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An Analysis of the Influences Contributing to Project Delays, Design Modifications, and Rework in Interdisciplinary Infrastructure Development in South Africa

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Abstract: Delays, reworks, and repeated revisions continue to hinder progress in South Africa's construction industry, despite ongoing efforts to improve project delivery. This study set out to explore the root causes of these recurring issues by reviewing existing literature and surveying 43 professionals working within the sector. By analyzing the collected data through stepwise multiple regression, t-tests, and the relative importance index, the research identified change-related and approval-related challenges as the most significant contributors to these setbacks. The findings also point to deeper systemic issues, including weak change management practices, inadequate design coordination tools, limited technological integration, and unclear project scopes—all of which are closely tied to the inefficiencies still troubling the industry.

Keywords: *Scope definition, Change Management, Approval, Delay, Rework, Revision.*

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I. INTRODUCTION

Multidisciplinary design encompasses a continuum of problem-solving tasks executed by professionals from many disciplines, aiming to meet clients' needs within assigned time and budget constraints. As construction projects continue to get more complex, multidisciplinary design can help mitigate the challenges. Yet this mustered a series of workman-like design efforts across numerous disciplines that will be inherently iterative and slow-burning; leading to long lead times, higher costs and less-than-optimal end results. When you have professionals with varying levels of expertise and experience, the process becomes even more complicated, making it essential to identify, manage, and resolve emerging issues effectively to minimize revisions, rework, and delays.

The multidisciplinary concept is still new and not all the multidisciplinary design projects progress smoothly which usually leads to backtracking. Yang and Wei (2010) pinpointed the major causes of these problems such as design changes, low labor productivity, poor planning, owner or designer mistakes, intervention by an external regulatory body, and force majeure. In construction projects, disputes, and claims often arise from time and cost overruns due to delays, rework, and revisions. Taking a coordinated plan — an effort to prevent these dynamics from developing — can greatly decrease project interruptions and improve overall efficiency.

Given this context, this study aims to identify the common factors contributing to delays, revisions, and rework in South African multidisciplinary design projects. Furthermore, it seeks to propose an effective mitigation plan to enhance design efficiency and minimize project disruptions.

A. State of the South African industry

In South Africa, like in many developing nations, solving complex multidisciplinary design problems often depends on ad hoc strategies formed from dominant voices rather than well-calibrated balance of perspectives. The current design practice accepts the strongest point of view instead of combining input from several disciplines, which would not do justice to a multidisciplinary problem (Shakeri and Brown, n.d.). Sequential design is another popular

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approach used to tackle complexity in South African multidisciplinary projects.

Where different disciplines participate in the design process one after another, sharing information only at interface points. This approach fails to identify conflicts between disciplines early on, leading to delayed conflict resolution, increased rework, and significant project delays (Shakeri and Brown, n.d.).

How design organizations align their workflows and project management strategies can impact how these multidisciplinary teams perform. It further defines the general character of the design firms that choose to operate in a given place. South Africa's engineering profession has continued to decline of technical staff (Lawless, 2007). So only two people in 100,000 in the population are civil engineering professionals (electrical engineering didn't fare much better: same patterns across the country). The shortage of qualified personnel has led to gaps in infrastructure and common problems of rework, revisions and delays (Lawless, 2007). In light of this acute shortage of technical talent, it is more important than ever for the South African sector to avoid time-consuming rework, rethink and rehash.

Design projects in South Africa employ traditional project planning tools like the Graphical Evaluation and Review Technique (GERT), Project Evaluation and Review Technique (PERT), and Critical Path Method (CPM). But these tools are really meant to assess the effect For instance, a typical interdisciplinary design project in South Africa is multi-disciplinary and cross-company where professionals from different design fields form a design team together either within the same firm or across firms. And these teams are formed to try to deliver a specific project in a time and a budget, frequently without a well defined way to define the requirements and to validate the design goals against these requirements. An assigned project manager or lead engineer generally does this oversight.

Marquardt and Nagl (2004) research reveals that South Africa's creative design processes stay poorly understood because appropriate documentation for design procedures and results does not exist. Without systematic documentation the design industry faces difficulties when reengineering processes and improving continuously because it cannot easily reuse past solutions and experiences which leads to increased inefficiencies.

