that the participants were asked to evaluate in terms of their contribution to construction site productivity. All of the criteria reached a mean between 4 and 5, that is, between very important and absolutely very important. The criterion "Proper storage of materials" had the highest mean and the overall mean was 4.257. The reliability value of the scale was found to be 0.828. This value is well above the limits of 0.5 suggested by Cronbach [76] and Helmstater [77] and 0.7 suggested by Bowling and Shah [78], indicating that the scale is reliable.

Table 3. Mean and standard deviation values of the criteria.

Nu	Criteria	*N*	Mean	Std. Dev.
K1	Identification of critical materials	70	4.4714	0.79348
K2	Creation of procurement plans	70	4.1286	0.83269
K3	Creating delivery plans	70	4.0857	0.89674
K4	Establishment of a material review team	70	4.2143	0.88289
K5	Managing the material inspection process	70	4.0286	0.86764
K6	Creating material inventory database	70	4.0571	0.79647
K7	Establishing storage areas on site	70	4.3571	0.76207
K8	Proper storage of materials	70	4.5714	0.57914
K9	Proper handling of materials	70	4.4000	0.66811
KORT	Overall average	70	4.2571	0.51409

4.3. Relationships between demographic variables and material management activities

It was investigated whether the opinions of the participants differed according to their various characteristics and the size of the construction sites. For this purpose, first of all, it is necessary to perform normality control of the data and decide which tests will be applied.

4.3.1. Normality test

Whether the data are normally distributed or not can be examined by different methods. One of these methods is checking Skewness and Kurtosis values of the data. According to **Table 4**, the Skewness value of the data was −0.551 and the Kurtosis value was −0.295. If Skewness and Kurtosis values are between −1.5 and +1.5, it is accepted that the data are normally distributed [72]. Accordingly, parametric tests were applied to the normally distributed data.

Table 4. Skewness and Kurtosis values of the scale.

		Statistic	Std. Error
Kort	Mean	4.2571	0.06145
	Skewness	−0.551	0.287
	Kurtosis	−0.295	0.566

4.3.2. Inferential analyses

To establish a material management system that will increase productivity at the construction site, first, it is necessary to see how employees handle the issue and whether there are differences between their perspectives. It would also be useful to examine whether the size of the construction site has an effect. For this, 7 hypotheses given in **Table 5** were tested.

Table 5. Hypothesis tested with *t* and ANOVA tests.

Nu	Hypothesis
H1	There is no significant difference between employee opinions according to gender.
H2	There is no significant difference between employee opinions according to age.
H3	There is no significant difference between employee opinions according to education level.
H4	There is no significant difference between employee opinions according to work experience.
H5	There is no significant difference between employee opinions according to profession.
H6	There is no significant difference between employee opinions acc. the number of employees.
H7	There is no significant difference between employee opinions acc. the financial size of the project.

Inferential statistics is statistics that aims to obtain analytical expressions for prediction or hypothesis testing about the statistical main mass character [79]. Inferential analysis tests are tests that compare the means of two or more groups to determine whether the difference is random or statistically significant. In order to see whether the opinions of the participants differed according to their demographic characteristics and construction site sizes, the parametric tests *T* test and ANOVA test were used since the data were normally distributed.

In order to see whether there is a significant difference between the opinions of the participants according to their gender and education level, the independent sample *T* test was performed. According to educational status of the participants, since the number of participants with master's and PhD degrees was low, they were evaluated in the university graduate group. According to **Table 6**, the sig (*p*) value for gender is 0.013 and for education level 0.017, which shows that there is a significant difference between the groups according to gender and education level. Thus, H1 and H3 are rejected.

Table 6. *T* test results according to gender and education level of the participants.

		Levene's Test for Eq. of Variances		*t*-test for Equality of Means		
		F	**Sig.**	***t***	**df**	**One-Sided *p* (Sig.)**
Gender	Equal var. ass.	0.243	0.624	−2.279	68	0.013
	Equal var. not ass.			−2.454	27.713	0.010
Educational Status	Equal var. ass.	0.017	0.896	−2.174	64	0.017
	Equal var. not ass.			−2.184	59.252	0.016

When the descriptive statistics presented in **Table 7** are analyzed, it is seen that the average for male is 4.18 and the average for female 4.50, while the average for high school and below is 4.09 and 4.37 for university.

