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Elaborating a Management Model for Sustainable Development in Cellulosic Industries

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ABSTRACT

Cellulose industries, as a vital and strategic sector in the global economy, play a crucial role in meeting the growing societal demand for cellulose products. This article aims to explain a comprehensive management model for sustainable development in cellulose industries that can help improve the environmental, economic, and social performance of these industries. This model seeks to identify and analyze the key components and indicators influencing sustainable development in this sector. Using qualitative and quantitative research methods, this article examines the challenges and opportunities in the path of sustainable development of cellulose industries and provides practical solutions for implementing this model. To this end, this study has identified the indicators and components influencing the sustainable development of production in cellulose industries. In selecting factors, efforts have been made to avoid bias. To ensure the initial conceptual model, the internal relationships of the model have been tested using quantitative methodologies. The statistical population of this research is selected cellulose industries, and after identifying the factors, the indicators have been prioritized based on the mean rank. The results show that the "laws" indicator received the highest rank and the "materials" indicator received the lowest rank. The researcher has estimated the most appropriate structural equation by examining structural equations and using standardized coefficients. Also, to confirm the validity of the model and accurate prediction in the future, the CV RED index has been used, and its positive value indicates the quality of the model. This research helps provide effective solutions for production sustainability in the papermaking industry.

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1. Introduction

Industry owners must produce goods that do not harm the environment, and this principle must be observed throughout all stages of design, production, and distribution. As a growing need, sustainable development emphasizes the balance between social, economic, and environmental issues. Sustainability means meeting the needs of the present generation without compromising the ability of future generations, and sustainable management helps reduce environmental and social risks in business. As one of the largest producers of pollutants, the paper and cardboard industry needs improvement in production processes and sustainable consumption. Given global challenges and legal pressures, companies must move towards using environmentally friendly resources and reducing waste. The concept of sustainable development addresses the integration of economic, social, and environmental goals and helps companies reduce their negative impacts [1,2]. Ultimately, by adding sustainability aspects, supply chain management seeks to create a balance between economic development and environmental protection. Therefore, in today's world, attention to environmental issues and sustainable development has become one of the main priorities for industries [3,4]. Cellulosic industries, as one of the key sectors in the global economy, face numerous challenges in the field of sustainability. Cellulosic products depend on natural resources and have significant environmental impacts due to their production and consumption processes. Therefore, defining an effective management model for sustainable development in these industries is essential [5,6,15].

Traditional management models often focus on cost optimization and productivity enhancement, paying less attention to social and environmental dimensions. Therefore, there is a felt need for a comprehensive and integrated approach that can simultaneously consider economic, social, and environmental aspects. This article examines and explains a management model for sustainable development in cellulosic industries, designed to reduce negative environmental impacts, improve local communities' quality of life, and increase economic productivity. Therefore, studying the explanation of a management model for sustainable development in cellulosic industries is of high importance and necessity. These industries, due to their reliance on natural resources and the environmental impacts resulting from production processes, are recognized as one of the sensitive and challenging sectors in the global economy. With increasing concerns about climate change, depletion of natural resources, and environmental pollution, the necessity of sustainable development in these industries is felt more than ever [7,8,9]. Firstly, cellulosic industries, as one of the largest consumers of natural resources, must move towards optimal and sustainable use of these resources. This research can help identify methods and strategies that lead to reduced consumption of water, energy, and raw materials, thereby reducing negative environmental impacts. Secondly, given the increasing social and legal pressures to comply with environmental standards, cellulosic industries require a comprehensive management model that can help them adapt to these requirements [10]. This research can contribute to the development of effective management frameworks for addressing these challenges and improving the environmental performance of industries. Thirdly, explaining a management model for sustainable development in cellulosic industries can lead to increased competitiveness of these industries in global markets. Given changes in consumption patterns and increasing demand for sustainable products, companies must move towards innovation and improvement of production processes to meet customer needs [11]. Finally, studying this field can help raise public awareness and increase the social responsibility of cellulosic industries. By providing practical and scientific solutions, it is possible to help improve the quality of life of local communities and protect the environment. Therefore, explaining a management model for sustainable development in cellulosic industries is a scientific necessity and a social and economic need that must be given special attention. By using this model, cellulosic industries can move towards more sustainable production and meet the needs of the present generation, without compromising the ability of future generations to meet their own needs. In this regard, the present article analyzes the challenges and opportunities in the path of sustainable development of cellulosic industries and provides practical solutions for implementing this model.

