IMPACT OF CHANGE ORDERS ON WASTE MATERIAL OF ROAD CONSTRUCTION PROJECT

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Abstract

Change orders in road construction project are a contributing factor to wastage, a concern underscored in recommendations for waste materials. The significant impact of change orders on waste materials becomes evident in various project phases, including implementation, handling, planning, procurement, and contractual aspects. Therefore, this research aims to explore the impact of change orders on waste materials, providing insights into the influential role across critical aspects of road construction projects. A dual approach was adopted, incorporating both interview and questionnaire methods, with the questionnaire's design established through the application of the Delphi method. The design was subsequently validated by experts following a series of tests, ensuring its effective distribution to a diverse audience, including consultants, contractors, and owners. The calculations were conducted using Factor Analysis and were analyzed with the assistance of SEM PLS 4.0. This comprehensive approach facilitated a thorough exploration of the research methodology and data analysis process.

Keywords: Impact of Change Orders, Waste Materials, Road Construction Project, Smart PLS 4.0, Factor Analysis.

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INTRODUCTION

Change to work in construction contracts, commonly referred to as change orders, is prone to occur at any stage of the project, either at the commencement, during, or end of the project timeline. Change orders are documented agreements to modify, add, or otherwise change the work outlined in the contract document at the time of bid opening. It is crucial that any proposed change remains in the defined scope of the original project, otherwise a modification to the contract becomes essential (Fisk & W.D.Reynolds, 2014). In many construction projects, frequent design changes may negatively affect project performance, cost overruns, delays, and function failures (Ahmad Aqil Zaidi et al., 2023)The research conducted by (Waty, Sofia, Gondokusumo, & Sulistio, 2018) showed that waste materials occurred in 107 road improvement projects, primarily attributed to change orders. Subsequent research by (Waty & Sulistio, 2019) confirmed this result, recommending that reducing change orders would minimize waste materials.

Waste material significantly impacts construction project, constituting approximately 40-60% of the operation costs (Waty et al., 2018). This waste undermines project success and diminishes the profits of implementing contractors, a concern observed in various building and workshop projects in recent years.The volume of waste varies among tasks, with road project experiencing higher waste levels, such as 20% for aggregate B and A, along with other materials (Waty et al., 2018). The resultant material waste often leads to rework, accounting for 30% of expenditures in construction project (Porwal et al., 2020)

(Ismail Abdul Rahman, 2015) conducted research on the causes and effects of construction waste in Malaysia, using PLS Structural Equation Modeling (SEM). (Durdyev et al., 2018) tested data concerning labor productivity using SEM, while (Naji et al., 2022) performed research analysis on the impact of change orders on project success using PLS-SEM. Therefore, this research aims to ascertain the impact of change orders on waste materials in road construction project by applying PLS-SEM. PLS-SEM analysis was executed to test: firstly, the measurement model (was tested to validate the instruments) and secondly, the structural model (was examined to test the hypothesis).(Siti Fatimah Hashim et al., 2023)

RESEARCH METHODOLOGY

This research included direct observations in the field and was achieved through interviews and discussions directly addressing the impact of change orders. Before data distribution, a Focused Group Discussion (FGD) was conducted with several experts to formulate the draft questionnaire. Trials were carried out multiple times until a pilot project was executed. The completed questionnaire was subsequently distributed to numerous proficient participants from various

competent stakeholders, including contractors, consultants, and owners. It used a comprehensive Likert scale ranging from 1 to 5, showing the extent of influence from very minimal to very significant.

Draft Questionnaire
Draft questionnaire assessing impact of change orders on road construction waste materials was developed, as outlined in Table 1.

