The Impact of Change Orders on the Waste Materials of Large-Scale Projects

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ABSTRACT

Change orders (CO) are formal agreements that alter, add to, or modify the work specified in a contract document. These changes often necessitate adjustments to the project scope, potentially requiring contract modification. Generally, CO have been identified as a significant contributor to Wast Materials (WM) in road improvement projects, as outlined in waste management recommendations. The impact of waste management on project success is substantial, as materials constitute a critical component of construction, accounting for approximately 40-60% of the total project cost. This research aimed to determine the impact of CO on project waste management, with a specific focus on large-scale projects. To achieve this objective, a 4-stage decision-making process was adopted using the Delphi method to design and distribute questionnaires. The results identified 2 variables, comprising 21 indicators, that contribute to waste management in road construction projects. Additionally, 3 primary impacts of CO were recorded, affecting costs, quality, and implementation time. Further analysis using Exploratory Factor Analysis (EFA) and Smart PLS 4.0 revealed that CO had a significant impact on 2 variables: procurement and material handling, as well as implementation and material planning. These variables, consisting of 21 indicators, accounted for 69% of the observed effects, with a prediction accuracy rate of 67.7% regarding the impact of changes in construction work.

Keywords-impact of change order; waste material; large-scale project; road construction project; factor analysis; smart pls 4.0

I. INTRODUCTION

Research on road construction projects revealed that three main materials - aggregate B, ready-mix concrete, and lean concrete - were the primary sources of WM [1]. This finding was based on the analysis of 45 construction projects. Subsequent studies in 2019 expanded on these results, suggesting that reducing CO could effectively mitigate waste [2]. This recommendation demonstrates the direct correlation between CO and waste management in construction endeavors. Typically, the impact of waste management extends beyond mere material loss, particularly in the Canadian context, where it has been associated with significant project inefficiencies, such as repetitive work, schedule delays, suboptimal construction methods, and increased waiting times. These factors collectively accounted for 63% of the waste generated in Canadian construction projects [1]. To quantify the relationship between specific materials and waste, a road construction project model equation was developed, which can be expressed as:

$$Y = 7.363 - 0.032X_3 - 0.078X_4 - 0.066X_6 \qquad (1)$$

where X_3 represents ready-mix concrete, X_4 denotes aggregate B, and X_6 corresponds to lean concrete [1].

Research has shown that the primary drivers of construction waste are design changes and CO on projects utilizing the design-build delivery system, which is widely adopted in Turkey [3]. Prior studies have indicated that the largest source of WM is CO, and rework accounts for 30% of construction costs [4]. Furthermore, the research suggests that a user's commitment to waste reduction during the pre-project planning stage, combined with a coordinated Building Information Modeling (BIM) design process, can potentially reduce construction WM by up to 25%. Another investigation explored the various factors contributing to the accumulation of construction WM in Nigeria. The three main causes of WM were identified as rework due to non-conformance with specifications, waste from uneconomical shape cutting, and waste resulting from CO and design modifications, with average relative contribution indices of 0.801, 0.791, and 0.773, respectively [5].

Existing research indicates that construction materials account for a substantial portion of the total municipal solid waste in mainland China, approximately 40%, as well as 26% of the total solid waste in the United States and 34% of all industrial waste in Europe [6]. The identification and categorization of 28 factors contributing to construction waste in Thailand was researched and resulted in four groups: design and documentation, materials and procurement, construction methods and planning, and human resources [7]. The researchers determined the four most influential factors within each category: design changes, inattentive work attitudes and behaviors, ineffective planning and scheduling, and issues with material storage. These findings can assist industry stakeholders in developing appropriate strategies to more effectively manage construction waste. Given that design changes are a primary driver of CO, the study's results demonstrate the impact of CO on WM [8].

The primary root cause of construction waste was constant design changes, which accounted for 78.9% of the issue. Additionally, the researchers found that incorrect material storage, poor material handling, weather effects, and errors in ordering materials from suppliers were other contributing factors. Furthermore, research using triangulation techniques revealed that 87.5% of construction practitioners in Malaysia agreed with the identified root causes of material waste in the construction sector [9].

Continuous design modifications leading to material waste are a primary driver of cost overruns in construction projects [8, 9]. The researcher aims to investigate how mitigating large-scale project material waste could potentially reduce the impact of CO, thereby minimizing schedule, quality, and cost performance challenges. The main objectives of this research involve conducting interviews with road construction specialists to investigate the influence of CO on WM in large-scale infrastructure projects, and based on insights from road construction experts, the impact can be reduced.

