Critical Success Factor Analysis of Asphalt Pavement Works of North Sumatera Province Roads in Mandailing Natal Regency

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ABSTRACT

From www.portibinews.com regarding the Audit Results Report of the North Sumatra Representative Audit Agency which was issued on May 26 2022 that the work at the North Sumatra Province Public Works and Spatial Planning Service in the 2020 budget year was Improvement of the Provincial Road Structure of the Jembatan Merah – Muarasoma Road Section in Mandailing Natal Regency there is a lack of volume and a lack of quality of work. The physical inspection of this work was carried out together with the Budget User Authority (KPA), the Activity Technical Implementation Officer (PPTK), the Supervisory Consultant, and the North Sumatra Province Inspectorate. This is the basis for this study to analyze the Critical Success Factor (CSF), identify CSFs that have a significant effect on the success of the implementation of asphalt paving work on North Sumatra Province roads in Mandailing Natal Regency and analyze the effect of CSFs on the achievement of performance indicators. The Partial Least Square - Structural Equation Modeling (PLS-SEM) analysis method is used in this study to analyze the CSF performance of the implementation of asphalt paving work on North Sumatra Province roads in Mandailing Natal Regency. This analysis method uses the help of Smart PLS software. PLS-SEM is more suitable for developing exploratory research that has limited theory development and PLS-SEM is also more suitable for use if the research data is ordinal (eg: Likert scale) and nominal and ignores normally distributed data (nonparametric). The results of the analysis show that the Critical Success Factor that has an impact on the success of the implementation of asphalt paving work on North Sumatra Province roads in Mandailing Natal Regency is the supervision factor with a value of 0.406 having the greatest impact. Other factors such as labor factors (0.281), environmental standard factors (0.228), quality test standard factors (0.214), equipment factors (0.176) have a moderate impact, while design error factors (0.109), material factors (0.088), work method factors (0.026) have a small impact. On the other hand, the factors that significantly influence the success of the implementation of asphalt paving work on North Sumatra Province roads in Mandailing Natal Regency in achieving performance indicators are the work method factor (X4), the quality test standard factor (X5), the environmental standard factor (X6), the supervision factor (X7), and the design error factor (X8). Overall, the Critical Success Factor factors for the performance of the implementation of asphalt paving work on North Sumatra Province roads in Mandailing Natal Regency influence the success in achieving performance indicators by 15.3%, while other variables outside this regression model influence the rest (100 - 15.3 = 84.7%).

Keywords: critical success factor; contractor performance; asphalt paving; PLS-SEM.

INTRODUCTION

The road network is one part of the transportation infrastructure that plays an important role in the economic, socio-cultural, environmental, political, defense and security sectors, and is used for the greatest prosperity of the people, so that the availability of roads is an absolute requirement for the development of a region. Good road handling must be in line with the implementation of a good quality management system to achieve road stability, considering that roads function to provide mobility between regions.

Quoted from www.portibinews.com regarding the Audit Results Report of the North Sumatra Representative of the Financial Audit Agency issued on May 26, 2022, that the work at the Public

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Works and Spatial Planning Service of North Sumatra Province in the 2020 budget year, namely the Improvement of the Provincial Road Structure of the Jembatan Merah - Muarasona Road Section in Mandailing Natal Regency, there was a lack of volume and lack of quality of work. The physical inspection of this work was carried out together with the Budget User Authority (KPA), Technical Implementation Officer for Activities (PPTK), Supervisory Consultant, and the North Sumatra Provincial Inspectorate.

This is the background of the research to analyze the Critical Success Factor (CSF) of the performance of the asphalt paving work implementation of North Sumatra Province roads in Mandailing Natal Regency. Many factors influence the success of project implementation such as labor factors, organizational structure, availability of materials, equipment, work methods and so on. These factors greatly influence the success of a project which is then commonly referred to as a success factor or critical success factor.