Table 1: Waste Material Variables and Indicators

Num	Source	Causes
1	**Design**	1. Errors in contract documents. 2. Incompleteness of contract documents. 3. Ordering errors due to the selection of different product specifications. 4. Incomplete information on road design drawings. 5. Lack of coordination with contractors and insufficient construction knowledge. 6. Insufficient information on material types and sizes. 7. Uncertain quantity of required material due to improper planning.
2	**Procurement**	8. Ordering errors leading to excess or shortage. 9. Disadvantages of ordering in small quantities. 10. Procuring materials not meeting project requirements. 11. Delays in material arrival. 12. Inadequate packaging leading to waste.
3	**Handling**	13. Material damage during transportation to or at the project location. 14. Damage caused by incorrect storage of materials. 15. Careless handling during the unloading of materials for warehouse storage. 16. Unfriendly or rude attitudes and actions by the project team and the workers. 17. Incidents of theft. 18. Material damage occurring on-site. 19. Errors in spreading material in the field.
4	**Implementation**	20. 20. Adverse weather conditions. 21. 21.Use of incorrect material necessitating replacement. 22. 22.Carelessness in mixing, processing, and using materials for warehouse storage. 23. 23.Inaccurate dimension measurements to prevent excess volume. 24. Damages caused by unskilled workers. 25. Excess volume due to unclear planning.

Num	Source	Causes
		26. Reparation efforts.
		27. Delayed image distribution.
		28. Slow revision and distribution of drawings.
5	**Residue**	29. Leftover materials from the usage process.
6	**The others**	30. Inadequate control of materials on the project and management planning for residual materials.
7	**Behavior control**	31. Deviations in material scheduling control.
		32. Deviations in material cost control.

(Bossink, 1996); (Gul Polat et, 2004); (Gaviland&Reynold, 1994) ;(Teo & Loosemore,2001)
;(Ekayanake,2004); (Alwi et al, 2002)

Source: (Waty & Sulistio, 2020)

The following were the Impacts of change orders:

1. Increased project financing (Shrestha & Fathi, 2019).
2. Reduced project quality (Shrestha & Fathi, 2019).
3. Extended project implementation time (Waty & Sulistio, 2022)

Data Analysis
Factor Analysis
Factor analysis was categorized into two types, namely Principal Component Analysis (PCA) and Factor Analysis (FA). Both analyses aimed to explain the structure of variations through a linear combination of the constituent variables. In essence, Factor Analysis or principal component analysis was desired to reduce and interpret data as a new variable in the form of a composite variable (Muhammmuddin et al., 2023). Barlet test of Sphericity served as a statistical test to examine the hypothesis that variables were uncorrelated in the population. The accuracy of Factor Analysis was evaluated using the Kaiser-Meyer Olkin (KMO) index. It was considered suitable when the KMO value ranged from 0.5 to 1 and perceived inappropriate otherwise.

Measure of Sampling (MSA)
Measure of Sampling Adequacy (MSA) served as a comparison index among the partial correlation coefficients for each variable, facilitating the assessment of relationships. Factor Analysis was applied to streamline waste material indicators for road construction project.

Partial Least Square 4.0 (PLS-SEM)
PLS-SEM aimed to identify predictive relationships by testing the connections between constructs to determine the influence (Sarstedt et al., 2021). In this context, the analysis tested the relationship between the impact of change orders and waste materials in road construction project. PLS-SEM analysis comprised

two sub-models, namely the measurement or outer model, and the structural or inner model (Sarstedt et al., 2021).

Initial Hypothesis
The initial hypothesis showed that the impact of change orders on waste materials significantly affected various aspects, namely:

1. Material planning.
2. Material procurement.
3. Material handling.
4. Material implementation.
5. Residual material.
6. Other materials.
7. Controlling workers' behavior.

ANALYSIS AND DISCUSSION
Data Acquistion
The questionnaire was returned by 700 respondents, including owners, consultants, and contractors from both the private and government sectors. Respondents had over 10 years of work experience, dominating at 63.14%, with project manager comprising 80% of the professional positions. According to (Zeng et al., 2021), the minimum number of respondents needed for research and data testing ranged from 25 to 1037, and the obtained 700 respondents were considered sufficient.

Factor Analysis
Based on Factor Analysis conducted, the following results were obtained.