The remainder of the article is organized as follows. Section 2 provides a literature review of past research to identify the research gap. Section 3 presents the proposed problem framework. Section 4 presents the results of applying the problem in a case study. Finally, Section 5 provides a general conclusion along with suggestions for future research.

2. Literature Review

Karimi Zare et al. [10], presented sustainable planning for energy supply management in the steel industry in their study. For this purpose, they proposed a multi-objective robust optimization model. New methods for sustainability planning have been developed to maximize profit while minimizing energy consumption and greenhouse gas emissions. Additionally, uncertainties have been considered, and robust optimization strategies have been identified for a grid-connected steel manufacturing company with an on-site energy generation system. The performance of the developed model was evaluated through extensive computational experiments. In their study, Boujenah et al. [5], presented a modified particle swarm optimization algorithm for the production and maintenance planning problem. For this purpose, they proposed a modified particle swarm optimization algorithm to solve integrated production planning under uncertainty. Gonzalez et al. [11], stated a problem for sustainable planning during the COVID-19 period in their study, aiming to introduce a bi-objective model to address sustainable planning for a multi-product, multi-period supply chain network that includes multiple suppliers, factories, and demand points. One objective of the model is to minimize the total cost of this network during the disaster period. The other objective is to calculate probable times to maximize the minimum confidence level of manufacturers during the COVID-19 pandemic. To solve the proposed model, the Imperialist Competitive Algorithm (MOICA) and Genetic Algorithm (NSGA-II) were used to measure the performance of the mentioned algorithm. Ghasemi et al. [12], presented a two-level decision-making system for optimizing a maintenance planning problem in their study, which, in this study, considering labor productivity, outsourcing option, and supplier flexibility, has been introduced. Dehghan Shoorkand et al. [7], presented a deep learning approach for proactive sustainable planning in their study, for which a multi-product, multi-period capacity sizing problem was considered. This creates a sustainable planning framework using deep learning and mathematical programming. The goal is to minimize the total costs of holding, setup, maintenance, reordering, and production, while meeting the demand for all products over the planning horizon. Aydin and Tirkolaee [13], presented a systematic literature review with a sustainability and circularity perspective in their study, stating that sustainable planning is the process of determining production levels, inventory, and workforce to meet demand requirements within a planning window of up to 1 year. As an emerging field, sustainable planning deals with adapting environmental, economic, and social sustainability criteria in the planning period, which in turn can be achieved by applying circular economy principles in real-world production activities. Chang and Lamannen [14], presented a fire detection method in smart city environments using a deep learning-based approach in their study. A new convolutional neural network for identifying fire areas using an advanced network (YOLO) has been developed, and based on the improved algorithm, they adapted the network to work on board using three layers.

Given the points mentioned above, despite the increasing importance of sustainable development in cellulosic industries, existing research in this area has not yet comprehensively and systematically elucidated effective management models. Most previous studies have focused on specific aspects of sustainability, such as resource management or pollution reduction, but there is a felt lack of a comprehensive model that considers all economic, social, and environmental dimensions. Furthermore, many studies have been conducted on a case-by-case basis and are limited to one or a few specific industries, and their results are not easily generalizable to other sectors of the cellulosic industries. This indicates the need for a holistic and multidimensional approach that can identify and analyze the key components influencing sustainable development in these industries. Also, in many cases, the lack of attention to the relationships between different components and their mutual impacts has led to the inefficiency of existing models. Additionally, the lack of reliable and comprehensive data on the sustainable performance of cellulosic industries is another challenge that highlights the need for further research. Therefore, this research is designed to fill these gaps and provide a comprehensive and practical management model for sustainable development in cellulosic industries. This model can be used as a guiding tool for managers and decision-makers to improve the sustainable performance of these industries.