II. LITERATURE REVIEW

A. Impact of Change Orders

CO in construction projects generally entails revisions, supplementary items, or removals to contractual agreements and design plans due to the inherent complexity of relationships and procedures in construction work [10-12].

This study examines the detrimental effects of CO on construction projects, as the industry accounted for 5% of the United States GDP in 2016. The findings forecast the impact of owner-determined cumulative CO, productivity monitoring, employee turnover, the proportion of managers' time allocation, and surplus labor. The research was carried out on electrical construction endeavors [13].

The factors contributing to CO in road maintenance projects include inadequate project scope, estimation inaccuracies, alterations to the initial design, modifications in material specifications, and research-related considerations [8]. From the contractor's perspective, the causes of CO in construction projects in Saudi Arabia are additional work requested by the owner, design flaws and omissions, poor coordination among construction stakeholders, defective work outcomes, and financial challenges faced by the owner. CO inevitably result in cost and time overruns for construction projects in Saudi Arabia [14].

B. Large Scale Projects

Projects are classified according to their funding requirements [15]. Medium to large-scale projects have a funding limit exceeding 15 billion Indonesian Rupiah. Additionally, the regulation stipulates that projects with budgets over 50 billion are considered large-scale. Furthermore, large-scale projects require more than 100,000 man-hours to complete [16].

The existing literature on the impact of CO on WM is limited in scope, focusing on general observations rather than specific, large-scale project data. Researchers now aim to investigate the influence of CO on road construction WM for projects of a larger scale.

III. RESEARCH METHODOLOGY

The study examines the impact of CO on the indicators that contribute to construction WM, which encompasses six variables: design, procurement, handling, implementation, attitudes, and behavioral control. EFA was employed to identify the underlying causes of WM through interviews with road construction experts and pilot project investigations. After this initial analysis, the findings were disseminated. Several iterative trials were conducted to refine the questionnaire, which was ultimately distributed to competent stakeholders.

A. Exploratory Factor Analysis

EFA is employed to extract indicators from variables that contribute to WM. A structural equation modeling approach was adopted to develop a model investigating the impact of CO on WM, which in turn increases project costs, diminishes project quality, and extends project implementation duration. Ultimately, the model is evaluated and validated using statistical techniques. The initial hypothesis formulated in this research consists of the impact of CO on material planning (x1), on material procurement (x2), on material handling (x3), on material implementation (x4), on attitudes (x5), and on behavioral control (x6). The impact of CO in construction involves increased project financing, reduced project quality, and extended the project implementation time [12, 17].

The literature review identified working memory as a key issue, indicating numerous potential causes of impaired working memory performance. Additionally, the researchers conducted interviews with nine industry practitioners to gain further insights into this critical topic [18].

TABLE I. DRAFT QUESTIONNAIRE.

Variable	Indicator
Design	1. Road design drawing information was incorrect. 2. Inaccurate completeness concerning material type and size in the tender documents. 3. Inadequate coordination with contractors, and lacking knowledge of road construction.
Procurement	4. Unable to ship orders in small quantities. 5. Remaining material due to the cutting process. 6. Inadequate material management and WM management plans.
Handling	7. Damage from shipping goods to/at the project location. 8. Spilled on the road. 9. On-site material damage due to slow cutting of concrete. 10. Field spreading errors. 11 Theft (can be sold on the road).
Implementation	12. Equipment not working properly. 13. Terrible climate change. 14. There were cases of work accidents on this site. 15. Errors caused by labor. 16. Unreliable equipment.
Attitude	17. Lack of effort Hesitancy to reduce material affects WM Lack of knowledge about residue values, residue impacts, ways to reduce residues, and responsibility for residues.
Behavior control	20. Inconsistencies in material scheduling. 21. Deviation of material cost control.

B. Questionnaire Survey

The survey was conducted using comprehensive data, which was analyzed employing EFA and Structural Equation Modeling (SEM) techniques as part of the current research. Respondents evaluated the factors contributing to material waste and the influence of change orders on project costs, quality, and timelines using a 1-6 scale, where 1 denoted very low and 6 represented very high levels of implementation. The initial section of the questionnaire gathered respondents' names, their duration of experience in the construction industry, and their positions within the company. To ensure suitability, a pilot survey was administered to 9 individuals who examined a list of material waste causes and the impact of change orders. The pilot also involved refining the wording to use language readily comprehensible to the respondents, including the questionnaire design and format.