Results from KMO and Barlett's
KMO and Barlett's Test showed a result of 0.826, signifying the suitability for proceeding with Factor Analysis calculations. The significance value of 0.000 being less than 0.05, confirmed the viability of continuing the analysis. Therefore, Factor Analysis was adopted, facilitating advancement to the next step of the research.
Based on the results obtained from the Anti Image calculation, as seen in the Measure of Sampling Aquadeacy (MSA), all indicators were considered usable, with values above 0.5. The 32 indicators contributed to the understanding of factors causing waste materials.

Eigenvalue
Based on the total variance results, as shown by the initial eigenvalue, it was determined that 9 factors were derived from multiple indicators, each surpassing

a value of 1. This constituted a cumulative percentage of 76.072% of the indicators contributing to the impact of change orders on waste materials, with the factors identified as follows:

1. Errors in contract documents, accounting for 11.238%.
2. Incompleteness of contract documents, representing 2.76%.
3. Ordering errors due to selecting different product specifications, accounting for 2.751%.
4. Incomplete information on road design drawings, signifying 1.759%
5. Lack of coordination with contractors and insufficient construction knowledge, representing 1.360%.
6. Insufficient information on material types and sizes in the documents, accounting for 1.261%.
7. Uncertain quantity of required material due to improper planning, signifying 1.131%.
8. Ordering errors resulting in excess or shortage, representing 1.071%.
9. Disadvantages of ordering in small quantities, accounting for 1.007%.

The results of the component transformation components showed that Factors 1 to 5 all had correlation values exceeding 0.5 and were considered feasible. Factor 6 was perceived to be not feasible, while 7 to 9 were declared feasible due to correlation values above 0.5.

Out of the 9 factors, only 8 were suitable to summarize the 32 indicators. Factor 8 could not be used as it only had 1 indicator, resulting in the application of 7 components with a total of 29 indicators. This discovery led to the change in the name and usage of the variables, resulting in the following grouping, namely Material Handling, Implementation, Contracts, Procurement, Planning, Usage, and Orders. Consequently, seven factors were considered suitable for processing in PLS-SEM, namely Factors 1, 2, 3, 4, 5, 7, and 9, generating new hypotheses as follows.

1. Impact of Change Orders on Material Handling with 3 indicators.
2. Impact of Change Orders on Material Implementation with 3 indicators.
3. Impact of Change Orders on Material Contracts with 11 indicators.
4. Impact of Change Orders on Material Procurement with 5 indicators.
5. Impact of Change Orders on Material Planning with 2 indicators.
6. Impact of Change Orders on Usage of Material with 2 indicators.
7. Impact of Change Orders on Ordering Material with 3 indicators.

Table 2: New Waste Material Variables and Indicators

Num		Variable/Indicator
1	X1	**Handling**
	X1.1	Careless handling during material unloading for warehouse storage.
	X1.2	Unfriendly attitudes or actions of the project team and project
	X1.3	workers.
	X1.4	Incident of theft.
	X1.5	Errors in field deployment.
	X1.6	Adverse weather conditions.
	X1.7	Damage caused by unskilled workers.
	X1.8	Excess volume due to unclear planning.
	X1.9	Material remaining from usage process.
	X1.10	Poor control and management planning for excess material.
	X1.11	Deviations in material scheduling control.
2	X2	Deviations in material cost control.
	X2.1	**Implementation**
	X2.2	Material damage on-site.
	X2.3	Impact of wrong storage of materials leading to waste.
	X2.4	Excess volume due to inaccurate dimensional measurements.
	X2.5	Slow revision and distribution of drawings.
3	X3	Impact of repair work.
	X3.1	**Contract**
	X3.2	Errors in contract documents.
	X3.3	Incompleteness of contract documents.
4	X4	Incomplete information on road design drawings.
	X4.1	**Procurement**
	X4.2	Impact of ordering errors resulting in excess or shortage.
	X4.3	Delay in materials arrival.
5	X5	Procuring materials not meeting project requirements.
	X5.1	**Planning**
	X5.2	Lack of coordination with contractors and insufficient construction
	X5.3	knowledge.
6	X6	Unknown amount of material required due to imperfect planning.
	X6.1	Insufficient information on material types and sizes on the contract
	X6.2	document.
7	X7	**Use of Materials**
	X7.1	Inadequate packaging leading to waste.
	X7.2	Use of incorrect material necessitating replacement.
		Ordering Materials
		Disadvantages of ordering in small quantities.
		Ordering error due to selecting different product specifications.