B. The objectives of this paper include:

This study explores the main drivers behind design delays, revisions, and rework in multidisciplinary infrastructure projects across South Africa. It aims to uncover essential project characteristics that influence design outcomes and examines the frequency and impact of key performance indicators in the design phase. Based on the findings, the paper proposes practical strategies to help reduce unnecessary revisions, prevent delays, and limit the need for rework—ultimately aiming to improve the overall efficiency of design processes in the South African construction industry.

C. The Paper Thus Answers the Following Questions

➢ *By what Features can we Define Multidisciplinary design Projects?*

- Which factors lead to revision and rework as well as delays in South African multidisciplinary design projects?
- What strategies can effectively prevent design revisions and minimize project delays and rework?

II. THEORETICAL FRAMEWORK

Several researchers have explored the most significant factors contributing to delays, rework, and revisions in multidisciplinary projects (Odeh & Battaineh, 2002; Toor & Ogunlana, 2008; Palaneeswaran, 2006; Love et al., 1999; Rounce, 1998; Taher & Pandey, 2013; Ramanathan et al., 2012). These studies have categorized the root causes of these inefficiencies into four main groups: Client-related, Consultant-related, Contractor-related, and External factors. The findings were derived from an extensive review of existing literature, evaluations of past and ongoing projects, and discussions and interviews with industry professionals.

Building upon this foundation, the present study selected 20 key causes of delays, rework, and revisions for further investigation. These factors were examined through questionnaire surveys and statistical analysis to determine their impact on project performance. The analysis of survey responses identified the top three contributors to project inefficiencies: drawing revisions, approval delays, and scope changes. To quantify and rank the significance of each identified cause, the study employed the Relative Importance Index (RII) equation.

This theoretical framework serves as the foundation for understanding the underlying causes of project delays and inefficiencies, providing a structured approach for further analysis and mitigation strategies in multidisciplinary design projects.

➢ *The Relative Importance Index (RII) value is Calculated using the Formula*

$$RII = \frac{Er}{A\,x\,N}\ (0 \leq \text{RII} \leq 1)$$

In this analysis, **E** represents the response categories for assessing the frequency of causes related to delays, rework, and revisions. These categories are as follows:

- 5 (Very Often)
- 4 (Often)
- 3 (Average)
- 2 (Sometimes)
- 1 (Never)

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➢ *Similarly, **E** is Also Used to Assess the level of Adequacy Regarding Project Characteristics, Where:*

- 5 (Most Adequate)
- 4 (Very Adequate)
- 3 (Adequate)
- 2 (Somewhat Adequate)
- 1 (Not Adequate)

The variable **R** indicates the rating assigned to each response (5, 4, 3, 2, or 1). The highest possible weight, denoted as **A**, is 5, and **N** refers to the total number of respondents surveyed (Chan and Kumaraswamy, 1997).

After calculation, the cause of delay, rework and revision with the highest index value is ranked the most important cause of delay, rework and revision, while the smallest index value arrived at is ranked the least important for each group.

The Cronbach's α (alpha) is a favorite method for establishing the coefficient of internal consistency (Cronbach, 1951). It is commonly used as an estimate of the reliability for a sample of examinees (Santos and Reynaldo, 1999). Gliem and Gliem, (2003) noted that it is important to calculate and report the Cronbach's alpha coefficient for internal consistency reliability when using scales such as the Likert-type scale. This study uses the Cronbach's α Alpha coefficient to show the reliability of the sample examined.

Cronbach's Alpha ranges between 0 and 1 and is used to describe how consistently a set of items measures a construct, especially in rating scales with multiple points, such as from 1 (poor) to 5. In general, the higher the Cronbach's Alpha score, the more reliable the scale is considered to be (Santos and Reynaldo, 1999).

➢ *According to Cronbach (1951), the Values of Alpha (α) Indicate Different Levels of Internal Consistency:*

- **α < 0.5**: Poor reliability
- **0.5 < α ≤ 0.7**: Sufficient reliability
- **α > 0.7**: Good reliability

In simpler terms, Cronbach's Alpha is a measure of how consistently the items on a scale or questionnaire are measuring the same thing.

Cronbach's can be defined as

$$\alpha = \frac{K\bar{c}}{(\bar{v} + (K-1)\bar{c})}$$

Where K is the number of variables, $\bar{v}$ is the average variance of each component (item), and $\bar{c}$ stands for the average covariance between the different items, calculated across the current sample—excluding the variance of each item itself. (http://en.wikipedia.org/wiki/Cronbach%27s_alpha...).

