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Assessing Factors Affecting Construction Equipment Productivity Using Structural Equation Modeling

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Abstract: The performance of the construction industry can be improved by understanding the factors that affect the productivity of its equipment. A hypothetical framework was used to analyze six vital construction equipment parameters to understand how they affect productivity in construction projects. Data collected through a survey of 110 respondents in the construction industry were analyzed using an exploratory factor analysis (EFA) and structural equation modeling (SEM). The final model obtained using SEM consisted of 31 attributes from six construction equipment productivity factors, namely management (MG), materials (MT), human (HM), technical (TN), environmental (EM), and other factors (OT). Construction equipment productivity was found to be significantly influenced by MT and OT in construction projects. This was mainly because of their corresponding subfactors, such as operating life and equipment age, and the occurrence of accidents during construction. Consequently, based on survey feedback from various construction professionals, present gaps in construction equipment productivity were analyzed, and recommendations were made to overcome the main limiting factors under MT and OT. This study identified and quantified the interrelationships between various construction equipment productivity constraints. Therefore, the results can help experts and specialists better comprehend how to overcome delays due to idle time and improve construction equipment productivity.

Keywords: construction equipment; productivity; construction projects; structural equation model; exploratory factor analysis

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1. Introduction

Construction is characterized by the ability to perform work more effectively and efficiently. A nation's construction industry plays a vital role in contributing to overall economic growth and provides numerous job opportunities [1]. Heavy-duty self-moving vehicles designed specifically for construction jobs are essential equipment for construction projects. Construction equipment is used to undertake fundamentally repetitive tasks and may be categorized based on its purpose [2]. The different types of construction equipment involved in construction projects include, among others, excavators, bulldozers, loaders, compactors, and dump trucks. Productivity is a key consideration in all industries, and production per labor/equipment hour is a well-known measure of productivity in the construction industry [3]. Construction equipment productivity substantially influences the overall productivity of the construction industry as well as the time and cost required for a specific construction project. Hence, project managers and jobsite workers must constantly monitor and supervise the tasks performed with construction equipment. A prior understanding of construction equipment management can help save the money and time involved in a particular project [4].

Development construction projects account for the majority of the construction industry's capital investments; thus, industry operators must increase the productivity of construction equipment to meet rising investor expectations [5]. Although many investigations have been conducted on the factors influencing construction equipment productivity using various methods, the majority of these studies have neglected to investigate the critical factors (in quantifiable terms) affecting construction equipment productivity in construction projects. Consequently, identifying and quantifying the correlations among various construction equipment productivity constraints are critical. Using this information, firms in the construction sector can direct their endeavors and assets toward important limiting factors for the best and most profitable outcomes. Therefore, the present study intended to fill this gap by examining the productivity characteristics of construction equipment, using construction projects as a starting point. This study aimed to accomplish the following objectives:

- Determine the critical factors affecting construction equipment productivity in construction projects.
- Identify the relationships among critical factors that limit the productivity of construction equipment using structural equation modeling (SEM).

SEM is a quantifiable method for assessing a series of interdependent relationships between dependent and independent variables [6]. It can also be defined as a measurable method for evaluating hypotheses regarding the correlations between observable and latent variables [7]. SEM is also regarded as a robust analysis approach for decision support system creation, prediction models, and risk analysis owing to its distinctive qualities [8]. The use of SEM in construction management has increased dramatically in recent years. In a previous study [9], SEM was used to quantify the correlations between the causes of project delays in building infrastructure in India. The usefulness of SEM in discovering connections among several independent variables was highlighted by Islam and Faniran (2016). Moreover, Gunduz et al. (2015) used SEM to examine the correlations among many construction site safety performance factors. This approach has proven to be beneficial for assessing and measuring the links between correlative variables [10]. Therefore, with sufficient data it can be used to analyze and measure the immediate and relative impacts of latent components.

Therefore, this study aimed to investigate the relationships between the critical factors affecting construction equipment productivity in construction projects by relying on previous research and aimed to provide a better understanding of six conjectured autonomous factors along with their fundamental subfactors that affect construction equipment productivity. The remainder of this paper is organized as follows: Section 2 examines the relevant literature, Section 3 details the research methodology, Section 4 discusses the results obtained from the SEM, and Section 5 provides the conclusion and limitations of the study, along with recommendations to overcome equipment productivity challenges.