Calculations with PLS-SEM
In the initial model of this research, the results of stage 1 calculations identified an outer loading on indicator 7.2 did not meet the requirements, as the outer loading was below 0.6 (GHOZALI & LATAN, 2015), leading to the removal of the indicator. The model was subsequently reanalyzed, achieving outer loading satisfying all criteria. A more in-depth examination regarding multi-collinearity showed that indicator 1.7 exceeded the threshold of 5 and needed to be removed. Several additional indicators were excluded due to having VIF number exceeding 5. These exclusions were part of PLS algorithm calculations in stage 1, resulting in the generation of both outer and inner models.

1. Outer Model
The outer model comprised of the following compo

Outer loading. The outer loading results met the requirements, all being above 0.6.

Construct Reliability. The construct reliability results showed that Cronbach's Alpha exceeded 0.65 and were considered acceptable ((J F Hair et al., 2019); (Sarstedt et al., 2020)
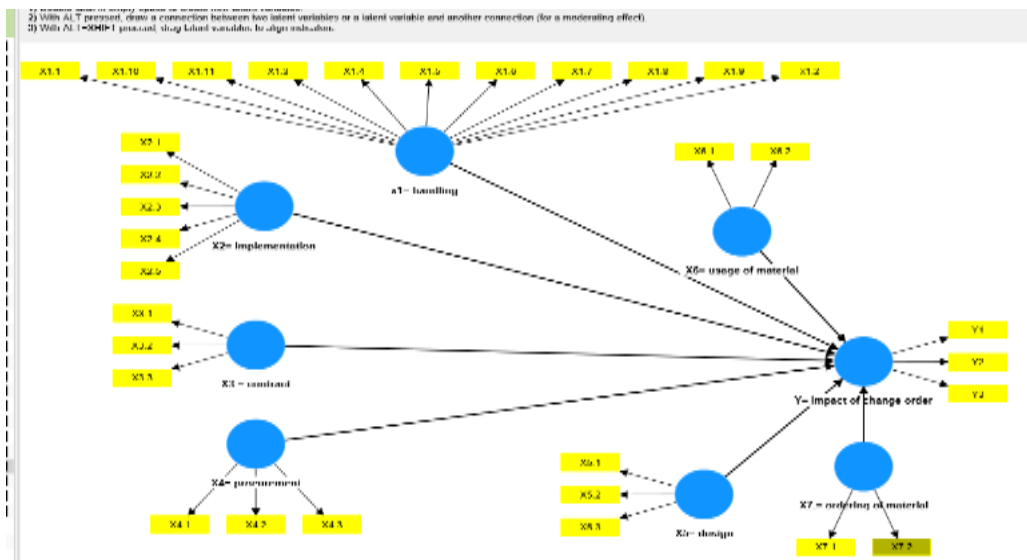
Stage 1(PLS Algorythm)

Figure 1. Initial model

Discriminant validity assessment included heterotrait-monotrait (HTMT) and Fornel Lacker Criterion.

HTMT results showed appropriateness since all were below 0.9. This outcome correlated with HTMT correlation ratio test, developed by (Henseler et al.,2016) which was used to evaluate the discriminant validity of SEM (variance-based). The test ensured the accuracy of measuring a specific correlation between two constructs. According to (Henseler et al., 2016) and (J. Hair & Alamer, 2022), for components in the model considered consistent, HTMT value had to be less than 0.90. Although HTMT value exceeded 0.9, the remaining values met the specified requirements.