3. Research Method

Generally, the current research is applied and developmental in terms of its objective. This is because this research aims to develop applied knowledge in a specific field. That is, it has been conducted with the intention of practical application of knowledge or to apply the findings to solve common specific problems within an organization. Furthermore, it is a process carried out to formulate and determine the suitability of a product. In terms of data collection, this research seeks solutions for the sustainability of production management in the cellulosic industry; in terms of nature, it is descriptive, belonging to the branch of survey methods. Survey research is used to collect data related to the present time. In this method, the researcher is not in a position to manipulate environmental variables and has less control over the research environment. Using the collected information and data, the researcher seeks a better and more complete understanding of the current situation. The statistical population of this research includes all producers and industry owners, experts, managers, academic and non-academic specialists, guilds, and chambers of commerce related to the paper and cardboard sector in the country's cellulosic industry. The sampling method in the current research is simple random because there is no significant difference between the number of eligible individuals in the selected companies, and each company has an equal chance of being selected. Cochran's formula was used to determine the sample size. The desired sample size was calculated using Cochran's formula, and 320 questionnaires were analyzed. The data collected in this research were analyzed using two statistical methods: descriptive and inferential. Descriptive statistics, such as frequency and percentage frequency, were used to draw charts and tables and analyze information, in other words, to provide an overall view and summary of the data. Using inferential statistics, the sampling results are generalized to the entire population. In this research, statistical tests such as Kolmogorov-Smirnov for normality or non-normality of data distribution, Cronbach's alpha for examining the reliability of the questionnaire, and the structural equation modeling method for examining relationships between variables and confirming or rejecting research hypotheses were used. Also, Smart-Pls software was used to analyze data, evaluate hypotheses, and confirm the proposed conceptual model. The initial variables for explaining the management model are considered according to Table 1.

Table 1. Variables of the Conceptual Research Model

Research Variables	Indicators	Indicator Source (Research Question Numbers)
Technological index	1- Research and development capability	(2,11,18,20)
	2- Technological capability	(5)
	2-1 Cleaner production	(5,6,13,16)
	A- Accessibility	(5)
	B- Usability	(6,13)
	C- Pollution prevention	(16)
	2-2- Industrial automation	(8,9,10)
	A- Waste control	(8)
	B- Calibration	(9)

Research Variables	Indicators	Indicator Source (Research Question Numbers)
	C- Quality monitoring	(10)
	2-3- Development	(3,7,14)
	A- Novelty and newness1	(7)
	B- Speed of change	(14)
	C- Level of transfer	(3)
	3- Design capability	(4,8,15,19)
Regulatory index	1- Sustainability of laws	(1,2,3,4,5)
	2- Supportiveness of laws	(6,7,11)
	3- Stability of laws	(8,12,13)
	3- Effectiveness of laws	(9,10,14,15,16,17)
Social index	1- Training	(1,2,3)
	2- Development	(4,5,6)
	3- Accountability	(7,8,9,10,11,12,13,14)
	4- Effective	(15,16,17,18,19)
Economic index	1- Financial capability	(1,2,4,5,12,18)
	2- Cheap resources	(3,9)
	3- Investment risk	(6,8,10,11,22)
	3- Competitiveness	(7,13,14,15,16,19,20,21)
Environmental indices	1- Environmental planning	(1,5,6)
	2- Environmental management	(2,4,9,10,11,12,13,14)
	3- Environmental assessment	(3,7,8,21)
	4- Environmental effectiveness	(14,15,16,17,18,19,20)
Human indices	1- Skill creation	(1,3,11)
	2- Knowledge enhancement	(2,4,5,6)
	3- Succession planning	(7,8,9,10)
	1- Skill creation	(1,3,11)

Research Variables	Indicators	Indicator Source (Research Question Numbers)
Material and product indices	1- Materials	(10)
	1-1- Sustainable supply	(1,10,11,12)
	1-2- Sustainable quality	(3,6,13)
	1-3- Diversity	(2)
	2- Product	(3)
	2-1- Sustainable production	(4,10,11)
	2-2- Sustainable control and monitoring	(7,8,13)
	2-3- Sustainable delivery	(9,12)
	2-4- Sustainable design	(5)

4. Findings

The results of the Friedman test show that the most important factor affecting production sustainability in the cellulosic industry was accessibility, and the least important factor among technological indicators was waste control. Among the indicators related to regulations, the most important factor affecting production sustainability was the supportive nature of regulations, and the effectiveness of regulations was of lower priority. Among the social indicators affecting sustainability in the cellulosic industry, responsibility was the most important factor, and development was the least important factor among social indicators. Among the economic indicators affecting production sustainability, the most important component was cheap resources (4.40), and the least important factor was financial capability (3.31). Among the environmental indicators, the most important factor was environmental risks (3.75), and the least important factor was planning. In terms of human indicators, the most important factor was succession planning (3.32), and the least important factor was skill creation (2.60). Among the material and product indicators, the most influential factor on production sustainability in the cellulosic industry was diversity, and the least important factor was monitoring control (2.33).