This study refers to previous research by [1], [2] on the Analysis of Critical Success Factors for the Performance of National Road Preservation Projects with the Long Segment Scheme (Case Study: National Road Preservation in the Implementation of National Roads in Region IV of North Sumatra Province). The difference between this study and previous studies is that there are different activities and research objects where previous studies used national road preservation activities with a long segment scheme in the Implementation of National Roads in Region IV of North Sumatra Province, while this study used asphalt paving work activities for North Sumatra Province roads in Mandailing Natal Regency. Then the difference in the use of samples in previous studies was 104 respondents representing 140 respondents in the Implementation of National Roads in Region IV of North Sumatra Province, while this study used 36 samples for all respondents in 1 (one) UPTD. PUPR Kotanopan PUPR Office of North Sumatra Province in Mandailing Natal Regency. Thus, the sample selected in this study is a sample that represents all populations in the North Sumatra Provincial Road Work Unit in Mandailing Natal Regency. The objectives of this study are as follows: 1) to analyze the elements of Critical Success Factor in the implementation of asphalt paving work on North Sumatra Province roads in Mandailing Natal Regency, 2) to identify Critical Success Factors that have a significant influence on the success of the implementation of asphalt paving work on North Sumatra Province roads in Mandailing Natal Regency, 3) to analyze the relationship between Critical Success Factor elements and the achievement of performance indicators for the implementation of asphalt paving work on North Sumatra Province roads in Mandailing Natal Regency.

Definition of Asphalt Pavement Work

Road construction has several types of pavement, one of which is flexible pavement. Based on [3], flexible pavement generally consists of three main layers, namely the surface course, base course, and subbase course as shown in Figure 1 below.

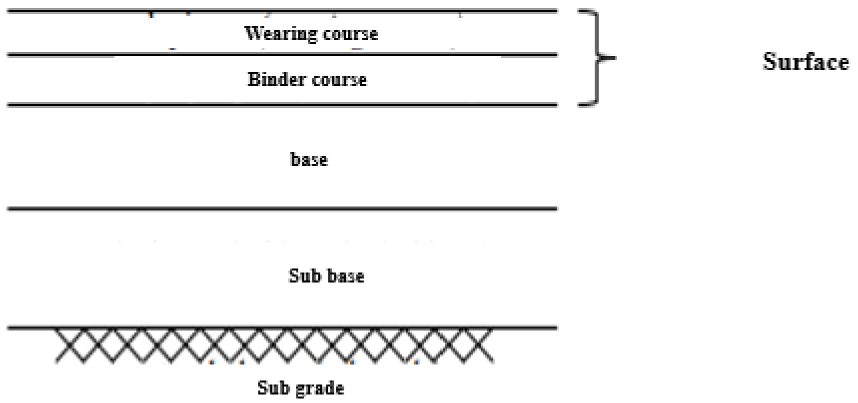

Figure 1. Flexible pavement structure [3]

Asphalt Pavement consists of 7 (seven) types of work, including Binder Absorption Layer Work, Adhesive Layer Work, Hot Asphalt Mix Work, Cold Asphalt Mix Work, Macadam Penetration Layer Work, Maintenance Work with Asphalt Coating, and Warm Asphalt Mix Work [4], [5].

Binder Absorption Layer Work (Prime Coat)

Prime Coat is part of the flexible pavement structure which functions as a cover for the base layer cavity. Prime Coat has no structural value, but it functions as structural resistance and strength, which is mainly in resisting lateral forces. Failure of the road pavement structure caused by improper determination of the quantity of prime coat such as slip cracks caused by the lack of prime coat function.

Tack Coat Work

According to [6], Tack Coat is a thin layer of asphalt that provides adhesion and strength between the old pavement layer and the new pavement layer, functions to provide binding power between the old and new layers, and is installed on a dry and clean asphalt surface.

Figure 2. Prime Coat and Tack Coat [4]

Hot Asphalt Mix Work

Hot asphalt mix is a flexible road pavement mixture consisting of material parts in the form of asphalt binder, fine aggregate, coarse aggregate, and filler with a certain ratio when hot.

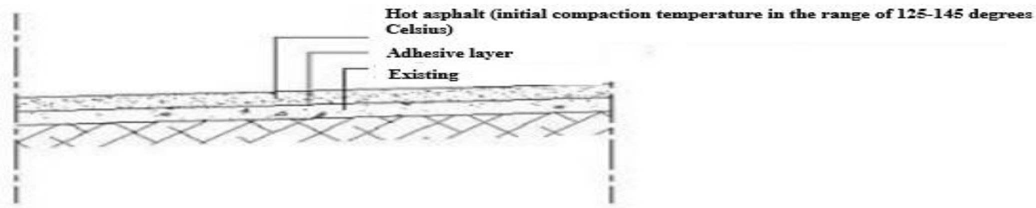

Figure 3. Hot Asphalt Mix [4]

Cold Asphalt Mix Work

Muna Muthia stated that cold asphalt mix is a flexible pavement material where asphalt and aggregate are mixed when cold and do not require heating. The advantages of this mixture are to save heating costs, easy implementation and environmentally friendly, providing added value during asphalt road construction work. In terms of savings, this work is more efficient than hot asphalt mix [7].