2. Review of Literature

The capacity to increase the value and quality of services or products is referred to as productivity [11]. Productivity focuses on the quantitative relationship between outputs and inputs (i.e., the ability of an industry to generate yields from inputs). Numerous perspectives or definitions exist regarding productivity, including the goals to be achieved, the assets utilized, the metrics implemented, and the standards used. Therefore, the common themes—regardless of the viewpoint or term used—in all contextual readings of productivity are efficiency and effectiveness [12]. The amount or measure of yield per unit of an asset input is a functional explanation that accurately reflects the meaning of the concept and emphasizes the information yield (input–yield) model. Previous studies [13] support this broad definition. Over the years, many studies have attempted to determine the factors that restrict construction equipment productivity in construction projects. To present the current state of the art, various works from the literature on construction equipment productivity are summarized in this section.

2.1. Construction Equipment Productivity Factors and Management

Earthmoving equipment management—or the lack thereof—generally causes most infrastructure productivity gaps. Kassem et al. (2020) created and tested a deep neural network (DNN) model to measure excavator productivity in infrastructure projects. Feature inputs included telematics data fields, and a DNN-calculated metric was presented for comparing excavator performance. A bottom-up benchmark measurement (excavation speed) was also presented and described to quantify and assess the uncovering work of an individual or construction equipment from a workspace to a full site.

Construction project management should prioritize construction equipment productivity. The most important construction equipment productivity factors were identified in a study by Abdelaal et al. [1] that involved a quantitative survey and exploratory subjective meetings with industry specialists in Gulf Cooperation Council (GCC) nations. The results showed that external factors such as design changes or scope changes are the most significant factors affecting construction equipment productivity. The causes that may be related to construction equipment on site were investigated by Khot and Patil [14]. Their study combined a literature review and a survey of construction equipment parameters. Questionnaires were sent to respondents with relevant experience for a quantitative study, and the final survey results were used to assess the main concerns.

Construction equipment efficiency was examined in a study by Manikandan et al. [15]. Construction organizations, equipment rental suppliers, and construction projects provided data. Finally, the study's results were compared to determine if there were any notable similarities or differences in construction equipment management procedures. Building project cost drivers were evaluated using the relative importance index (RII). It was determined that five key factors contributed to the breakdown of equipment: improper maintenance of equipment, a lack of necessary equipment, poor performance of equipment, efficiency of equipment, and inadequate modern equipment.

The productivity of construction equipment and its influencing factors were determined by Methe et al. [16]. Responses gathered through a survey of 20 organizations involved in building construction were analyzed using the RII technique. According to the results, the most significant factor impacting construction equipment productivity is a lack of operator skill due to operator/human factors. Numerous components that impact construction equipment management and construction site productivity were identified by Ranjithapriya and Arulselvan [17]. They developed a questionnaire that was divided into categories based on the profiles of respondents, and the RII technique was used to rank the factors that affect construction equipment productivity. According to their findings, late inspection, site quality, operator efficiency, and the availability of qualified operators are all factors that impact construction equipment productivity.

Earthmoving and highway construction use heavy equipment. A questionnaire was used to investigate effective hauling equipment use, including fuel usage, transportation and road conditions, and labor and soil quality in a study by Salem et al. [18]. A fuzzy set-based system was proposed for evaluating and prioritizing issues. The framework's output was put forward as an early warning system that emphasizes hauling equipment efficiency in earthmoving. This can help owners and contractors make proactive rather than reactive decisions, maximizing construction equipment use.

2.2. Construction Equipment Productivity Factors Adapted from Previous Research

As shown in Table 1, earlier research has provided a foundation for discovering the key factors affecting construction equipment productivity (the first objective of this study) [1,2,5,19–29]. However, depending on the input from numerous construction industry specialists, it is apparent that identifying the factors—or limitations—affecting construction equipment productivity has become crucial. Accordingly, this study aimed to quantify the precise connections between the various factors affecting construction equipment productivity and how they connect in terms of overall production efficiency in construction projects.

Table 1. Construction equipment productivity factors adapted from previous research.