Fornel Lacker Criterion. Fornel Lacker calculations showed that the computation of constructs X1 and X1 was higher than X1 and X2. For example, when calculating the construct X1 with X1, the result was 0.789, exceeding the comparison with X2, which was 0.514. Similarly, the calculation of construct X2 with X2 exceeded the values of X2 with X3 or X2 with X1, persisting until X7.

2. Inner Model
The results of the inner model were as follows.

Adjusted R square
Adjusted R square results showed a coefficient of determination of 0.733. This suggested that 73.3% of the impact of change orders on waste materials for road construction project could be explained.

According to (Chin, 1998) and (GHOZALI & LATAN, 2015), adjusted R square value of 0.67 was considered strong, 0.33 was moderate, and 0.19 was weak. Consequently, the results of this coefficient of determination showed a strong relationship, as the obtained value of 73.3% exceeded the threshold of 67%.

Feasibility of the Model
The model fit results suggested that NFI was 0.626, showing a model closer to 1 was preferable. Additionally, SRMR was 0.090, below 0.1, signifying that the model was feasible.

Multicollinearity Test
Multicollinearity test results showed that all indicators were below 5 (Christian M. Ringle, Marco SarstedHair, 2023). The final model for this research was depicted in Figure
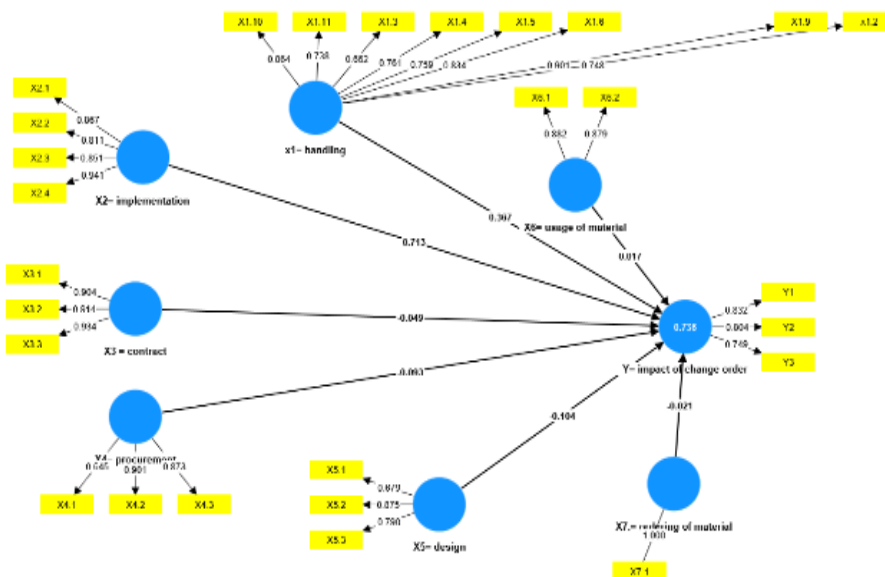
Figure 2. Final Research Model

Bootstrapping Results (Stage 2)

The second stage of calculation focused on examining the correlation or regression relationship of each latent variable, as shown in the following results. The specific outcomes of the relationship are presented in Table 3, focusing on the Path Coefficient.

Table 3: Path Coefficient

	Original sample (O)	Mean (M)	Standard Deviation (STDEV)	O/STDEV	P values
X2=implementation →Y=impact of change order	0,713	0,712	0,027	28,863	0,000
X3= contract→Y = impact of change order	-0,049	-0,049	0,019	2,585	0,010
X4 = procurement→ Y= impact of change order	-0,093	-0,093	0,023	4,116	0,000
X5=design→Y =impact of change order	-0,104	-0,104	0,024	4,377	0,000
X6= usage of material→Y = impact of change order	0,017	0,017	0,023	0,716	0,474

	Original sample (O)	Mean (M)	Standard Deviation (STDEV)	O/STDEV	P values
X7= ordering of material→ Y = impact of change order	-0,021	-0,021	0,026	0,799	0,424
X1 = handling → Y = impact change order	0,367	0,367	0,029	12,746	0,000

The path coefficient results indicated that the regression relationship occurred as follows:

1. Handling at 0.367.
2. Implementation at 0.713.
3. Material Planning at -0.104.
4. Material procurement at -0.093.
5. Material contracts at -0.049.