In this context, the **number of variables** refers to the factors being analyzed. The **average variance** of each component (or item) is a measure of how much the individual components differ from the mean, and the **average of all covariances** between the components reflects the overall relationship between the components, excluding their individual variances (source: Wikipedia on Cronbach's Alpha).

The mean is a widely used technique for determining the average of a data set consisting of two or more values. In this case, the mean formula was applied to determine the average value for each cause of delay, rework, and revision listed in the questionnaire. The relationship between the rankings of these variables is confirmed through their respective mean values.

Formula for calculating the mean

$$= (x) = \frac{\sum(Frequency \times data\ value)}{number\ of\ data\ value}$$

The Pearson correlation coefficient is a statistical tool used to assess the strength and direction of the linear relationship between two variables in a given sample. The resultant sample correlation coefficient can be used to estimate the correlation for the total population. This study uses the Pearson correlation coefficient to show the relationships between the variables in the sample

The Pearson correlation coefficient, commonly represented by **"r"**, is used to measure the strength and direction of a linear relationship between two variables in a sample. The formula for calculating **r** is given by:

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{\left[n\sum x^2 - (\sum x)^2\right]\left[n\sum y^2 - (\sum y)^2\right]}}$$

➢ *Where,*

- **r** – Pearson correlation coefficient
- **x** – Observations from the first variable
- **y** – Observations from the second variable
- **n** – Number of paired data points

The Pearson correlation coefficient ranges between -1 and +1, with -1 indicating a perfect negative linear relationship, +1 representing a perfect positive linear relationship, and 0 denoting the absence of any linear correlation (Assaf et al., 1995).

To analyze the data, a one-sample t-test was conducted using SPSS (Statistical Package for the Social Sciences). This test was used to compare respondents' estimates of the causes of delays, rework, and revisions, helping to determine whether there were any significant differences between the mean values. The test was appropriate as the variables followed a continuous distribution and were measured using an ordinal scale.

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III. RESEARCH METHODOLOGY

This study utilized self-administered questionnaires due to their convenience in distribution and response collection. The questionnaires were sent via email, postal mail, or delivered in person, allowing respondents the flexibility to complete them at their convenience without external pressure. This approach helped minimize potential bias, which can sometimes arise in face-to-face interviews where the interviewer may unintentionally influence responses. By eliminating such influence, the validity and consistency of the collected data were enhanced.

A thorough literature review was carried out to gather relevant insights into the factors contributing to delays, rework, and revisions in multidisciplinary design projects. Additionally, a small-scale, semi-structured interview was carried out with industry experts to further identify key causes of these project inefficiencies. The findings from both the literature review and expert interviews informed us of the development of the questionnaire used in the survey.

The target respondents for this study included engineers, design managers, project managers, and architects involved in multidisciplinary design projects across South Africa.

The investigation focused on Gauteng, as it houses approximately 70% of the country's design and construction firm headquarters. The study involved the distribution of 70 questionnaires to professionals in the field, yielding 50 responses, ensuing in a response rate of 71%. However, only 43 of these responses were fully completed and deemed valid for analysis. Among the respondents, 37% were project managers, 33% were civil engineers, 12% were mechanical engineers, while architects and electrical engineers each accounted for 2%.

➢ *To Analyze the Collected data, a Combination of five Statistical Methods was Employed:*

- **Cronbach's Alpha Coefficient** – To check the dependability of the results and internal consistency of the questionnaire.
- **Mean Analysis** – to ascertain the average significance of different factors.
- **Relative Importance Index (RII)** – to rank the identified causes based on their impact.
- **One-Sample t-Test** – to evaluate the statistical significance of the findings.
- **Pearson Correlation Coefficient** – to assess the relationship between different variables affecting project performance.

This multi-method approach ensured a comprehensive and reliable analysis of the factors influencing delays, rework, and revisions in South African multidisciplinary design projects.

➢ *Consistency of the Result*

Before diving into a detailed analysis of the study's constructs, it was essential to first check how reliable the data was. This was done using Cronbach's alpha, a measure that shows how consistently a group of items or questions captures a particular concept. A value above 0.7 is generally seen as a sign of good reliability (Cronbach, 1951).

Table 1 gives an overview of the descriptive statistics and reliability scores for the key constructs used in the study. The constructs examined include factors contributing to delays, rework, and revisions, project characteristics, and key design performance indicators.