Latent Factors	Observable Variables		Relevant Literature
Management (MG)	MG1	Delay in equipment inspection	[1,2,5,19–29]
	MG2	Permit delay from authorities	
	MG3	Financial problems in the project	
	MG4	Poorly defined project objectives	
	MG5	Lack of routine checking of work at the construction site	
Materials (MT)	MT1	Operating life and age of equipment	
	MT2	Lack of proper maintenance of equipment	
	MT3	Unavailability/high cost of spare equipment parts	
	MT4	Size of the equipment	
	MT5	Delay in mobilizing the equipment at the construction site	
	MT6	Two or more groups sharing the same equipment	
	MT7	Lack of required construction materials for the respective work	
Human (HM)	HM1	Operator's efficiency in handling the equipment	
	HM2	Unavailability of skilled equipment operators/workers	
	HM3	Operator's age	
	HM4	Morality and disloyalty of equipment operators/workers	
	HM5	Lack of financial motivation of the equipment operators/workers	
	HM6	Personal problems of equipment operators/workers	
	HM7	Lack of training for the equipment operators	
Technical (TN)	TN1	Complex designs and incomplete drawings	
	TN2	Improper construction procedures and practices	
	TN3	Repeating work due to error	
	TN4	Excess workload for equipment without required break time	
	TN5	Lack of new methods and technology in construction	
	TN6	Improper work scheduling of equipment	
Environmental (EM)	EM1	Temperature, rain, wind, and humidity	
	EM2	Type of soil at site	
	EM3	Site condition and obstacles on site	
Other (OT)	OT1	Accidents occurring during the construction process	
	OT2	Lack of implementation of principles, government regulations, and guidelines	
	OT3	Lack of safety measures	
	OT4	Shortage of water and/or power supply	
	OT5	Miscommunication between owner, designer, and contractor	

3. Research Methodology

This study was conducted according to the methodology outlined in Figure 1, which illustrates the various steps involved in this study. The literature review stage was conducted to identify gaps in the equipment productivity literature, breaks, and conflicts of interest and determine the need for more research related to construction equipment types and factors affecting productivity that were not determined using SEM. Following this, various types of construction equipment used in construction projects and their applications were reviewed, which aided in identifying factors such as MG, MT, HM, TN, and EM that restrict their productivity. Various factors affecting the productivity of construction equipment used in construction projects have been identified using earlier studies or input from working experts and construction-related specialists [30]. Following the identification of these factors, appropriate questionnaires for data collection were compiled, depending on the attributes being considered. Data gathering acquires indispensable information regarding a sample, as data play a vital role while conducting a survey [31]. Questionnaires were provided to various construction organizations for data gathering, and interviews were conducted with construction personnel, consultants, clients, engineers, managers, contractors, and architects.

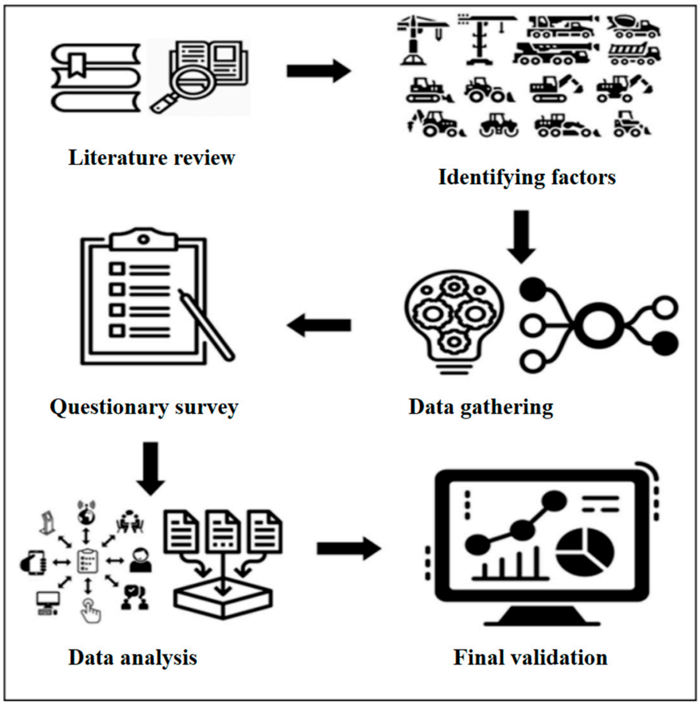

Figure 1. Methodology used in this study.

This study used a statement-style questionnaire that clearly expressed a particular opinion of the participants. Depending on the type of information required from the respondents, both open-ended and closed-ended statements were used in this survey. Most of the statements in the poll were multiple choice, and the results were determined using a seven-point Likert scale, with responses varying from strongly agree (high) to strongly disagree (low). Some statements were also presented in checkbox form and written answers (open-ended statements). The collected data were examined and analyzed using an exploratory factor analysis (EFA) and SEM. After analyzing the information gathered from the respondents, the factors that affect construction equipment productivity in construction projects were identified, and they are discussed based on the outputs in Section 4. The findings, limitations, and recommendations based on the feedback obtained from the various construction professionals through the questionnaire are discussed in Section 5.