C. Data Collection

This study focuses on Indonesian road construction, using road projects as the units of analysis to collect relevant data. The research targets large construction companies, as the focus is on large-scale projects. The required sample size for the research and testing procedures ranges from 25 to 1,037, and the 267 samples obtained are sufficient, as they fall within this acceptable range [19].

D. Grouping Impact of a Change Order on Waste Material

This study identifies 21 indicators of 6 material waste variables that capture the impact of change orders on material waste, with the aim of reducing the associated costs, quality issues, and time effects. Therefore, these variables need to be pruned and reduced using EFA.

EFA allows for the identification of underlying factors that characterize the structure of the variables, as represented by their correlations [20]. The SPSS software was utilized to conduct the EFA. Loading factors above 0.5 were considered in grouping the variables. Given the sample size exceeding 100, several tests were employed to assess the suitability of the questionnaire for EFA [21, 22]. Additionally, the Scree plot was used to determine the number of factors from the EFA, considering eigenvalues above 1.

E. Partial Least Squares Structural Equation Modeling

Partial Least Squares Structural Equation Modeling (PLS-SEM) is a non-parametric, exploratory technique that enables the examination of unobserved variables by analyzing the underlying constructs of indicators, resulting in moderately enhanced precision compared to other multivariate component evaluation approaches. Hypothesis testing facilitates the evaluation of unconstrained hypotheses, the assessment of relationships between variables, and the utilization of multiple advanced models to analyze a large number of variables with multiple correlations, thereby improving validity and reliability [23].

Group comparisons using the model are more extensive than those available through traditional statistical analysis, allowing a deeper investigation into the impact of change orders on material waste in road construction projects. The primary objectives of this research are to thoroughly examine the influence of change orders on material waste in road projects and to develop a comprehensive model depicting this relationship, which could lead to more efficient and sustainable construction practices [23].

Data processing through PLS-SEM is carried out with three calculations:

- Phase I: Encompasses two key components: the inner model and the outer model. The inner model involves various statistical metrics such as R-squared, F-squared, Goodness of Fit (GF), and Variance Inflation Factor. The outer model, on the other hand, focuses on assessing the reliability, validity, discriminant validity, cross-loadings, and outer loadings of the measurement model.
- Phase II: Bootstrapping to test the hypothesis.
- Phase III: PLS is used to predict the results of the impact of CO on WM and the construction field.

F. Model Assessment

The internal consistency of the constructs was assessed by calculating Cronbach's Alpha (Cα). Generally, the lower threshold for acceptable reliability is 0.7, although 0.6 may also be considered sufficient for research purposes. Reliability was further evaluated through the metric of Composite Reliability (CR) measures. The CR value should ideally exceed 0.7 [20]. The model was also validated for convergent validity, which was determined by calculating the Average Variance Extracted (AVE) factor. The AVE must be greater than 0.5, and the CR must exceed 0.7 to establish reliability. Additionally, the CR value of each factor should be greater than 0.5, with 0.7 being an acceptable threshold [24]. The model was also assessed for convergent validity, which involved determining the average variance extracted. This assessment of internal consistency, composite reliability, and convergent validity is crucial for ensuring the reliability and validity of the research model and its underlying constructs [22].

IV. DATA ANALYSIS AND RESULTS

The average value of the 21 contributing factors of WM has been calculated. Based on the EFA, the key drivers of large-scale project WM were identified. The Bartlett's test of sphericity proposed a approximate chi-square of 4883.592 and Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy yielded a value of 0.971, with a significance level of 0.05 for both. The KMO value of 0.971, which exceeds 0.5, indicates that the data is suitable for the next stage of analysis [23, 25].