Table 1 Descriptive Statistics for Research Constructs

Constructs	No of Items	Mean	SD	Cronbach's alpha	Reliability Assessment
Causes of delay, rework and revisions	20	57.98	11.29	0.87	Good
Project Characteristics	11	31.90	6.89	0.89	Good
Key design performance indicators	08	26.51	6.62	0.90	Good

These results confirm that the data collection tool—the questionnaire—demonstrated strong internal consistency across all three measured constructs.

Before conducting an in-depth analysis of the research constructs, their reliability was first evaluated using Cronbach's alpha coefficient. According to Cronbach (1951), a coefficient value above 0.7 is typically considered to reflect a reliable and consistent measure.

Table 1 summarizes the number of items assessed for each construct and their corresponding reliability values. The constructs assessed in this study include the causes of delay, rework, and revisions, project characteristics, and key design performance indicators. The calculated alpha values for these constructs were 0.869, 0.885, and 0.900, respectively—each exceeding the 0.7 threshold, indicating a strong level of internal consistency.

➢ *Cronbach's Interpretation of Alpha Values can be Summarized as Follows:*

- $\alpha < 0.5$: Low reliability
- $0.5 < \alpha \leq 0.7$: Moderate or acceptable reliability
- $\alpha > 0.7$: High reliability

Given the limited research on these specific issues within the South African context, the strong alpha values obtained here reinforce the reliability of the questionnaire as a valid research tool (Love et al., 2004).

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Table 2 The Relative Importance Index values of the top ten factors that Cause delay, Rework and Revision in the South African Construction Industry

Factors that cause delay, rework and revision	RII	Rank	Group
Changes in project scope	0.71	1	Change-related
Delays in approval processes	0.70	2	Approval-related
Design Change	0.68	3	Change-related
Client-initiated changes	0.68	4	Change-related
Poor Scope Definition	0.68	5	Scope-related
Resources	0.63	6	Resource-related
Poor Information Flow	0.63	7	Information-related
Lack of input Information	0.61	8	Information-related
Unrealistic Project Time Estimate	0.62	9	Time-related
Insufficient Design Details	0.61	10	Design-related

The Relative Importance Index (RII) method was applied to determine the ranking of each factor contributing to delays, rework, and revisions as identified in the questionnaire responses. This approach helps prioritize issues based on their perceived impact. The RII value for each factor was computed using the following formula:

$$RII = \frac{Er}{A\,x\,N}\ (0 \leq \text{RII} \leq 1)$$

- *Where*

In this study, **E** represents the response categories used to assess the frequency of causes for delays, rework, and revisions, as well as the adequacy of project characteristics. The response categories are:

- *For Frequency:*

- 5 (Very Often)
- 4 (Often)
- 3 (Average)
- 2 (Sometimes)
- 1 (Never)

- *For Adequacy:*

- 5 (Most Adequate)
- 4 (Very Adequate)
- 3 (Adequate)
- 2 (Somewhat Adequate)
- 1 (Not Adequate)

R refers to the rating associated with each response (5, 4, 3, 2, or 1). Ranked the highest, **A**, is 5, and **N** represents the total count of survey respondents surveyed (Chan and Kumaraswamy, 1997).

$$RII \text{ for Scope Change} = \frac{(1x1) + (10x2) + (5x3) + (18x4) + (9x5)}{5\times 43} = 0.7116$$

RII for Scope Change = 0.7116

The remaining factors were also assessed using the same computational Methods.

Table 2 presents the ten most significant causes of delays, rework, and revisions. As shown in table 4, issues related to changes are consistently ranked among the top five factors contributing to these challenges.The frequency scores for these causes of delay, rework, and revisions are also highlighted in the table.

Table 3 Frequency Scores for Causes of delay, Rework and Revisions

Causes of delays, rework & revision	RII (Rank)	Frequency of scores					Mean score	Total
Frequency		1	2	3	4	5		
Scope Change	1	1	10	5	18	9	3.558	43
Approval Delay	2	nil	8	9	22	4	3.512	43
Design Change	3	nil	11	9	18	5	3.395	43
Owners Initiated changes	4	3	6	9	21	4	3.395	43
Poor Scope Definition	5	2	9	12	10	10	3.395	43
Resources	6	3	9	16	9	6	3.140	43
Poor Information Flow	7	2	9	17	11	4	3.140	43
Lack of input Information	8	3	8	17	10	4	3.095	42
Unrealistic Project Time Estimate	9	2	15	5	19	2	3.093	43
Insufficient Design Details	10	1	18	8	11	5	3.023	43
Lack of Coordination between Designers	11	2	15	12	6	7	**2.954**	43
Inadequate Planning & Scheduling	12	3	19	10	6	5	**2.791**	43
Design errors and Omissions	13	1	21	8	11	1	**2.698**	43
Lack of Experienced Designers	14	6	16	7	9	4	**2.674**	43