3.1. Hypothesis Development

Some direct relationships emerged between the management, equipment, material, human, technical, and other factors as they affected the equipment productivity in first-hand data based on possible connections between the concepts. These factors were positively correlated with equipment productivity. In the proposed model, arrows indicated which factors had positive or negative effects on equipment productivity. Project duration (EP1), estimated project cost (EP2), and desired quality outcome (EP3) were the attributes of the equipment productivity (EP) parameter, to which all six factors—MG, MT, HM, TN, EM, and OT—were linked for measuring the impact of each factor in affecting the construction equipment productivity, as shown in Figure 2.

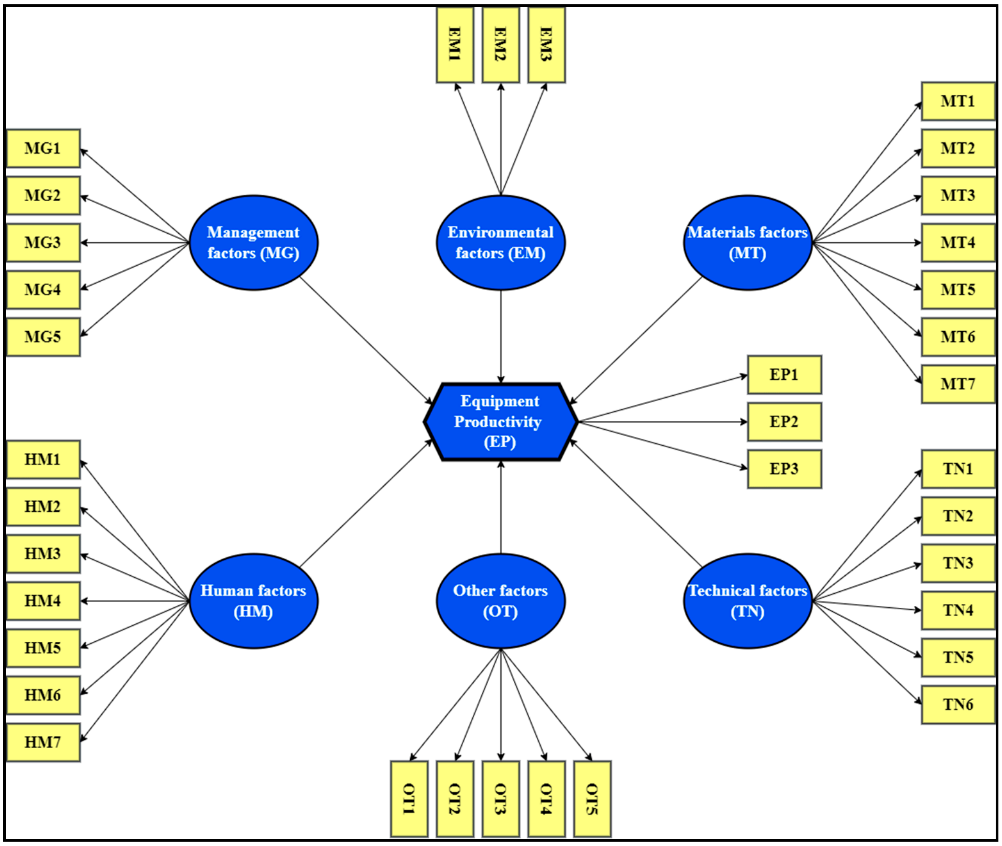

Figure 2. Hypothesis development using SEM.

3.2. Demographic Data

The questionnaires were circulated through datasets of organizations involved in the construction sector. For the questionnaire responses to be valid and reliable, several factors were considered, including the respondents' experience in the construction industry. Among the 130 distributed surveys, 110 were legitimate—84% of the total—as some questionnaires were incomplete and some replies were invalid [9]. However, despite the relatively small sample size, the work experience of respondents and their positions at the highest levels of the organizations confirmed the quality and reliability of the data [10].