Table 7. Descriptive statistics according to gender and education level of participants.

	Variable	*N*	Mean	Std. Deviation
Gender	Male	54	4.1831	0.51267
	Female	16	4.5069	0.44808
Educational Status	Highschool and below	28	4.0913	0.50335
	University	38	4.3684	0.51801

ANOVA tests were conducted to determine whether there is a significant difference between the opinions of the participants according to their age groups, years of work experience and occupations. According to the test results presented in **Table 8**, there is no significant difference in terms of age groups (sig. = 0.290) and work experience (sig. = 0.810), while there is a significant difference in terms of occupations (sig. = 0.016). Accordingly, H2 and H4 are accepted and H5 is rejected. When descriptive statistics according to occupations are analyzed, the average of civil engineers was the highest with 4.48 and the average of technicians was the lowest with 3.97.

Table 8. ANOVA test results according to age, work experience duration and occupation of the participants.

		Sum of Squares	df	Mean Square	*F*	Sig.
Age Group	Between Groups	1.000	3	0.333	1.277	0.290
	Within Groups	17.236	66	0.261		
	Total	18.236	69			
Work Experience	Between Groups	0.435	4	0.109	0.397	0.810
	Within Groups	17.801	65	0.274		
	Total	18.236	69			
Profession	Between Groups	2.611	3	0.870	3.676	0.016
	Within Groups	15.625	66	0.237		
	Total	18.236	69			

Table 9. ANOVA test results according to the size of the site.

		Sum of Squares	df	Mean Square	*F*	Sig.
Number of Employees	Between Groups	4.968	3	1.656	8.237	< 0.001
	Within Groups	13.268	66	0.201		
	Total	18.236	69			
Project Size	Between Groups	3.720	2	1.860	8.586	< 0.001
	Within Groups	14.515	67	0.217		
	Total	18.236	69			

Whether the opinions of the participants differed according to the size of the construction sites was also investigated with ANOVA tests. When the results presented in **Table 9** are analyzed, it is seen that there is a significant difference between the participants views according to both the number of employees at the construction site (sig. < 0.001) and the size of the ongoing project (sig. < 0.001).

Accordingly, both H6 and H7 are rejected.

In the descriptive statistics according to the number of employees, the average was the highest with 4.44 in construction sites with more than 200 employees and the lowest with 3.76 in construction sites with 50–100 employees. In terms of project size, it was realized as 3.97 for those with less than 20 million TL and 4.46 for those with more than 100 million TL (**Table 10**).

Table 10. Descriptive statistics according to the size of the site.

		N	Mean	Std. Dev.
Number of Employees	Less than 10	7	4.1111	0.56656
	10–50	10	4.3333	0.34347
	51–100	14	3.7619	0.62529
	More than 200	39 (37 + 2)	4.4414	0.37905
Project Size	Less than 20 million TL	23 (20 + 3)	3.9710	0.56974
	20–50 million TL	7	4.0635	0.55872
	More than 100 million TL	40	4.4556	0.37558
	Total	70	4.2571	0.51409

4.4. Relative importance indexes of material management criteria

The inferential analysis results showed that there were significant differences between opinions according to different demographic characteristics. Therefore, the relative importance coefficients of the criteria were calculated over all participants as well as according to various demographic characteristics with the following formula.

$IRI = \Sigma W / A \times N$

IRI: Index of relative importance.

W: The weights given by each participant for that proposition as (1—Not important, 2—Somewhat important, 3—Average important, 4—Very important and 5—Absolutely very important).

A: The highest weight value. In this case it is 5.

N: Total number of participants.

Table 11. Relative importance of criteria according to overall assessments.

Criteria	Rank	*IRI*
K8—Proper storage of materials	1	0.914
K1—Identification of critical materials	2	0.894
K9—Proper handling of materials	3	0.880
K7—Establishing storage areas on site	4	0.871
K4—Establishment of a material inspection team	5	0.843
K2—Establishment of procurement plans	6	0.826
K3—Creating a delivery plan	7	0.817
K6—Creating a material inventory database	8	0.811
K5—Managing the material inspection process	9	0.806

The relative importance values obtained according to all participant evaluations are presented in **Table 11**. According to this, the most important criterion in terms of increasing efficiency at the construction site was the proper storage of materials. This criterion was followed by identification of critical materials, proper handling of materials and creating storage areas on site. The criterion with the lowest relative importance was the management of the material inspection process.