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Clashes in Drawings	15	3	19	9	9	2	**2.651**	43
Project Complexity	16	1	22	16	3	1	**2.558**	43
Differing Site Conditions	17	3	19	18	2	nil	**2.395**	43
Vendors Error and Omissions	18	2	28	9	4	nil	**2.349**	43
Inappropriate Assumptions	19	8	21	7	6	1	**2.326**	43
Amendments to regulatory laws	20	17	19	5	1	nil	**1.721**	43

The mean is a commonly used statistical tool for determining the average of a set of numerical values. The study employed mean calculations to determine the average rating of each factor identified as contributing to delays, rework, and revisions, as captured through the questionnaire.

➢ *Calculation of Mean Scores*

Using Table 3 as an example, the responses for scope change were distributed as follows: one respondent selected a score of 1, ten chose 2, five selected 3, eighteen rated it 4, and nine gave it a 5. The total number of valid responses for this item was 43.

$$\text{Formula for calculating the mean} = (x) = \frac{\sum(Frequency \times data\ value)}{number\ of\ data\ value}$$

$$\text{Average value for Scope Change} = \frac{(1x1) + (10x2) + (5x3) + (18x4) + (9x5)}{43} = 3.5581$$

➢ *Average for Scope Change = **3.5581***

Similar calculations were performed for the remaining factors, resulting in the following mean scores: The mean scores calculated for each factor provide insight into how frequently they were perceived to contribute to delays, rework, and revisions. The results are summarized as follows:

- Approval Delays had the highest mean score at 3.5116, indicating frequent occurrence.
- Design Changes, Owner-Initiated Changes, and Poor Scope Definition each received a mean score of 3.3953, suggesting they are also significant contributors.
- Resource Availability and Poor Information Flow both scored 3.1395, reflecting a moderate impact.
- Lack of Input Information followed closely with a mean of 3.0952, while Unrealistic Project Time Estimates came in at 3.0930.
- Insufficient Design Details scored slightly lower at 3.0233, and Lack of Coordination Between Designers was rated at 2.9535.
- Inadequate Planning and Scheduling received a mean score of 2.7907.
- Design Errors and Omissions were rated at 2.6977, and Lack of Experienced Designers at 2.6744.
- Drawing Clashes had a mean score of 2.6512, indicating it was among the lesser-reported issues.

➢ *Additional Factors with lower mean scores Suggest Less Frequent Contribution to Project delays, Rework, and Revisions:*

- Project Complexity had a mean score of 2.5581, reflecting occasional impact.
- Differing Site Conditions were rated at 2.3953, suggesting limited influence.
- Vendor Errors and Omissions received a score of 2.3488, while Inappropriate Assumptions followed closely with 2.3256.
- The least impactful factor, based on responses, was Regulatory Changes and Legal Modifications, which had the lowest mean score of 1.7209. These values are presented in Table 4.7.

➢ *One-Sample T-Test Analysis for Causes of Delay, Rework, and Revision*

Before carrying out a one-sample t-test, it's important to check that the dependent variable is approximately normally distributed. However, thanks to the central limit theorem, if the sample size is 30 or more, the distribution of the sample mean can be treated as roughly normal—even if the original data isn't.

As noted by Ghasemi and Zahediasl (2012), parametric tests like the t-test can still be valid for large sample sizes, even when the data doesn't perfectly follow a normal distribution. This is because, with larger samples—typically more than 30 or 40—the sampling distribution of the mean tends to become normal regardless of the data's original distribution.

To determine whether the identified causes significantly deviate from a neutral benchmark, a one-sample t-test was conducted using a test value of 3. This value corresponds to the "average" rating on the 5-point Likert scale used in the questionnaire.

The purpose of this analysis was to assess whether the mean ratings for each factor were statistically different from the hypothesized population mean. According to the results, factors with p-value of less than 0.05 was used as the threshold for statistical significance, suggesting that the likelihood of the observed differences being due to random variation is low.