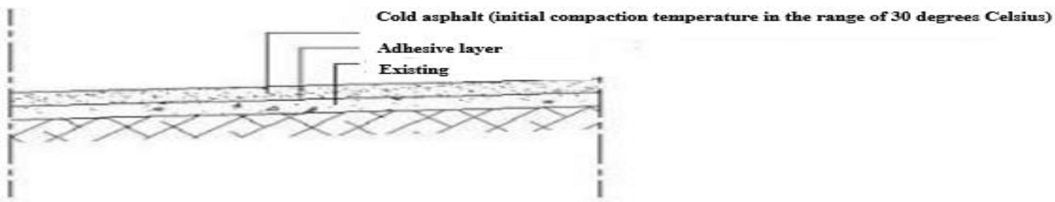

Figure 4. Cold Asphalt Mix [4]

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Macadam Penetration Layer Work

According to Kholidia Ayunaning, macadam penetration layer is a pavement in the form of main aggregate and locking aggregate that has an open and uniform gradation, asphalt is bound by spraying on top and compacted layer by layer, when it will be used as a surface layer, it needs to be coated with asphalt with a cover stone. How to use macadam penetration layer can be placed on various conditions or types of pavement, both new pavement and old pavement, can function as a foundation layer and surface layer with light or medium traffic levels. Macadam penetration layer has moderate permeability, and has a rough surface [8].

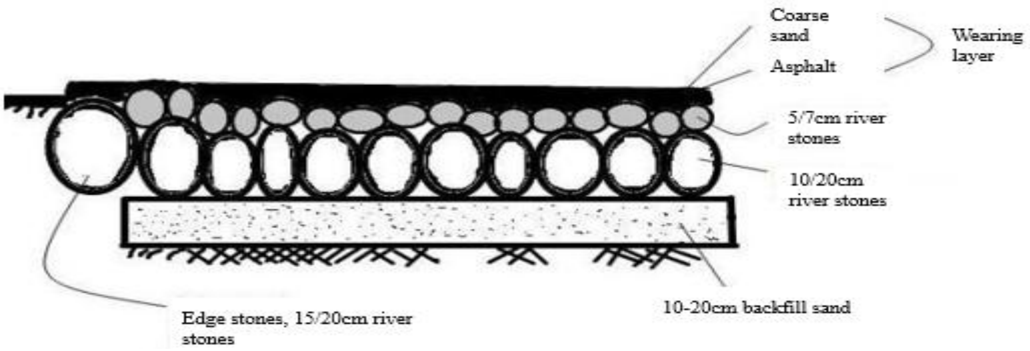

Figure 5. Macadam Penetration Layer [4]

Maintenance Work with Asphalt Coating

According to [4], this work includes the implementation of asphalt coating work which can consist of one or two layers of asphalt coating, each layer is given an asphalt binder and then covered with aggregate granules. This asphalt coating is generally spread over a Class A Aggregate Foundation Layer that has been given a Binder Absorption Layer or an Asphalt Foundation Layer, or over an existing asphalt surface for maintenance.

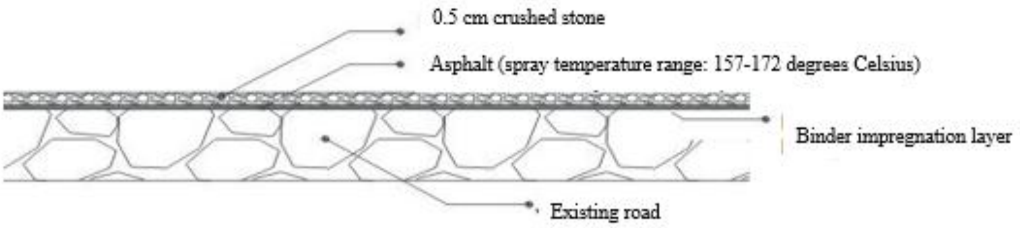

Figure 6. Maintenance with Asphalt Coating (Source: General Specification of Bina Marga, 2018)

Warm Asphalt Mix Work

Warm asphalt mix with low temperature can result in significant savings in fuel usage. The method used is warm mix asphalt where the temperature used is lower than hot asphalt mix around 130 degrees Celsius.