Moreover, in all indicators affecting production sustainability in the cellulosic industry, there was a significant difference between the current situation and the importance of the indicator. Furthermore, all indicators and components were confirmed based on the confirmatory factor analysis results. The path coefficient indicates the existence of a linear causal relationship and its strength and direction between two latent variables. It is the same regression coefficient in the standard state that we observed in more straightforward and multiple regression models. It is a number between -1 and +1; if it is equal to zero, it indicates the absence of a linear causal relationship between two latent variables. In the mentioned model, all standardized coefficients were greater than 0.3, and the obtained t-values were also greater than 1.96, so the model's validity is also confirmed.

Table 2. Prioritization of strategies for production sustainability in the cellulosic industry

Criterion	Average	Average rating
Rules	4.1412	7.00
Economic	3.5727	5.60
Environmental	3.5143	5.30
Technology	3.1600	3.30
Social	3.1000	2.95
Human	3.1000	2.25
Materials	2.9923	1.60

Friedman test results show that the most important solution for production sustainability is the legal factor, and the least important factor affecting the paper industry is the material factor. This relationship is also statistically significant, as the obtained significance level is less than 0.05**.**

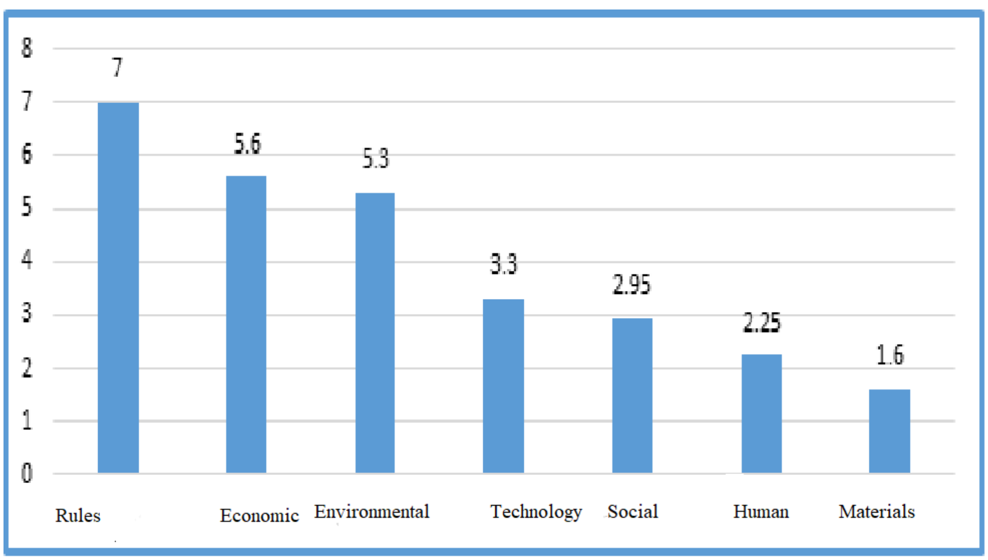

Figure 1. Importance of each management sustainability criterion in cellulosic industries

Table 3. Results of structural equations regarding effective strategies for production sustainability in the cellulosic industry

Criterion	Standardized coefficients	Significance coefficients	Statistical results
Rules	0.545	5.37	Confirmation
Economic	0.408	5.25	Confirmation
Environmental	0.360	5.63	Confirmation
Technology	0.313	5.57	Confirmation
Social	0.301	6.22	Confirmation
Human	0.190	2.14	Confirmation
Materials	0.118	5.50	Confirmation