Two Factors were rejected, indicating no relationship, namely Use of Materials and Ordering materials. Among the five variables with a relationship, a factor showed a strong connection, namely Implementation with a coefficient of 0.713, exceeding the threshold of 0.6 (J. Hair & Alamer, 2022). Consequently, when considering the 7 factors X, the following conclusions were obtained.

1. Five factors showed a direct and significant relationship.
2. Two factors had no direct and insignificant effect.
3. Five factors showed a significant relationship between waste material in road construction project and impact of change orders. Therefore, based on the results, five factors were identified, namely:

    1. Four X variables with a moderating effect based on the path coefficient.
    a. Variable X1 signifying Handling (0.367).
    b. Variable X4 indicating Design (-0.104).
    c. Variable X5 representing Procurement (-0.093).
    d. Variable X3 denoting Material Contracts (-0.049).

    2. One X variable with an influence based on the path coefficient
    a. Variable X2 representing Implementation (0.713).

PLS Predict Change Orders' Impact (CVPAT) Stage 3

Table 4: PLS Predict Change Orders' Impact

	Q²predict	PLS-SEM RMSE	PLS-SEM MAE	LM RMSE	LM MAE
Y1	0,407	0,774	0,584	0,639	0,493
Y2	0,340	0,903	0,730	0,684	0,534
Y3	0,574	0,745	0,598	0,453	0,335

SEM PLS model prediction accuracy test results were presented in Table 4, where the model accuracy test showed predictions above 0.35 for two impacts in PLS Predict (CVPAT, Cross-Validated Predictive Ability Test) calculation. The impacts included Y1 (increase in project financing), Y2 (reduction in project quality), and Y3 (extended project implementation time).

Q square, used to determine the route model capacity prediction model accuracy (Joseph F. Hair et al., 2019), showed that both impacts were substantial due to change orders, with predicted capacity values of y1=0.407, y2 = 0.345, and Y3 = 0.574. The significant predictive capacity established a strong relationship, as each indicator surpassed the 0.35 threshold (Joseph F. Hair et al., 2019), both for Y1 and Y3. However, Y2 had a value of 0.34, which was close to a large predictive capacity. The model showed a substantial predictive relevance capacity for X1 to X7, contributing to a 72.9% impact of change orders regarding project waste materials, specifically Y1, Y2, and Y3.

Hypothesis Test Results

The results of hypothesis testing on the 7 variables were as follows:

a. Five latent variables met the requirements, each with the respective indicators, namely:

   1.   Handling with 8 indicators.
   2.   Implementation with 4 indicators.
   3.   Procurement with 3 indicators.
   4.   Planning with 3 indicators.
   5.   Contract with 3 indicators.

b. Two variables did not meet the requirements. The total number of indicators generated that met the requirements was 21
.

c. Below were the Hypothesis test results.

   1.   Impact of change orders had a significant effect on material handling.

2. Impact of change orders showed a significant influence on material implementation.
3. Impact of change orders suggested a significant effect on material procurement.
4. Impact of change orders indicated a significant influence on material planning.
5. Impact of change orders showed a significant effect on material contracts.
6. Impact of change orders did not influence material use.
7. Impact of change orders showed no significant effect on material orders.

Variables and Indicators Meeting the Specified Requirements
The indicators below were arranged based on the largest to smallest t-statistic results for each variable.