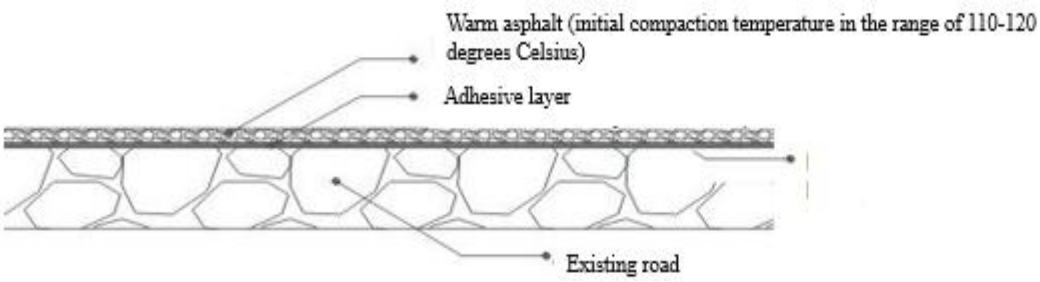

Figure 7. Warm Asphalt Mix [4], [17]

Project Performance

Project performance can be measured and evaluated using a number of performance indicators that can be linked to various dimensions (groups) such as time cost, quality, client satisfaction, client change, business performance, health and safety [9], [18]. Furthermore, time, cost, and quality are the three main dimensions in performance evaluation in the construction industry known as the iron triangle.

Project cost performance is used to indicate whether the project is in accordance with the agreed budget. This is important because resources are often limited and cost overruns must be avoided. Then the project time performance is an assessment of how well the project adheres to the planned schedule over a certain period of time. Therefore, the project time or schedule performance is calculated as a percentage between the actual completion time and the planned completion time. Projects with a delay percentage below 10% are considered extraordinary in terms of time or schedule performance, those between 10% to 20% are considered average projects while those above 20% are considered poor projects [10], [11].

Identification of labor factors

Human resources have two meanings: (1) work effort or services that can be provided in the production process. In other words, human resources reflect the quality of effort given by a person in a certain time to produce goods and services; (2) Human resources concerning humans who are able to work means being able to carry out activities that have economic activities, namely that these activities produce goods or services to meet the needs or the community [11]. Planning regarding field workers aims to make road construction work run more effectively and efficiently. Regarding the preparation of performance indicators for the implementation of national road handling activities, it states that field labor factors that have the potential to influence the achievement of road project quality are divided into 11 (eleven) indicators, namely: (1) Number of workers; (2) Workforce skills certificates; (3) Work experience; (4) Placement of workers; (5) Workforce attitudes towards repairs; (6) Understanding of material and equipment technology; (7) Workforce attitudes towards quality standards; (8) Workforce productivity; (9) Workforce age; (10) Cooperation between workers and (11) Workforce attitudes towards K3 provisions. These eleven indicators are the basis for determining the indicators in this study, in addition to the researcher's experience while working in the field [12], [19].

Critical Success Factor

Critical Success Factors (CSFs) are important factors that can ensure that a business can grow and successfully run according to expectations, CSFs are elements needed for an organization or project to meet its targets and objectives. The CSF methodology is a procedure for clarifying several key areas that determine managerial success. This method has been used as a management step since the 1970s in various fields such as financial services, information systems, and manufacturing industries [13].

The Critical Success Factor for each project in various countries will differ from other countries depending on the work environment, policies, and legal frameworks of each. In addition, CSFs will develop along with changes in the environment, the company's position in an industry, or when certain challenges or opportunities arise for the industry [14]-[16].

The differences between Key Performance Indicators (KPIs) and Critical Success Factors (CSFs) include the following:

Furthermore, the differences between Critical Success Factors and Key Performance Indicators can be simplified in Table 1 below.

Table 1. Differences between CSFs and KPIs

Differences	Critical Success Factor	Key Performance Indicator
Answering questions	What must be done to achieve success?	Have the activities been successful?

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Differences	Critical Success Factor	Key Performance Indicator
Main purpose	Determining the requirements for achieving success	Shows what has been done
Type of measurement	Qualitative	Quantitative
Dependence	Can stand alone	Depends on a benchmark

RESEARCH METHODOLOGY

Research Location

The research was conducted on the road section of North Sumatra Province located in Mandailing Natal Regency which can be seen in Figure 2 below.

Figure 8. Research location (Source: PUPR Office of North Sumatra Province)

At the Public Works and Spatial Planning Office of North Sumatra Province, UPTD. Kotanopan In 2024 there are 2 (two) asphalt paving work packages, namely:

1. Improvement of the Provincial Road Structure on the Jembatan Merah - Muarasoma section in Mandailing Natal Regency along 2.0 km.
2. Improvement of the Provincial Road Structure on the Muarasoma - Sp. Gambir section in Mandailing Natal Regency along 1.5 km.

Scope and Stages of Research

The steps of this research are shown in the Research Flow Diagram in Figure 9 below.