TABLE II. VARIABLE AND INDICATOR IN PLS-SEM

Indicator	Variable 1 (Procurement, handling, and implementation of materials)	Variable 2 (material planning)
x4.3	Unreliable equipment	-
x3.3	Field spreading errors	-
x3.4	The equipment was not working properly	-
x5.1	Lack of Effort	-
x4.5	Inadequate material management and WM management plans	-
x5.2	Hesitancy to reduce material-affected WM	-
x6.2	deviations in material cost control	-
x3.2	on-site material damage due to slow cutting of concrete	-
x4.4	Remaining material due to the cutting process	-
x5.3	Lack of knowledge about residue values, residue impacts, ways to reduce residues, and responsibility for residues	-
x4.2	Errors caused by labor	-
x2.3	Spilled on the road	-
x2.2	Damage from shipping goods to/at the project location	-
x3.1	theft (may be sold on the street)	-
x6.1	Inconsistencies in material scheduling	-
x4.1	There were cases of work accidents on this site	-
x2.1	Unable to ship orders in small quantities	-
x1.1	-	Road design drawing information is incorrect
x1.3	-	Inaccurate completeness concerning material type and material size in the tender documents,
x1.2	-	Inadequate coordination with contractors, and lacking knowledge of road construction

The overall variance accounted for is 66.387%, which is considered satisfactory as it exceeds the recommended threshold of 60% [26]. The analysis extracted six factors, which were then consolidated into two distinct factors.

- Inadequate information on road design drawings leads to WM in road construction projects, resulting in 13,050 CO.
- Inadequate coordination with contractors and insufficient understanding of road construction processes contribute to project WM of 1,305 units.

Indicator values from no. 3 to no. 21 are not able to explain the causal indicator factors for the impact of change orders on large-scale material waste.

The indicator values ranging from 3 to 21 are unable to fully explain the causal indicator factors that underlie the impact of CO on large-scale WM. The results of the transformation matrix component indicate that factor 1, which is named material procurement, handling, and execution, has a correlation value of 0.892 > 0.5. Additionally, factor 2, which refers to material planning, also has a correlation value of 0.892 > 0.5. The indicators and variables used in this research were shown in Table II. Structural models are developed to test hypotheses, which are presented in Figure 1. SEM models can be based on a comprehensive theoretical review [20]. While the commonly used rule of thumb regarding mandatory sample sizes of more than 200 is conservative and simplistic, a sample size of more than 100 is recommended [22, 27]. In the current study, the obtained sample size was 267, which exceeds the recommended minimum, providing a robust foundation for the SEM analysis [22].

As shown in Table III, the validity and reliability test results indicate that the CR is greater than 0.7, the AVE exceeds 0.5, and the Cα is greater than 0.7. Additionally, the outer loading has met the required threshold of exceeding 0.7 [20].

TABLE III. RELIABILITY AND VALIDITY OF MEASUREMENT MODEL

Indicator	Cronbach's Alpha	Composite Reliability	Average Variance Extracted
x1	0.972	0.972	0.676
x2	0.758	0.766	0.673
y1	0.852	0.867	0.783

Discriminant validity expressed in Hetero Trait-Mono Trait (HTMT), Fornel Lacker (FL) and Cross Loading (CL). The HTMT ratio analysis indicated that the level of correlations was appropriate, as the observed values were below the 0.9 threshold [26, 28]. The findings of FL's computations indicated that the construct calculations for x1, with a value of 0.822, were higher than the value of 0.632 for x1 with x2. Likewise, the value of 0.821 for x2 was greater than the 0.698 value for y1 with x2. The CL analysis revealed that the loading of construct x1.1 on factor x1 was consistently higher than its loading on factor x2 (x1.1 = 0.856, x1.1 = 0.480). Similarly, the loading of x1.10 on factor x1 (x1.10 = 0.847) exceeded its loading on factor x2 (x1.10 = 0.552), up to x1.11.