The findings revealed that several factors—such as scope changes, approval delays, and design changes—had mean values significantly higher than 3, indicating these issues were experienced more frequently than average. On the other hand, some variables like regulatory changes, vendor errors, and inappropriate assumptions had significantly lower mean scores, suggesting they were not major contributors to delays, rework, or revisions in most projects.

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This analysis provides statistical backing for prioritizing the top-ranked issues in efforts to reduce inefficiencies in multidisciplinary infrastructure projects.

This table presents the outcomes of the one-sample t-test conducted on the various causes of delay, rework, and revision. Each factor's mean score is compared to the test value of 3—representing an "average" level on the Likert scale. The statistical significance of each factor is indicated by the p-value, while the Relative Importance Index (RII) is also provided to show the perceived weight or impact of each cause based on respondent ratings.

Table 4 Results of One-Sample T-Test for Delay, Rework, and Revision Factors Alongside Relative Importance Index (RII) Values

Test Value = 3						
S/no	**Causes of delay, rework, or /and revision**	**Mean**	**Sig (P value)**	**Hypothesis Result**	**RII**	**Rank**
1	Unrealistic Project Time Estimate	3.093	.578	H0-accepted	0.619	9
2	Poor Scope Definition	3.395	.036	H0- rejected	0.679	5
3	Scope Change	3.558	.003	H0- rejected	0.712	1
4	Project Complexity	2.558	.000	H0- rejected	0.512	16
5	Insufficient Design Details	3.023	.893	H0-accepted	0.605	10
6	Design Change	3.395	.013	H0- rejected	0.679	3
7	Clashes in Drawings	2.651	.046	H0- rejected	0.530	15
8	Lack of Coordination between Designers	2.954	.809	H0-accepted	0.591	11
9	Lack of Experienced Designers	2.674	.104	H0-accepted	0.535	14
10	Poor Information Flow	3.140	.372	H0-accepted	0.628	7
11	Lack of input Information	3.140	.562	H0-accepted	0.605	8
12	Inappropriate Assumptions	2.326	.000	H0- rejected	0.465	19
13	Inadequate Planning & Scheduling	2.791	.238	H0-accepted	0.558	12
14	Owners Initiated changes	3.395	.020	H0- rejected	0.679	4
15	Differing Site Conditions	2.395	.000	H0- rejected	0.479	17
16	Changes in Laws of Regulatory Agencies	1.721	.000	H0- rejected	0.344	20
17	Design Errors and Omissions	2.698	.062	H0-accepted	0.540	13
18	Vendors Error and Omissions	2.349	.000	H0- rejected	0.470	18
19	Approval Delay	3.512	.001	H0- rejected	0.702	2
20	Resources	3.140	.421	H0-accepted	0.628	6

**. Correlation is significant at the 0.05 level (2-tailed).
Note: Null Hypothesis = Ho: $\mu = 3$ Alternate Hypothesis = Ha: $\mu \neq 3$ If $p < 0.05$, reject H0 If $p > 0.05$, accept the null hypothesis or fail to reject null hypothesis

A one-sample t-test was performed to assess whether the sample mean significantly deviates from the hypothesized population mean of 3. The first row of Table 4 shows the postulated population mean, against which the sample mean is being compared. The typical level of significance used for this test is 0.05, as indicated by the "Sig. (2-tailed)" value.

When the p-value is less than 0.05, it suggests that the sample's estimated population mean is statistically different from the hypothesized mean, leading to the rejection of the null hypothesis in support of the alternative hypothesis. Conversely, if the p-value exceeds 0.05, it means there is no significant difference between the sample mean and the hypothesized mean, and the null hypothesis is either accepted or not rejected.

In this analysis, a test value of 3 was used for the t-test, as 3 corresponds to an "average" rating on the 5-point Likert scale from the survey. Based on the data presented in Table 4, the researcher has 95% confidence that the observed outcomes reflect true differences rather than chance.

From the same table, we can see the top ten factors causing delays, rework, and revisions, based on the Relative Importance Index. These factors include: "scope change," "approval delays," "design change," "owners-initiated changes," "poor scope definition," "resources," "poor information flow," "lack of input information," "unrealistic project time estimate," and "insufficient design details." All of these factors have mean values greater than 3 (the hypothesized average), indicating that they have a significant impact on delays, rework, and revisions. Factors with mean values below 3 are less influential.

Looking at the data from Table 4, it's clear that several factors contribute significantly to delays and rework in South African design projects. Among the most impactful are "scope changes," "approval delays," and "design changes." On the other hand, factors like "changes in laws of regulatory agencies," "inappropriate assumptions," and "vendor errors and omissions" have less of an impact.