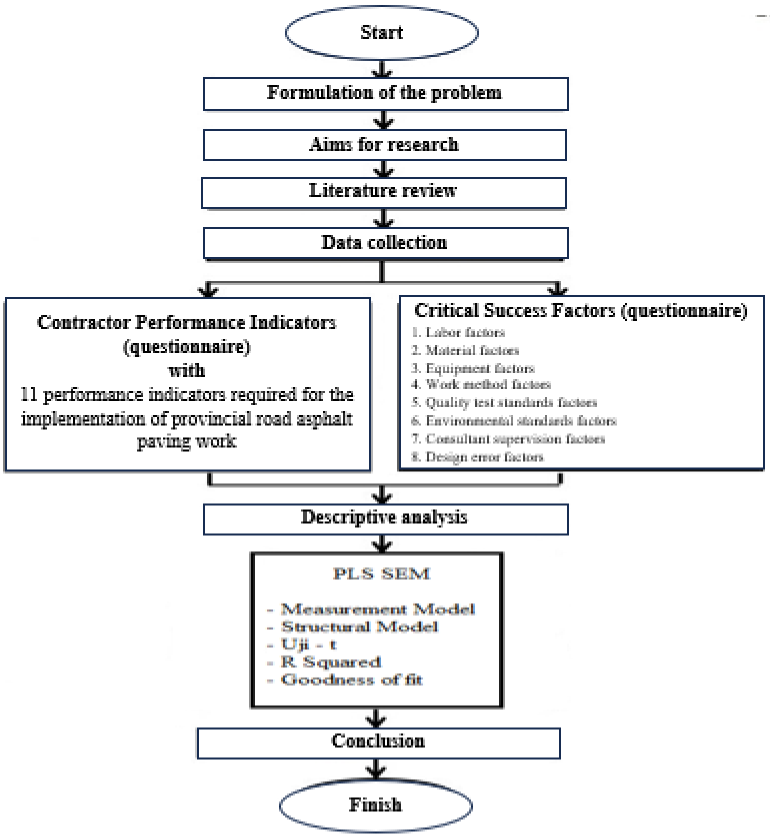

Figure 9. Research Flowchart

PLS-SEM

PLS-SEM (Partial Least Square SEM) is an SEM method that has the objective of maximizing variance in explaining dependent variables. The PLS-SEM model consists of two elements, namely a structural model that connects the correlation between latent variables and a measurement model that displays the relationship between construct variables and their indicators. In achieving prediction goals, PLS-SEM estimates the coefficients (correlations between variables) to maximize the R-Square of the endogenous variable construct.

With this feature, PLS-SEM tends to be preferred for theory development. Specifically, the logic of the PLS-SEM approach is that all indicator variances should be used to estimate model relationships, with a particular focus on predicting dependent variables. PLS-SEM tends to be more suitable for developing exploratory research that has limited theory development. PLS-SEM is also more appropriate if the research data is in ordinal (eg: Likert scale) and nominal [1].

PLS-SEM analysis with SMARTPLS

PLS-SEM analysis was carried out with the help of the SMARTPLS program version 4.1.0.9. The stages of PLS-SEM analysis with the SMARTPLS program are as follows:

1. Create a new worksheet (new project).
2. Import data, at this stage the data to be analyzed is imported with csv, txt, and other supporting data formats. An example of the display of the input data interface that has been imported into SMARTPLS.
3. Forming a latent variable structure, at this stage the latent variable is formed by inputting indicators according to the variable group. The display of latent variables in SMARTPLS can be seen in Figure 10 below.

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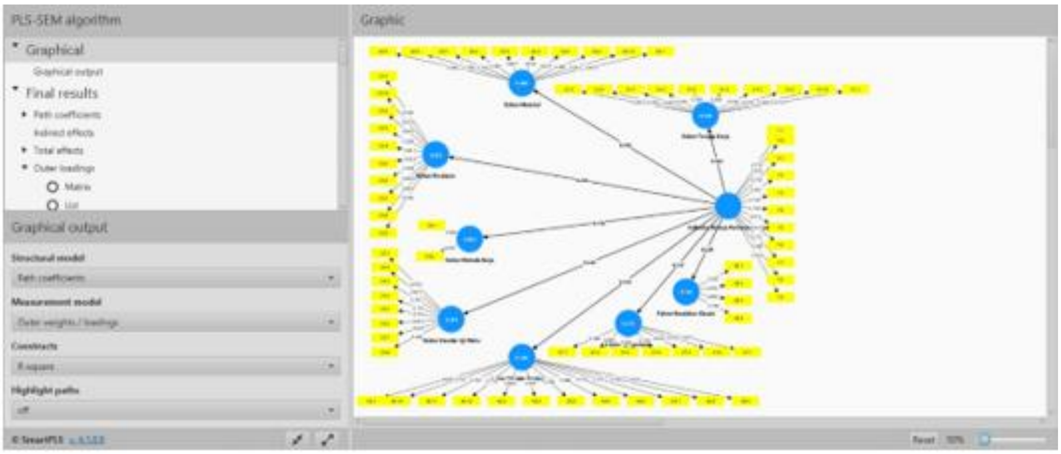