Participants were selected to participate in the study according to their knowledge and experience. Experts may be selected according to their gender, sector, experience, and designation to provide information during the discussion. The number of participants in a study may vary from a few to many and from a national to an international level, depending on the purpose of the study [11]. A study's participant count may also vary in accordance with the study's purpose, the participants' experience, and their level of expertise [32]. As per the guidelines, 120–200 experts should be used for homogeneous populations, i.e., professionals with expertise in the same field, and 0–120 experts should be used for heterogeneous populations, i.e., professionals of different professional levels with similar subject matter expertise [5]. There were 140 invited participants, of which 110 professionals expressed interest in the project and participated in the study. Table 2 lists the summary of respondents. In the gender category, there were more male than female participants. In the sector category, the public and private sectors provided 56 and 54 responses, respectively—a near-even split. Regarding the experience category, the participants with 11–15 years of experience were the greatest, and only 17 participants had less than 5 years of experience. The respondents comprised 46 project managers, 25 engineers, 23 contractors, and 16 from the other category.

Table 2. Summary of respondents' profile.

Category	Subcategory	Total	Respondents %
Gender	Male	69	72.37
	Female	41	27.63
Sector	Public	56	59.73
	Private	54	40.27
Experience (years)	<5	17	10.86
	5–10	25	18.07
	11–15	44	54.21
	>15	24	16.86
Designation	Project Managers	46	43.37
	Engineers	25	26.50
	Contractors	23	21.68
	Others	16	8.43

3.3. Data Analysis

EFA and SEM were performed using SPSS and SmartPLS software to experimentally assess the hypothetical model of construction equipment productivity factors using data from the questionnaire. SPSS, a statistical data analysis application for the social sciences, is used by many academics for their research. To maximize their research and survey activities, most renowned researchers use SPSS to analyze survey data and extract text data. SmartPLS is the most comprehensive and frequently used PLS-SEM analysis software available today, according to several reviewed studies [6,21,33]. The software's seamless design makes it ideal for new researchers, as it can easily define and evaluate PLS path models [34].

3.3.1. Exploratory Factor Analysis (EFA)

EFA was used to examine the connections among various factors and consolidate the information, confirming the structure of the construction equipment productivity factor model. The principal component matrix was frequently rotated for easy interpretation of the obtained variables [17], with varimax chosen over the other rotation techniques available in SPSS, as it was frequently used to rotate the answers of the vital components [16]. As a result, the process needed to rotate factors such that the variety of the squared factor loadings increased, making it easier to comprehend the loadings based on their importance. A factor with a loading of less than 0.40 (the cut-off for significance) was considered to be a poor determinant and was excluded owing to the small sample size [8]. Consequently, two problematic entries were eliminated from the data list based on their loadings: the equipment size (MT4) and the personal problems of equipment operators/workers (HM6).

Table 3 lists the six fundamental parameters (as per the hypothetical framework) described by 31 elements, along with factor loadings and Kaiser–Meyer–Olkin (KMO) values, which were determined using SPSS software. The KMO values measure the sampling adequacy of the data, which was used to determine the suitability of the data for factor analysis. The six underlying components are the MG, MT, HM, TN, EM, and OT factors.

Table 3. Factor loadings and KMO values extracted from the EFA.

Factors	Items		Factor Loadings	KMO Values
Management (MG)	MG1	Delay in equipment inspection	0.775	0.745
	MG2	Permit delay from authorities	0.926	
	MG3	Financial problems in the project	0.933	
	MG4	Poorly defined project objectives	0.774	
	MG5	Lack of routine checking of work at the construction site	0.932	
Materials (MT)	MT1	Operating life and age of equipment	0.707	0.836
	MT2	Lack of proper maintenance of equipment	0.952	
	MT3	Unavailability/high cost of spare equipment parts	0.960	
	MT5	Delay in mobilizing the equipment at the construction site	0.704	
	MT6	Two or more groups sharing the same equipment	0.956	
	MT7	Lack of required construction materials for the respective work	0.953	
Human (HM)	HM1	Operator’s efficiency in handling the equipment	0.855	0.792
	HM2	Unavailability of skilled equipment operators/workers	0.873	
	HM3	Operator’s age	0.856	
	HM4	Morality and disloyalty of equipment operators/workers	0.847	
	HM5	Lack of financial motivation of the equipment operators/workers	0.844	
	HM7	Lack of training for the equipment operators	0.843	
Technical (TN)	TN1	Complex designs and incomplete drawings	0.948	0.778
	TN2	Improper construction procedures and practices	0.733	
	TN3	Repeating work due to error	0.953	
	TN4	Excess workload for equipment without required break time	0.703	
	TN5	Lack of new methods and technology in construction	0.957	
	TN6	Improper work scheduling of equipment	0.953	
Environmental (EM)	EM1	Temperature, rain, wind, and humidity	0.821	0.706
	EM2	Type of soil at site	0.863	
	EM3	Site condition and obstacles on site	0.859	
Other (OT)	OT1	Accidents occurring during the construction process	0.984	0.892
	OT2	Implementation of principles, government regulations, and guidelines	0.618	
	OT3	Lack of safety measures	0.979	
	OT4	Shortage of water and/or power supply	0.973	
	OT5	Miscommunication between owner, designer, and contractor	0.986	