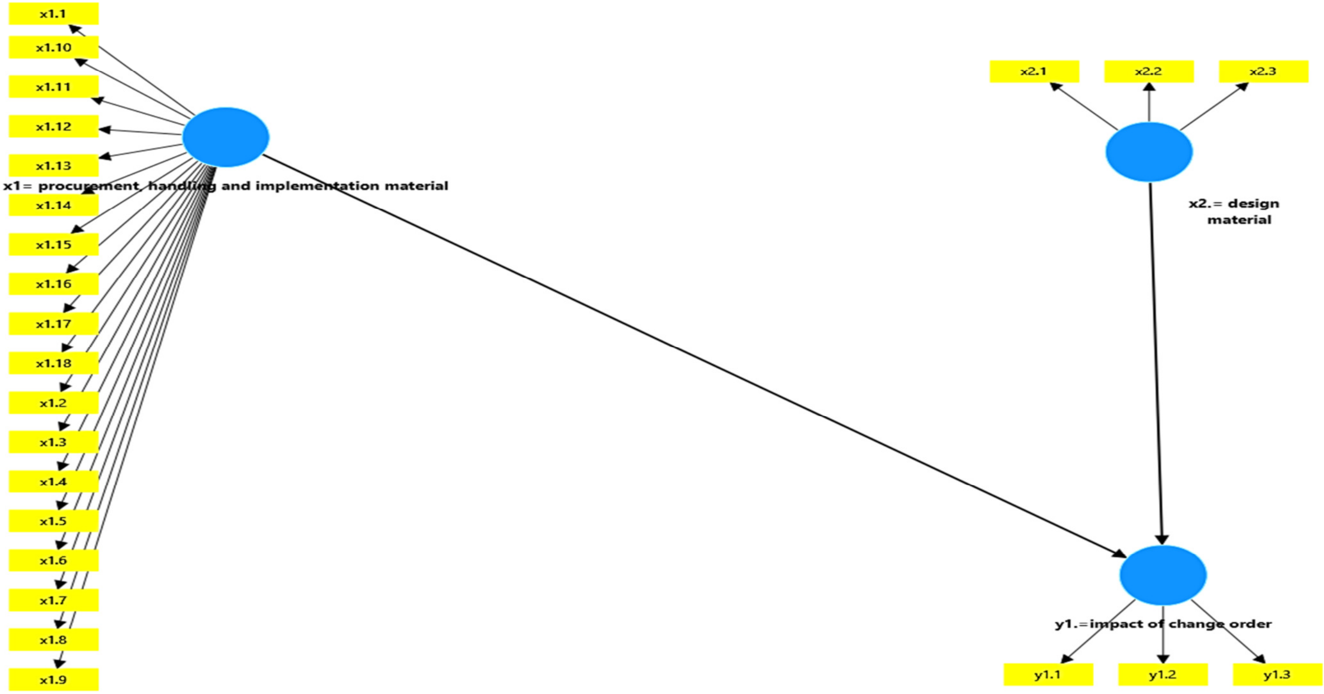

Fig. 1. Initial PLS hypothesis.

The adjusted R-squared was found to be 0.690, indicating that 69% of the variability in the dependent variable was explained by the independent variables. This suggests a strong relationship, as an R-squared value above 0.67 is generally considered strong, while 0.33 is moderate and 0.19 is weak [29, 30]. The results demonstrate the joint influence of the independent variables x, x2 on the dependent variable y1.

F-squared results implied that 2 variables were influential because the values were more than 0.02, namely, especially for x1 with an F2 value of 0.662 > 0.35 which states that variable x1 has a strong relationship with the impact of change orders, where:

The F-squared analysis suggested that two variables were impactful, as their values exceeded 0.02. Specifically, the F-squared value for variable x1 was 0.662, which is greater than 0.35, indicating that x1 has a strong association with the impact of change orders. Specifically, x1 procurement, handling, and implementation of materials receives a value of 0.663 while x2 referring to material planning was calculated to 0.212. The F-squared statistic was computed to assess the model's GF. Additionally, the variance inflation factor values were found to be less than 5, indicating the absence of multicollinearity.

The study examined several GF indices. The results indicate that the Normal Fit Index (NFI) was 0.881, which is considered desirable as it is closer to 1, suggesting the model fit is satisfactory. Additionally, the NFI was less than 1, which is the established threshold for an acceptable model. The Standardized Root Mean Square Residual (SRMS) was 0.056, which meets the criterion of being less than 0.08, indicating acceptable results [31]. The d_{ULS} value of 0.939 and the d_G value of 0.481 both exceeded the required threshold of 0.05, further supporting the conclusion that the model is acceptable based on the GF measures presented in Table IV.

TABLE IV. GOODNESS OF FIT

	Saturated Model	Estimated Model
SRMR	0.056	0.056
d_{ULS}	0.939	0.939
d_G	0.481	0.481
Chi-Square	693.643	693.643
NFI	0.881	0.881

The study employed the bootstrapping method to investigate the hypotheses, as the variables did not exhibit collinearity. The second-stage PLS-SEM calculations, specifically the bootstrapping analysis, were used to test the hypotheses involving these two variables. The first-stage PLS calculations comprised an examination of the inner and outer models, including assessments of validity, reliability, GF, discriminant validity, outer loadings, CLs, multicollinearity, and the R-squared.