Figure 10. Latent variable display in SMARTPLS

Connecting between latent variables, this stage is based on the model framework (Inner Structural Model) that has been created. Each variable has a relationship with its variables based on the arrow line. A variable is considered an independent variable when the arrow line moves away from the variable, on the other hand, a variable is considered a dependent variable when the arrow line approaches the variable. The relationship diagram between variables can be seen in Figure 11 below.

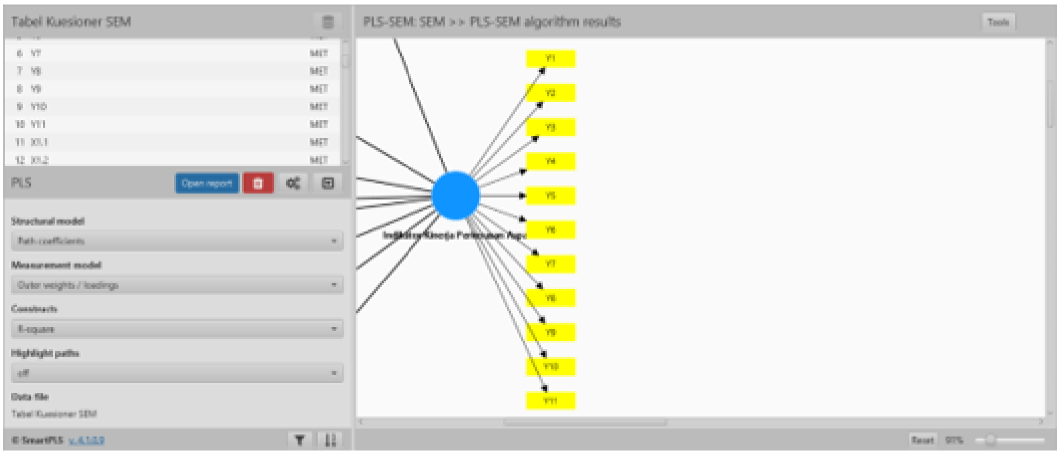

Figure 11. Relationship between variables

PLS-SEM Model Testing

Model testing consists of PLS-SEM variable testing and PLS SEM model quality testing.

Table 2. Variable testing in the PLS-SEM model

Model		Types of testing	Parameter	Value	Interpretation
		Reliability Indicator	Loading Factor	≥0.7	Reliable
Outer Model	Measurement	Reliability Construct	Cronbarch's Alpha	≥0.6	Reliable
			Composite Reability	≥0.7	Reliable
		Validity Convergent	Average Variance Extracted	≥0.5	Valid

Model		Types of testing	Parameter	Value	Interpretation
Inner Model	Structural	Validity Discriminant	Fornell-Larcker Criterion	≥0.7	Valid
		Path coefficient	β-value	Worth positive	Correlation Positive
				Worth negative	Correlation Negative
		Significance test (t-test)	p-value	≤0.05	Significant
		Effect Size Test	f-square	≥0.02	Small
				≥0.15	Medium
				≥0.35	Large

RESULTS AND DISCUSSION

Respondent Overview

A questionnaire survey was conducted on road organizers involved in the implementation of North Sumatra provincial road works in Mandailing Natal Regency. The road organizers are UPTD PUPR Kotanopan, Public Works and Spatial Planning Agency of North Sumatra Province, Supervisory Consultant, and Implementing Contractor. Each respondent who fills out the questionnaire is required to be able to represent the agency and company that oversees it.

PLS-SEM Analysis

PLS-SEM data analysis was carried out using the SMARTPLS program version 4.1.0.9. In general, PLS-SEM analysis is carried out in two stages: the outer measurement model and the inner structural model (Hussain et al., 2018).

Outer Measurement Model

The indicator reliability test is carried out to describe its latent variables in the form of standardized loading factors (0 to 1) in accordance with the previous chapter. Indicators that have a loading factor value greater than 0.7 will be accepted while indicators with a value less than 0.7 will be eliminated. The indicators that form the latent variables of this study have been summarized in the PLS-SEM Multivariate Analysis table.