Differences were found between the opinions of the participants according to some demographic characteristics. The relative importance indices and averages of the criteria for these cases are given in **Table 11**. While males stated proper storage of materials, proper handling, and identification of critical materials as the top three criteria in terms of their contribution to productivity at the construction site, females stated identification of critical materials, establishment of a material control team and proper storage of materials as the top three criteria. Similar differences were also obtained according to education and professions of the participants (**Table 12**).

Table 12. Top three criteria by gender, education level and occupation.

Gender	**Criteria**	***N***	**Mean**	***IRI***	**Gender**	**Criteria**	***N***	**Mean**	***IRI***
	K8	54	4.593	0.919		K1	16	4.875	0.975
Male	K9	54	4.407	0.881	Female	K4	16	4.625	0.925
	K1	54	4.352	0.870		K8	16	4.505	0.901
Educ. Status	Criteria	*N*	Mean	*IRI*	Educ. Status	Criteria	*N*	Mean	*IRI*
	K8	28	4.500	0.900		K1	38	4.632	0.926
Highschool	K7	28	4.3939	0.879	University	K8	38	4.605	0.921
	K9	28	4.286	0.857		K9	38	4.474	0.895
Profession	Criteria	*N*	Mean	*IRI*	Profession	Criteria	*N*	Mean	*IRI*
	K7	15	4.600	0.920		K1	26	4.731	0.946
Craftsman/worker	K8	15	4.600	0.920	Civil Engineer	K8	26	4.692	0.938
	K1	15	4.400	0.880		K9	26	4.577	0.915
	K8	15	4.533	0.907		K1	14	4.500	0.900
Technician	K7	15	4.267	0.853	Other Engineers	K8	14	4.357	0.871
	K9	15	4.267	0.853		K2	14	4.286	0.857

According to the size of the construction site, the evaluation was based on the number of employees at the construction site and the budget of the ongoing project. In **Table 13**, the first four criteria are presented together since the 3rd and 4th criteria have the same relative importance value for many groups. In the evaluation based on the number of employees, the criteria of proper storage and proper handling of materials in terms of efficiency at the construction site were among the top four criteria in all four groups.

Table 13. Top four criteria according to construction site size.

Number of Emp.	**Criteria**	***N***	**Mean**	***IRI***	**Number of Emp.**	**Criteria**	***N***	**Mean**	***IRI***
	K3	7	4.5714	0.914		K8	14	4.6429	0.929
Less than 10	K7	7	4.4286	0.886	50–100	K7	14	4.3571	0.871
	K8	7	4.4286	0.886		K9	14	3.9286	0.786

Table 13. (*Continued*).

Number of Emp.	**Criteria**	***N***	**Mean**	***IRI***	**Number of Emp.**	**Criteria**	***N***	**Mean**	***IRI***
Less than 10	K9	7	4.4286	0.886		K1	14	3.7857	0.757
10–50	K1	10	4.7	0.940	More than 200	K1	39	4.7436	0.949
	K8	10	4.6	0.920		K8	39	4.5641	0.913
	K9	10	4.5	0.900		K9	39	4.5385	0.908
	K7	10	4.5	0.900		K2	39	4.4103	0.882
Project Size	Criteria	*N*	Mean	*IRI*	Project Size	Criteria	*N*	Mean	*IRI*
Less than 20 million TL	K8	23	4.652	0.930	More than 100 million TL	K1	40	4.750	0.950
	K7	23	4.435	0.887		K8	40	4.575	0.915
	K1	23	4.130	0.826		K9	40	4.550	0.910
	K9	23	4.130	0.826		K2	40	4.425	0.885
20–50 million TL	K9	7	4.429	0.886					
	K3	7	4.286	0.857					
	K7	7	4.286	0.857					
	K8	7	4.286	0.857					