The findings from hypothesis testing indicate that change orders have a significant impact on x1 and x2, with a P-value less than 0.05. The path coefficient for x1 is 0.583, which exceeds 0.5 and suggests a strong relationship between x1 and the impact of change orders. In contrast, the path coefficient for x2 is 0.33, indicating a moderate relationship between x2 and the impact of change orders. The final model is depicted in Figure 2 and summarized in Table V.

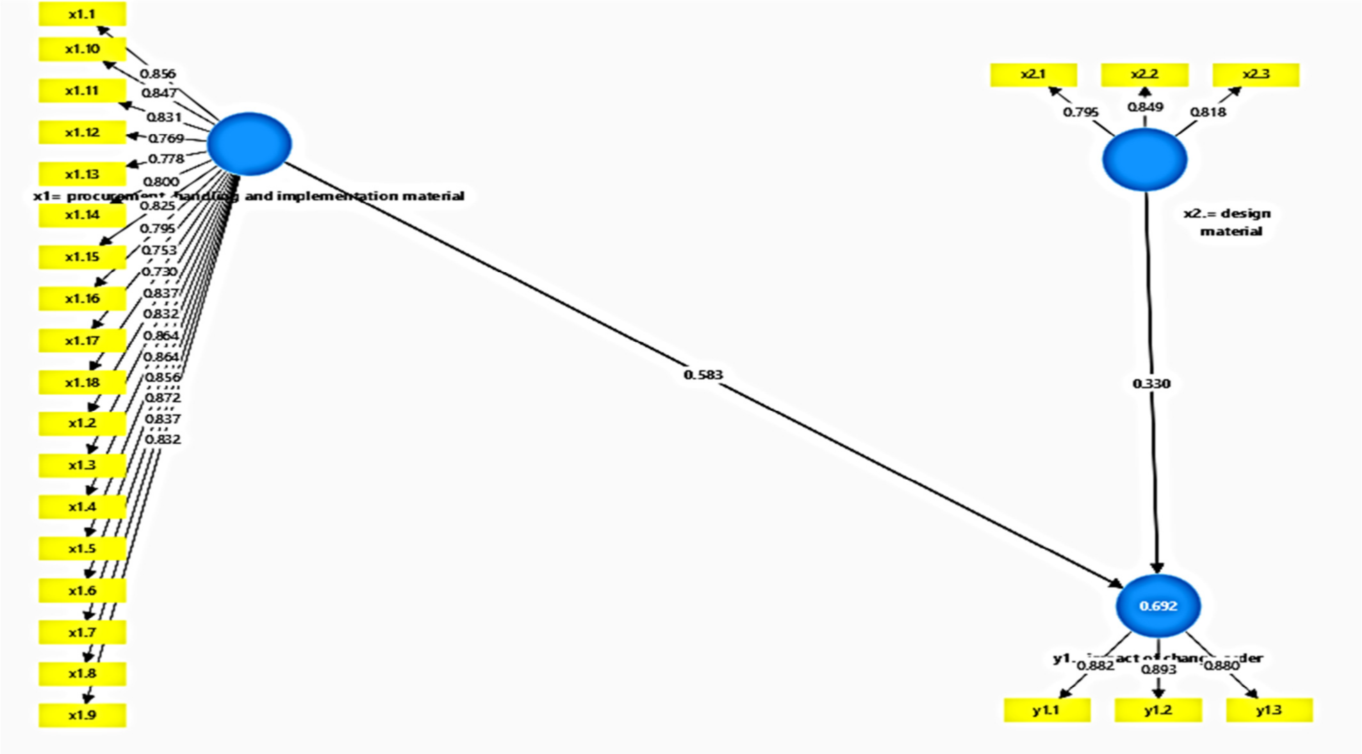

Fig. 2. The final model of PLS algorithm.

TABLE V. PATH COEFFICIENTS

	Original Sample	Standard Deviation	T statistics (O/STDEV)	P values
x1 > y1	0.583	0.060	9.718	0.000
x2 > y1	0.330	0.067	4.918	0.000

The calculation of the third stage of PLS-SEM involves the use of PLS-SEM Predict, which is employed to assess the accuracy of the CO impact model on large-scale project WM. The model accuracy level derived from the PLS-SEM Predict results is 0.677, indicating a 67.7% accuracy level for the impact of CO on WM, material handling, procurement, implementation, and material design. Additionally, the model exhibits a high level of accuracy, with Q2 values greater than 0.35, in capturing the impact of change orders on project costs, quality, and time [32]. Specifically, the impact on increasing project costs is 0.478, the impact on reducing project quality is 0.458, and the impact on extending project time is 0.633.