After the factors were categorized and named, Cronbach’s alpha was determined using SmartPLS software to ensure that the components of each factor were internally consistent. When Cronbach’s alpha is greater than 0.7, the categorical level is considered to be high [25], indicating that it is internally consistent. Table 4 shows the values of Cronbach’s alpha, along with the rho_A, composite reliability, and average variance extracted (AVE), which determines the reliability and validity of the data.

Table 4. Data reliability and validity.

Factors		Cronbach's Alpha	rho_A	Composite Reliability	AVE
Management (MG)	MG1	0.919	0.935	0.940	0.759
	MG2				
	MG3				
	MG4				
	MG5				
Materials (MT)	MT1	0.938	0.954	0.953	0.774
	MT2				
	MT3				
	MT5				
	MT6				
	MT7				
Human (HM)	HM1	0.925	0.938	0.940	0.725
	HM2				
	HM3				
	HM4				
	HM5				
	HM7				
Technical (TN)	TN1	0.940	0.954	0.954	0.777
	TN2				
	TN3				
	TN4				
	TN5				
	TN6				
Environmental (EM)	EM1	0.804	0.840	0.883	0.716
	EM2				
	EM3				
Other (O)	OT1	0.948	0.961	0.964	0.845
	OT2				
	OT3				
	OT4				
	OT5				
Equipment productivity (EP)	EP1	0.865	0.889	0.920	0.796
	EP2				
	EP3				

3.3.2. Structural Equation Modeling (SEM)

SEM consists of two parts: an estimation model and a primary model. As mentioned in the preceding section, the factor investigation provides the estimation model, considering how effectively the identified parameters (exogenous variables) estimate latent factors [33,35]. Model optimization can be accomplished through the elimination of weakly connected linkages or by eliminating attributes with weak relationships to their latent parameters [28,36–39]. The equipment size (MT4) and the personal problems of equipment operators/workers (HM6) were two attributes that had weak correlations with their latent components. These two attributes had factor loadings below 0.40, as mentioned in the previous section. Therefore, they were removed as part of the model modification. Figure 3 shows how the factors that affect construction equipment productivity were modified.

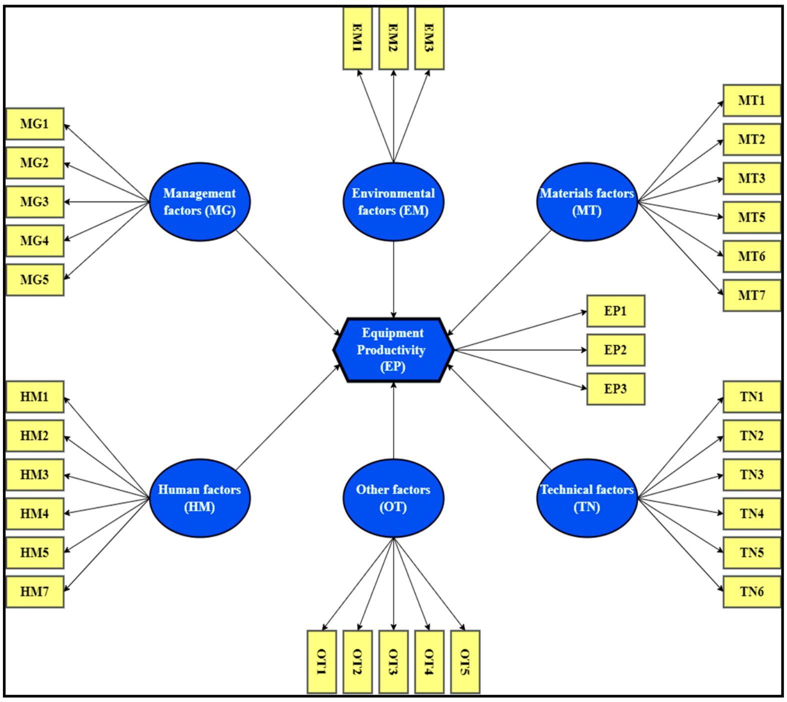

Figure 3. Modified framework using SEM.