5. Discussion

One of the main points that this study reveals is that the average of all criteria is evaluated between very important and absolutely very important. Therefore, it is possible to say that even though the participants' gender, profession, educational background or construction site are different, their awareness of the importance of material management is high. The second point is that the opinion on the extent to which materials management criteria contribute to construction site productivity does not vary according to age and length of work experience of the participants, but varies according to gender, education, occupation and size of the construction site. While the overall average for women was 4.5, it was 4.18 for men. In addition, the averages of women were higher than men in each of the activities separately. In this case, it is possible to say that women attribute higher importance to material management practices. As a result, it can be said that if a choice will be made among employees with similar abilities, it would be the right choice to assign women in material management activities. In addition, although the basic aspects are determined by management, materials management is a collaborative process involving employees from all levels and professions. It is therefore important to take into account the opinions and working conditions of all employees in general when establishing processes. Similarly, the size of construction sites naturally affects the stages of the materials management process in different ways. A problem with procurement, for example, which can be easily dealt with on a small construction site, may cause a complete work stoppage on a large construction site. Therefore, the size of the construction site, which can be represented by the number of employees on site or the budget of the project, should also be taken into account when establishing materials management processes.

When the opinions of the participants are evaluated in general, the most important criteria are proper storage of materials, identification of critical materials and proper handling of materials. Due to the significant differences between the opinions of the participants, it is possible that there may be hesitation in generalizing the opinions. However, a detailed examination showed that despite the different characteristics of the participants, the storage and handling of materials were among the top three or four most important criteria in almost all evaluations, although the order varied. In one study, which was taken as a reference during the development of the scale, the criteria of proper storage and handling of materials were not included at all for the reasons mentioned earlier [66]. The criterion of protection and maintenance of received materials was ranked fourth in one study and ninth among nine criteria in another study [64,65]. However, in developing countries like Turkey, there are economic uncertainties and problems with business ethics. Turkey is still one of the countries with the highest inflation rate in the world, and this causes major increases in material prices during the process. Similarly, lack of business ethics of some suppliers causes problems in getting the material ready on site on time. To cope with these problems, contractors often prefer to procure and store materials in advance. Storing the materials at the construction site naturally requires more handling of the materials compared to the materials received at the place closest to the place of production. Both storing materials and handling these materials from warehouses to the manufacturing site create additional OHS problems [39]. All kinds of accidents, large and small, at the construction site also have a negative impact on productivity [80]. On the other hand, improper storage, such as disorganized stock, misclassification, misallocation, miss tacking, etc. cause material loss, delays in removing the material from the warehouse, labor, and time losses [81,82]. It is thought that the fact that the participants frequently experience such problems plays an important role in their evaluation of storage as the most important criterion. In order not to interrupt the production, the materials must be ready at the place where the production will be carried out on time. It was evaluated that the respondents gave high importance to the material handling criterion since they experienced the contribution of material handling to the production process, to effective use of labor power and to system flexibility.

Identification of critical materials, which was found to be the second most important criterion in the overall evaluation, was also among the top three criteria in most of the evaluations made according to different characteristics. In the two studies that included this criterion [65,66], it was found to be the most important criterion. Considering that any disruption in the supply of critical materials will cause disruption of the work program, it is clear that to identify critical materials at the beginning of the work is important.

This study has some limitations. It was mainly carried out in residential and stadium construction sites with limited participants. More studies can be conducted with more participants and in different construction sites such as roads and dams where the weight of materials in construction process is high. Again, it is possible to conduct studies that examine the relationship between construction site productivity and material management processes in more depth through the variables to be defined. In this context, examination of only one or a few of the material management processes in more detail through both qualitative and quantitative surveys may be useful. Thus, the strengths and weaknesses of the firms in these processes may be discovered and finally reveal their effect on productivity through qualitative or quantitative indicators.

Each study to be conducted for this purpose will be a guide for increasing efficiency and competitiveness in the construction sector.

6. Conclusion

Researches show that good materials management practices on the construction site will lead to more predictable project outcomes and increased productivity on construction sites [3,9,14].

According to the results of the study, following conclusions can be drawn:

- The importance of nine different material management practices, ranging from materials identification to procurement, from inspection to storage, is generally good understood.
- Proper storage, identifying critical materials and proper handling were identified as the most important practices.
- In countries such as Turkey, where economic uncertainty is high, the prevalence of pre-procurement of materials makes storage and handling of materials important.
- Identification of critical materials is critical in terms of adhering to the work schedule and preventing delays.
- The importance that respondents attributed to materials management practices varies according to variables such as gender, education, occupation, and size of construction site.
- Establishing management processes and determining the people who will take part in the processes should not be static but should be based on different practices.

Although it is possible to generalize the results for similar countries since the study was conducted in Turkey, a developing country, it would be appropriate to conduct local research since local characteristics have different effects on management processes.

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