Based on the results obtained from the analysis of research data, the "rules index" with a path coefficient of 0.545 and a statistic of 5.37 affects production sustainability. In other words, the "rules index" had the strongest relationship with production sustainability, and this relationship has been statistically confirmed. There was a positive and significant relationship between the "economic index" and production sustainability. The path coefficient value was 0.408, and the statistic obtained was 5.25, which indicates the significance of the model, and in other words, the impact ranking of this factor is second. Also, the "environmental index" with a path coefficient of 0.360 and a statistic of 55.63 affects production sustainability. In other words, there is a positive and significant relationship between the "environmental index" and production sustainability, and this relationship has been statistically confirmed. The "technology index" with a path coefficient of 0.313 and a statistic of 5.57 affects production sustainability. In other words, there is a positive and significant relationship between the "technology index" and production sustainability, and this relationship has been statistically confirmed. The "social index" with a path coefficient of 0.301 and a statistic of 6.22 affects production sustainability. In other words, there is a positive and significant relationship between the "social index" and production sustainability, and this relationship has been statistically confirmed. The "human index" with a path coefficient of 0.118 and a statistic of 5.50 affects production sustainability. In other words, there is a positive and significant relationship between the "human index" and production sustainability, and this relationship has been statistically confirmed. The "materials and product index" with a path coefficient of 0.190 and a statistic of 2.14 affects production sustainability. In other words, there is a positive and significant relationship between the "social index" and production sustainability, and this relationship has been statistically confirmed.

4.1. Predictive Relevance (Q^2)

Predictive relevance is another indicator for evaluating the structural model and its quality, aiming to assess the structural model's ability to predict using the blindfolding method. The most famous and well-known criterion for measuring this ability is Stone-Geisser's Q^2 index, based on which the model should predict the indicators of endogenous latent variables. Q^2 values above zero indicate that the observed values are well reconstructed and the model has predictive ability; in other words, if all obtained values for the CV Red index are positive, it can be said that the structural model has good quality.

Table 4. CV RED Index Values

Research variables	CV RED
Laws and regulations	*
Economic indicator	*
Environmental indicator	*
Technological indicator	*
Social indicator	*
Human indicator	*
Material indicator	*
Production sustainability	0.595

*The CV Red value is calculated for endogenous latent variables.

As shown in Table 4, all endogenous variables in the study obtained positive Q2 values, which indicates that these variables were well reconstructed in this study and have predictive ability.

4.2. Criteria for Testing the Overall PLS Model

An index for assessing the overall model in PLS analysis, known as Goodness of Fit (GOF), proposed by Tenenhaus et al. (2005), is used in structural equation modeling. In other words, we have used the GOF criterion or index to examine the validity or quality of the model in PLS analysis. This GOF index is a number between zero and one, and the closer its value is to one, the higher the validity and quality of the model. This index considers both the measurement and structural models and is used as a criterion for assessing the model's overall performance. This index is calculated as follows:

$$GOF = \sqrt{\text{average (Commonality)} \times \text{average } (R^2)} = 0.644$$

Communality= 0.595

R^2= 0.698

Henseler et al. (2009) determined three values of 0.15, 0.2, and 0.35 as weak, moderate, and strong predictive power. A strong model fit was determined based on the value obtained from the above formula.