1. Implementation Variable (X2) consisted of indicators ranked from highest to lowest including:
   - Slow revision and distribution of drawings (X2.4),
   - Material damage at the location (X2.1),
   - Inaccurate dimensional measurements resulting in excessive volume, and
   - Material storage errors causing material damage (X2.2).

2. Handling variables (X1) arranged from highest to lowest order.
   - Adverse weather conditions (X1.5),
   - Poor material control on the project and improper planning for remaining material (X1.9),
   - Deviations in material scheduling control (X1 10),
   - Material damage by unskilled workers (X1.6),
   - Deviations in controlling material costs (X1.11),
   - Errors in distributing materials on the field (X1.4),
   - Unfriendly attitudes or actions of the project team and workers (X1.2), and
   - Incident of theft (X1.3).

3. Material Planning Variables (X5) ordered from highest to lowest.
   1. Unknown amount of material required due to improper planning (X5.2),
   2. Lack of information on material types and sizes in documents (X5.3), and
   3. Lack of coordination with contractors and insufficient construction knowledge (X5.1).

4. Material Procurement Variable (X4) consisted of:
   - Procuring materials not meeting project requirements (X4.3),
   - Delay in materials arrival (X4.2), and
   - Impact of ordering errors resulting in excess or shortage (X4.1).

5. Material Contract Variable (X3) included:
   - Incomplete information on road design drawings (X3.3),
   - Incomplete contract documentation (X3.2), and the indicator analysis ranged from five highest to lowest, namely:

   1. Slow revision and distribution of drawings. This factor, identified as a major cause of change to work, led to change orders in the material implementation variable. In the research by (Valencia Livia, 2023), it was identified as a significant contributor.
   2. Material damage on-site. Damage to materials on site, categorized under the implementation variable, resulted from transportation to and from the project location, leading to waste materials, and was acknowledged as the cause of waste in (Valencia Livia, 2023).
   3. Inaccurate dimensional measurements resulting in excess volume were part of the material implementation variable to trigger change orders. The inaccuracy in dimensional measurements causing excess volume was recognized as a waste factor (Valencia Livia, 2023).
   4. Wrong storage of materials causing damage. Incorrect storage fell under the material implementation variable. The action led to the need for reordering, generating waste materials, and potential change orders. Research also stated the incorrect storage of materials as a cause of waste (Kaliannan et al.,2018)
   5. Poor control and management planning for excess material. This aspect, falling under material handling variables, resulted in change orders, rework, and construction waste (Kaliannan et al., 2018).

   The impact of change orders on waste materials for road construction project was 73.3%. It showed a 71.3% influence on implementation, 36.7% on handling, -10.4% on design, -9.3% on procurement, and -4.9% on contracts.

CONCLUSION

In conclusion, after processing and analyzing the original data, comprising 6 variables with 32 indicators, Factor Analysis was carried out. This process yielded 7 variables with 29 indicators, which were grouped and further calculated using SEM PLS 4.0, leading to a significantly improved model. The findings derived from this analysis were as follows:

1. Impact of change orders on waste materials for road construction project, analyzed from the highest to lowest based on statistical results (t-statistic) and the resulting path coefficient, included:

   - Variable X4 signifying Implementation (0.713),
   - Variable X3 representing Handling (0.367),
   - Variable X3 denoting Design (-0.104),
   - Variable X2 indicating Procurement (-0.093), and
   - Variable X1 representing Material contract (-0.049).

2. The impact of change orders on waste materials for road construction project was 73.3%, with an influence of 71.3% on material implementation, 36.7% on material handling, -10.4% on design, -9.3% on material procurement, and -4.9% on contracts. Additionally, the model prediction accuracy was 72.9%, resulting in the impact of change orders on increasing project financing, reducing project quality, and extending project implementation time.

3. There were 5 influential indicators, namely:

   a. Slow revision and distribution of drawings,
   b. Material damage on-site,
   c. Inaccurate dimensional measurements resulting in excess volume,
   d. Wrong storage of materials causing material damage,
   e. Poor control and management planning for excess material,

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