The South African design industry faces challenges with the adoption of modern information technology, which exacerbates issues related to scope and design changes, further increasing delays and rework.

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Additionally, the mean value for "lack of input information" is slightly higher than "unrealistic project time estimate," but this is due to a missing data point. However, "lack of input information" still has a lower Relative Importance Index value than "unrealistic project time estimate," suggesting it's slightly less influential overall.

Table 5 Frequency scores and mean Values for Project Characteristics

S/No	Project characteristics	RII	Frequency of scores					Mean score	Total
	Frequency		1	2	3	4	5		
1	Scope Definition	5	3	11	19	7	3	2.907	43
2	Project Organization	3	1	9	22	9	2	3.047	43
3	Design Coordination	4	2	9	24	6	2	2.930	43
4	Interface Management	8	3	11	18	9	1	2.857	43
5	Design Planning	2	2	10	19	8	4	3.047	43
6	Design Documentation	1	1	8	23	8	3	3.093	43
7	Change Management	7	3	9	23	7	1	2.861	43
8	Resources	11	1	18	17	6	1	2.721	43
9	Coordination Tools	9	2	12	23	5	1	2.791	43
10	Design Verification	6	2	14	17	8	2	2.861	43
11	Design Approval	10	5	14	14	7	3	2.744	43

➢ *Calculation of Mean Scores*

Based on Table 3, the responses for *scope definition* were distributed as follows: 3 participants rated it as 1, 11 gave it a 2, 19 selected a 3, 7 chose 4, and 3 rated it as 5. The total number of valid responses for this item was 43.

$$\text{Formula for calculating the mean} = (x) = \frac{\sum(Frequency \times data\ value)}{number\ of\ data\ value}$$

$$\text{Mean score for scope definition} = \frac{(3x1) + (11x2) + (19x3) + (7x4) + (3x5)}{43} = 2.9070$$

The calculated mean score for scope definition was 2.9070. Similar calculations were performed for the remaining factors, and the resulting values are presented in Table 3.

Table 6 Top Project Characteristics Based on Relative Importance Index (RII)

S/No	Project Characteristic	RII	Group
1	Design Documentation	0.619	Documentation (Adequate)
2	Design Planning	0.609	Planning (Inadequate)
3	Project Organization	0.609	Organization (Inadequate)
4	Design Coordination	0.586	Coordination (Inadequate)
5	Scope Definition	0.581	Scope-related (Inadequate)
6	Design Verification	0.572	Design-related (Inadequate)
7	Change Management	0.572	Change-related (Inadequate)
8	Interface Management	0.558	Interface-related (Inadequate)
9	Coordination Tools	0.558	Synchronization- related (Inadequate)
10	Design Approval	0.549	Approval-related (Inadequate)
11	Resources	0.544	Resource (Inadequate)

The table above ranks key project characteristics according to their Relative Importance Index (RII) values, highlighting their perceived adequacy in multidisciplinary design projects:

➢ Design Documentation had the highest RII at 0.6186, indicating it was generally viewed as adequate.
➢ Design Planning and Project Organization followed with identical RII scores of 0.6093, though both were considered inadequate.
➢ Design Coordination scored 0.5860, suggesting room for improvement.
➢ Scope Definition came in at 0.5813, also viewed as inadequate.
➢ Design Verification and Change Management both had RII values of 0.5720.
➢ Interface Management and Coordination Tools were rated slightly lower, each with a score of 0.5581.
➢ Design Approval was evaluated at 0.5488, and
➢ Resources received the lowest RII at 0.5441, indicating the greatest perceived inadequacy.

Only Design Documentation stood out as being adequately addressed. All other characteristics were identified as needing improvement to enhance project performance and reduce inefficiencies. The **Relative Importance Index (RII)** formula was applied to rank the project characteristics identified in the questionnaire based on their perceived level of adequacy and impact.