A validation of the framework for factors affecting construction equipment productivity is illustrated in Figure 4, along with their respective β values, exhibiting the impacts of the six factors on construction equipment productivity. There are significant positive standardized path coefficients for all variables ($p \leq 0.005$) and multiple square correlations (R2) for construction equipment productivity in construction projects, as shown in Table 5.

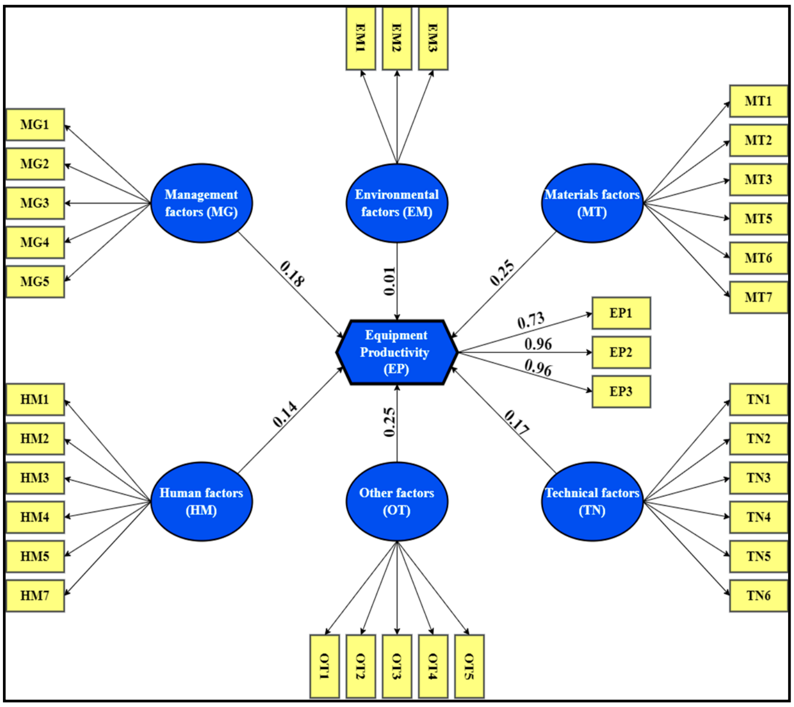

Figure 4. Validated framework using SEM.

Table 5. Coefficients of standardization and R^2 values of the variables.

Paths	Standardized Path Coefficients [a]	R^2
MG1 ← MG	0.76	0.58
MG2 ← MG	0.94	0.88
MG3 ← MG	0.94	0.88
MG4 ← MG	0.76	0.58
MG5 ← MG	0.94	0.88
MT1 ← MT	0.71	0.50
MT2 ← MT	0.95	0.90
MT3 ← MT	0.96	0.92
MT5 ← MT	0.70	0.49
MT6 ← MT	0.96	0.92
MT7 ← MT	0.95	0.90
HM1 ← HM	0.81	0.66
HM2 ← HM	0.91	0.83
HM3 ← HM	0.90	0.81
HM4 ← HM	0.80	0.64
HM5 ← HM	0.89	0.79
HM7 ← HM	0.79	0.62
TN1 ← TN	0.95	0.90
TN2 ← TN	0.73	0.53
TN3 ← TN	0.95	0.90
TN4 ← TN	0.70	0.49
TN5 ← TN	0.96	0.92
TN6 ← TN	0.95	0.90
EM1 ← EM	0.81	0.66
EM2 ← EM	0.89	0.79
EM3 ← EM	0.83	0.69
OT1 ← OT	0.98	0.96
OT2 ← OT	0.64	0.40
OT3 ← OT	0.98	0.96
OT4 ← OT	0.97	0.94
OT5 ← OT	0.98	0.96

[a] The significance level was set at $p \leq 0.05$.

4. Discussion

The final SEM model shows that, based on their β values, MT and OT were the two most significant parameters to have impacts on construction equipment productivity. Both parameters had the same β value of 0.25. The influences of the MT and OT factors were found to be the most significant because of their respective underlying subfactors. The subfactors involved in the MT factors were the operating life and age of equipment, a lack of proper maintenance of equipment, the unavailability or high cost of equipment spare parts, delays in mobilizing the equipment at the site, two or more groups sharing the same equipment, and a lack of required construction materials. The subfactors involved in the OT factors were accidents occurring during the construction process; the improper implementation of principles, government regulations, and guidelines; a lack of safety measures; a shortage of water and/or power supply; and miscommunication between owners, designers, and contractors. Additionally, it was established that factors such as the use of suitable materials required for construction; the quality of the maintenance of construction equipment; miscommunication; and the lack of proper implementation of standards, government laws, and regulations significantly affect the productivity of construction equipment.