Multivariate PLS-SEM analysis aims to identify exogenous variables that have a significant effect on endogenous variables and the magnitude of their influence. The influence of exogenous variables on endogenous variables will be measured based on the path coefficient value of the significance test (t-test) and the effect size test (f-square). Exogenous variables are variables that have an influence on other variables while endogenous variables are variables that are influenced by other variables.

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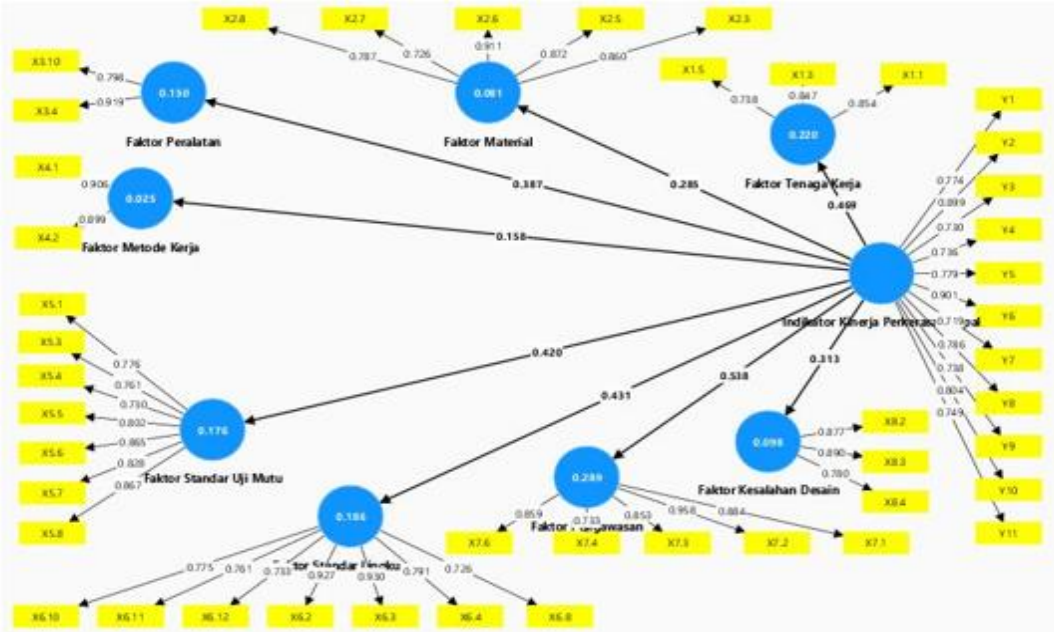

Figure 12. Structural Image of PLS-SEM Model

Figure 12 explains the correlation structure of the two main PLS-SEM models, namely the outer measurement model and the inner structural model. The outer measurement model is the correlation between the construct indicator and the latent variable. The value between the indicator and the latent variable is the loading factor value. Furthermore, the inner structural model is the relationship between the latent variables. The value between the latent variables is the coefficient value of the variable.

Table 3. Significance Test

No	Variables	T-statistics	P-values	Description
1.	Labor factor (x1)	1.643	0.100	Not significant
2.	Material factor (x2)	1.540	0.124	Not significant
3.	Equipment factor (x3)	0.838	0.402	Not significant
4.	Work method factor (x4)	3.423	0.001	Significant
5.	Quality test standard factor (x5)	2.010	0.044	Significant
6.	Environmental standard factor (x6)	3.443	0.001	Significant
7.	Supervision factor (x7)	3.418	0.001	Significant
8.	Design error factor (x8)	3.850	0.001	Significant

(Source: Researcher Processing with SmartPLS 4 Application, 2024)

To determine the significance of the influence of independent variables on the dependent variable, a significance test is carried out. The results of the hypothesis significance test can be seen in Table 4 below. The variables said to have a significant effect on the dependent variable are the work method factor (X4), the quality test standard factor (X5), the environmental standard factor (X6), the supervision factor (X7), and the design error factor (X8).

Table 4. F-Square Value

No	Variables	F-Square	Keterangan
1.	Labor factor (x1)	0.281	Medium effect
2.	Material factor (x2)	0.088	Small effect
3.	Equipment factor (x3)	0.176	Medium effect
4.	Work method factor (x4)	0.026	Small effect

No	Variables	F-Square	Keterangan
5.	Quality test standard factor (x5)	0.214	Medium effect
6.	Environmental standard factor (x6)	0.228	Medium effect
7.	Supervision factor (x7)	0.496	High effect
8.	Design error factor (x8)	0.109	Small effect

F-square value cut off: ≥0.02 (small), ≥0.15 (medium), and ≥0.35 (high)

The dependent variable is then represented by the level of influence on the dependent variable in the weak to strong category using the F-Square value according to the explanation in the previous chapter. Table 4.7 explains that the highest F-Square value is found in the monitoring factor variable (X7) with a high effect category while other variables have a medium effect category and a low effect category.