The PLS-SEM model's predictive performance was evaluated using the PLS Predict test, which revealed high prediction accuracy for increased project financing, reduced project quality, and extended project implementation time.

V. DISCUSSION

The optimal selection for the influence of CO on the WM of road construction projects, based on PLS-SEM highest outer loading, involves x1 choosing the seven most appropriate indicators and x2 selecting the three most relevant ones, respectively.

Deviations from effective management of material costs (x1.7) were a primary factor that impacted waste management, leading to material price increases and project delays [33]. Inadequate material and waste management plans (x1.5), particularly when incorporating user-proposed changes, resulted in WM issues in research studies [34]. This factor was also the principal cause of WM challenges in Oman. Lack of effort (x1.4) affected WM, which led to change orders for road construction projects due to poor material quality control. Equipment reliability issues (x1.1) contributed to WM in construction research studies in Oman. Hesitation in reducing materials (x1.6) impacted WM and diminished the quality of project materials [35]. Insufficient understanding of residual material value, consequences, reduction methods, and responsibility led to WM problems (x1.10). Proactive WM measures from the outset, such as preventing material accumulation, reducing debris, and minimizing interference with other tasks, were necessary. Contractors' lack of expertise in material management, consequence comprehension, and WM reduction contributed to rework that exacerbated WM in construction projects. Errors in material application (x1.2) in the field resulted in rework, COs, and WM for road construction projects. Additionally, rework was a consequence of waste in the research studies [36].

Inadequate coordination with contractors and limited knowledge of road construction (x2.3) led to CO and waste management issues in road construction projects. This factor also contributed to the lack of information in design planning, which prompted WM research [37]. The research found that the primary cause of waste was design changes in Korea. Inaccurate or incomplete information regarding material types and sizes in the tender documents (x2.2) resulted in rework and other activities that caused CO and WM in road construction projects. Additionally, rework was a consequence of waste identified in prior research [37]. Inaccurate road design drawings led to design changes (x2.1), resulting in work adjustments and the creation of CO. According to existing research, errors in design details were a primary cause of waste [3]. Furthermore, previous studies identified design changes as the main factor contributing to WM issues [9, 34].

Based on this research, the impact of CO in construction is described as follows:

1. An escalation in project expenditures stemming from the impact of CO diminished the profits of service providers and compromised the productivity of the work delivered.
2. The impact of CO adversely affected project quality, consequently reducing project productivity in a manner that was detrimental to the overall project performance.
3. Prolonged project implementation duration led to project delays, which adversely impacted the project.

VI. CONCLUSION

In conclusion, the data was processed and analyzed using PLS-SEM 4.0 application, which included 6 variables and 21 indicators. Exploratory Factor Analysis (EFA) was then conducted, grouping the indicators into 2 variables. These 2 variables were subsequently calculated using PLS-SEM 4.0 to generate the model, leading to the following conclusions.

The statistical analysis revealed that for road construction projects, the effect of Change Order (CO) on Material Waste (WM) exhibited a hierarchical pattern, with procurement, handling, and implementation of materials (x1) demonstrating a path coefficient of 0.58, followed by material design (x2) at 0.33.

CO was found to contribute significantly to waste in road construction projects, accounting for 69% of total waste. CO also had a substantial impact of 58.3% on the procurement, handling, and implementation of materials, in addition to affecting material planning by 33%. Furthermore, predictive models demonstrated an accuracy of 67.7% in forecasting the effects of CO, which included increased project costs, reduced quality, and extended implementation timelines.

The study identified the ten most important factors contributing to WM in road construction projects including deviations in material cost control, inadequate material management and WM management plans, lack of effort, unreliable equipment, hesitation in reducing material has an impact on WM, lack of knowledge about residue values, residue impacts, ways to reduce residues, and responsibility for residues, errors during the distribution of materials in the field, inadequate coordination with contractors, and lacking knowledge of road construction, inaccurate completeness concerning material type and material size in the tender documents, and road design drawing information is incorrect.

Based on these findings, the recommended approach is to concentrate more on procurement, material handling implementation, and material planning in relation to the ten key impacts of CO on WM in road construction projects. This focus will help mitigate the influence of CO on waste management in large-scale road construction initiatives.

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