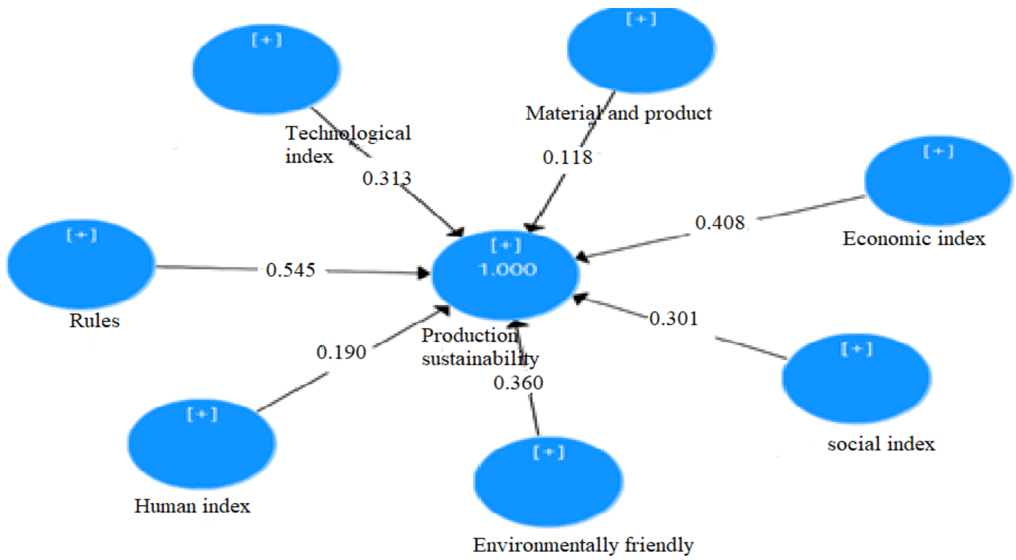

Figure (2). Results of structural equations based on standardized coefficients

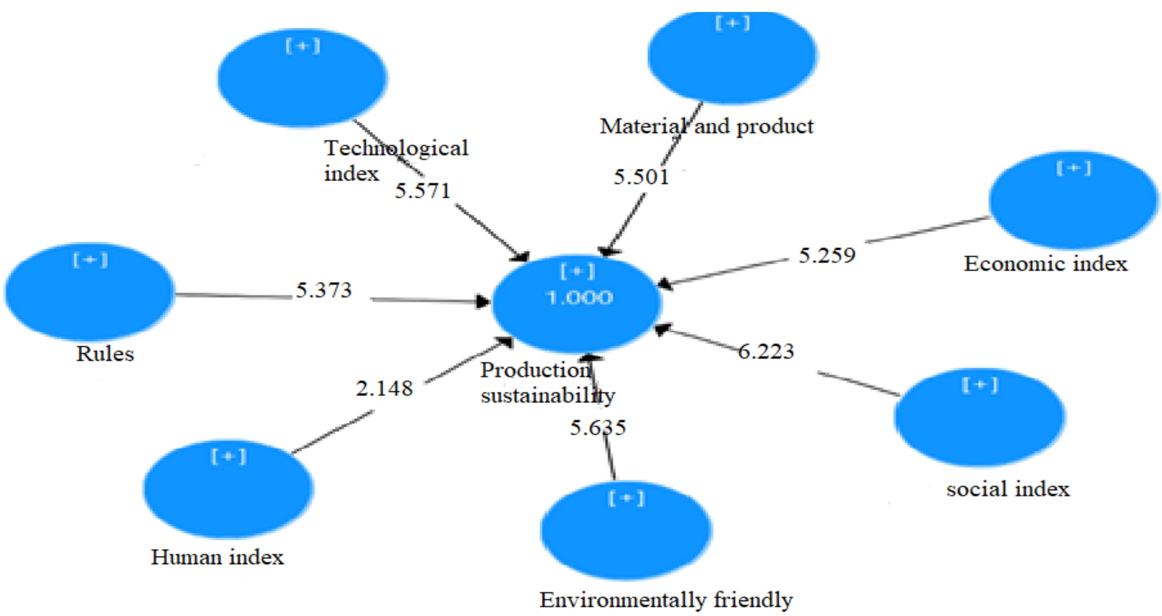

Figure 3. Results of structural equations based on significance coefficients

5. Conclusion

This study aimed to identify indicators, components, and influential factors for sustainable production development in the cellulosic industries sector through in-depth library research among a large number of internal and external theoretical sources, thereby taking a step towards achieving the conceptual model of the research. In this research, 9 main components were identified, and several influential factors were considered for each. The mean, standard, and significant coefficients based on the t-statistic were estimated for the considered factors. Based on the results obtained from the t-test, all considered influential factors were confirmed, as they fall within the permissible range for this statistic at a 95% confidence interval. Throughout the studies, efforts were made to select indicators and influential factors in a way that would prevent bias. After ensuring the initial conceptual model and confirming the model's structure, it was necessary to test the internal relationships of the model using quantitative methodologies. To do this, and based on the hypothetical relationships in the model, they were evaluated in the quantitative and computational phase of the research. To determine the conceptual model of the research, it was necessary to design and apply an appropriate quantitative methodology. For this purpose, a broad statistical population is needed. For this reason, cellulosic industries were considered as the population. After identifying and examining the factors, the indicators were prioritized based on their average rank, and according to the results, the "laws" indicator received the highest rank and the "materials" indicator received the lowest rank. Through a more detailed examination, the researcher performed the results of structural equations analysis regarding effective solutions for production sustainability in the papermaking industry using standardized and significance coefficients. Based on this, the most appropriate structural equation was estimated. Also, to confirm the validity of the model for accurate future prediction, the CV RED index was used. Given the positive value of this index for the variables, it can be concluded that the constructed model possesses the necessary quality.

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