PLS-SEM Model Testing

PLS-SEM model testing will be carried out by measuring both the outer measurement model and the inner structural model as a whole in the form of a goodness of fit index. The Goodness of Fit Index test is obtained from the square root of the average R2 value (R-Square) with the average communality (average AVE value).

Table 5. Model determination coefficient

No	Variable	R-Square	R-Square adjusted
1.	Achievement of indicators for the implementation of asphalt paving work on provincial roads	0.153	0.128

Based on table 5, the coefficient of determination of the model in explaining the dependent variable is 0.153 or 15.3%. This figure means that the elements of the critical success factor of the performance of the asphalt paving work of the North Sumatra provincial road in Mandailing Natal Regency have an effect on the success in achieving performance indicators of 15.3% while the rest (100 - 15.3 = 84.7%) is influenced by other variables outside this regression model.

Table 6. Goodness of Fit Index

No	Variables	Average variance extracted	R-Square (R2)
1.	Design error factors	0.723	
2.	Material factors	0.696	
3.	Work method factors	0.815	
4.	Supervision factors	0.740	
5.	Equipment factors	0.741	
6.	Environmental standard factors	0.656	
7.	Quality test standard factors	0.649	
8.	Labor factors	0.664	
9.	Indicators of asphalt paving work implementation for provincial roads	0.617	0.153
10.	Average values	0.700	0.153
11.	Average R2 x Average communality	0.107	
12.	GOF*	**0.327**	

*GoF Value Cut-off: ≥0.1 (small), ≥0.25 (medium), and ≥0.36 (large)

Table 6 shows the results of the Goodness of Fit Index test. The Goodness of Fit Index value is obtained using the following equation:

$$GoF = \sqrt{\text{Average } R^2 \text{ x Average Communality}}$$

$$GoF = \sqrt{0.153 \times 0.700}$$

$$GoF = 0.327$$

Where:
- GoF : Goodness of Fit
- Average R^2 : Coefficient of Determination
- Average Communality : Average AVE value

From this equation, the Goodness of Fit Index model value is 0.327 with a medium value category (≥0.25). The Goodness of Fit Index value then becomes a representation of the research measurement that the model has a model fit that is quite adequate in explaining or predicting the correlation of research data.

Discussion

Critical Success Factors that significantly influence project success, the first is the work method factor (X4). This result is different from previous studies that identified skilled and experienced workers as significantly influencing project success. Furthermore, the supervision factor (X7) also has a significant impact on project success. This is also different from the research conducted by Marpaung where quality test standards have the greatest impact on project success. With good supervision, it will be able to improve the performance of the implementation of asphalt paving work on the North Sumatra provincial road in Mandailing Natal Regency [1].

CONCLUSION

Based on the results of data analysis on the Critical Success Factor of the performance of the asphalt paving work implementation of the North Sumatra provincial road in Mandailing Natal district, the conclusions of this study are: 1) the factors that are Critical Success Factors in the implementation of asphalt paving work on provincial roads and have an impact (size effect) on the success of the implementation of asphalt paving work on provincial roads in Mandailing Natal district are the supervision factor with a value of 0.406 having the greatest impact. Other factors such as labor factors (0.281), environmental standard factors (0.228), quality test standard factors (0.214), equipment factors (0.176) have a moderate impact, while design error factors (0.109), material factors (0.088), work method factors (0.026) have a small impact, 2) based on the results of the PLS-SEM multivariate analysis, the Critical Success Factors that have a significant influence on the success of the implementation of asphalt paving work on provincial roads in Mandailing Natal Regency are the work method factor (X4), quality test standard factor (X5), environmental standard factor (X6), supervision factor (X7), and design error factor (X8). Working methods and quality tests that are in accordance with procedures without any design errors and pay attention to environmental standards and good supervision will be able to improve the performance of the implementation of asphalt paving work on North Sumatra provincial roads in Mandailing Natal Regency, 3) Overall, the elements of the Critical Success Factor for the performance of asphalt paving work on North Sumatra provincial roads in Mandailing Natal Regency have an effect on the success in achieving performance indicators of 15.3%, while the rest (100 - 15.3 = 84.7%) is influenced by other variables outside this regression model.

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