MG and TN were ranked as the third and fourth parameters influencing construction equipment productivity, with β values of 0.18 and 0.17, respectively. The subfactors involved in the MG factors were delays in equipment inspection, permit delays from authorities, financial problems in the project, poorly defined project objectives, and a lack of routine checking of work at the construction site. The subfactors involved in the TN factors were complex designs and incomplete drawings, improper construction procedures and practices, repeating work due to errors, excess workload for equipment without the required break time, a lack of new methods and technology in construction, and improper work scheduling of equipment. It was previously determined that delays in equipment inspection, financial problems, repeating work due to error/design changes, and improper work scheduling of equipment are factors that notably affect construction equipment productivity [1,40–42].

HM ranked fifth as a parameter affecting construction equipment productivity, with a β value of 0.14. The subfactors involved in the HM factors were the efficiency of operators in handling the equipment, the unavailability of skilled equipment operators/workers, the ages of the operators, the morality and disloyalty of equipment operators/workers, the lack of financial motivation of the equipment operators/workers, and the lack of training of the equipment operators. Specifically, the efficiency of operators and the availability of skilled operators were the factors that mainly influenced the productivity of construction equipment when compared to other HM factors, which is also justified in the literature [1,31,32,43].

The parameter EM proved to be insignificant, with a low β value of 0.01. The subfactors of the EM factors were the climatic conditions, the type of soil at the construction site, and the site conditions and obstacles on site. In this study, the β value was low based on the analysis performed with the response data; however, based on a previous study, the environment significantly influenced the productivity of construction equipment. Subfactors EP1, EP2, and EP3 were highly correlated with the overall EP, which was evident from the values obtained from the final SEM model.

5. Conclusions and Recommendations

In this study, factors that influence construction equipment productivity in construction projects were identified. A novel SEM approach was developed based on a literature review of current studies focusing on productivity measurements and data collected from participants. The model was verified using a survey with the participation of 110 experts in the field. The model indicated the MT and OT factors, which ranked highest among the surveyed parameters, to likely be important predictors of equipment productivity.

An SEM model was developed in this study based on survey data collected from a single region, namely India. A similar study could be conducted in other countries because the level of recognition of the importance of productivity when using construction equipment varies from one country to another. This study sought to understand how these factors interact structurally and to identify measures for enhancing productivity in different regions. Depending on the project under consideration, the implications of the findings may vary. Furthermore, future research may be able to quantify these interrelationships using large-scale studies.

The dependability and legitimacy of the factor structure of construction equipment productivity in construction projects were assessed using EFA. The final structural model was developed using SEM to evaluate the interactions between the construction equipment productivity factors. Based on the findings of the study, MT and OT were the two most significant parameters affecting construction equipment productivity, and both parameters had the same β value of 0.25. Despite the efforts made to quantify the links between construction EP factors in construction projects, this study was limited by the small sample size (110 responses). Further research with a larger sample size is advised for model evaluation.

The recommendations to overcome the main subfactors under MT and OT are as follows:

- The equipment used should be in good condition and should be maintained properly to avoid breakdown. Each group should have separate equipment for the respective work to complete the task without notable delays. Planning is imperative so that the construction materials required for the work are readily available to avoid construction equipment being idle.
- Proper safety measures should be implemented at the construction site to avoid accidents that will possibly harm personnel, delay the construction process, and affect equipment productivity. Finally, efforts should be made to have effective communication between the owner, designer, and contractor to improve the equipment's productivity.

The recommendations to overcome the factors under the other parameters are as follows:

- The equipment operators and workers should be trained properly so that tasks are completed with limited delays and without repeating work. Proper construction procedures/practices should be followed, and a proper cash flow should be maintained. In the future, government policies should aim to spread awareness and education on weather changes by offering training, conferences, and seminars to share knowledge and skills.
- The appropriate equipment must be selected for a specific job, and proper work scheduling of construction equipment should be performed, as this plays a major role in improving construction equipment productivity. Moreover, site conditions should be properly maintained on a daily basis for the smooth functioning of the construction equipment.

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