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The relative importance index (RII) value is calculated using the formula

$$RII = \frac{Er}{A \times N} \quad (0 \leq \text{RII} \leq 1)$$

- *Where*

In this study, **E** represents the index used for the response categories, which are:

- *For Determining the Frequency of Causes of delay, Rework, and Revisions:*

- 5 (Very Often)
- 4 (Often)
- 3 (Average)
- 2 (Sometimes)
- 1 (Never)

- *For Evaluating the Adequacy of Project Characteristics:*

- 5 (Most Adequate)
- 4 (Very Adequate)
- 3 (Adequate)
- 2 (Somewhat Adequate)
- 1 (Not Adequate)

R is the rating assigned to each response, ranging from 5 to 1. The highest possible weight, denoted as **A**, is 5, and **N** refers to the total number of respondents involved in the study (Chan and Kumaraswamy, 1997).

$$\text{RII for Design Documentation} = \frac{(1x1) + (8x2) + (23x3) + (8x4) + (3x5)}{5 \times 43} = 0.6186$$

RII for Design Documentation = 0.6186 Similar analyses were conducted for the remaining factors.

Table 1 displays the top ten causes of delay, rework, and revisions. As shown in Table 2, all issues related to changes are ranked among the top five factors. Table 5 reveals that design documentation is the only aspect deemed adequate regarding the project characteristics. In contrast, the other factors were identified as inadequate, which significantly impacts the design process, contributing to delays and rework.

- *T-test Analysis for Project Characteristics*

Table 7 One sample t-test analysis for project characteristics and relative importance index values

Test Value = 3						
S/no	**Project Characteristics**	**Mean**	**Sig (P value)**	**Hypothesis Result**	**RII**	**Rank**
1	Scope Definition	2.907	.543	H0-accepted	0.581	5
2	Project Organization	3.047	.720	H0-accepted	0.609	3
3	Design Coordination	2.930	.596	H0-accepted	0.586	4
4	Interface Management	2.857	.323	H0-accepted	0.558	8
5	Design Planning	3.047	.762	H0-accepted	0.609	2
6	Design Documentation	3.093	.486	H0-accepted	0.619	1
7	Change Management	2.861	.294	H0-accepted	0.572	7
8	Resources	2.721	.032	H0- rejected	0.544	11
9	Coordination Tools	2.791	.095	H0-accepted	0.558	9
10	Design Verification	2.861	.336	H0-accepted	0.572	6
11	Design Approval	2.744	.132	H0-accepted	0.549	10

- *A Correlation is Deemed Statistically Significant at the 0.05 level (two-tailed).*

- Null Hypothesis (H_0): The population mean (μ) is equal to 3
- Alternative Hypothesis (H_a): The population mean (μ) is not equal to 3

If the p-value is less than 0.05, the null hypothesis is rejected, indicating a statistically significant difference from the hypothesized mean.

- *Interpreting the T-Test Results*

To evaluate whether the average ratings from the survey meaningfully differ from a neutral benchmark, a one-sample t-test was performed. The test compared each factor's mean score to a reference value of **3**, which represents a midpoint or "average" response on the Likert scale.

- *Understanding the Hypotheses*

- Null Hypothesis (H_0): The true population mean (μ) is equal to 3, indicating no significant deviation from the average.
- Alternative Hypothesis (H_a): The true population mean (μ) is not equal to 3, suggesting a statistically significant difference.

- *How We Interpret the Results*

- If the p-value is less than 0.05, we reject the null hypothesis, meaning the difference observed is statistically significant.
- If the p-value is greater than 0.05, we fail to reject the null, implying that the sample mean is not significantly different from the hypothesized average.

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➢ *Key Findings from the Analysis*

The first row of Table 7 displays the test value of 3, which represents an "average" rating on the 5-point Likert scale used in the questionnaire. This value served as the benchmark for comparing the actual mean responses for each project characteristic.

➢ *The Results Show that:*

- When the p-value (Sig. 2-tailed) is less than 0.05, the difference between the sample mean and the reference value is considered statistically significant. In such cases, the null hypothesis is rejected, supporting the idea that the response differs meaningfully from the average.
- If the p-value exceeds 0.05, the result is considered not statistically significant, and we fail to reject the null hypothesis. This indicates that the sample mean does not show a significant difference from the hypothesized population mean.

Based on the data in Table 7, we can be **95% confident** that the significant findings are not due to random variation but reflect actual perceptions among the respondents.

The data reveals that for most project characteristics, the actual mean falls at or below the hypothesized mean of 3. This suggests that these aspects are generally inadequate or somewhat lacking in South African design projects. However, the variables with mean values above 3 are considered adequate.

➢ *Key Insights from the Findings:*

- The only characteristics that appear to be adequate are design documentation and design planning.
- The top three most adequate project characteristics are:
- Design documentation
- Design planning
- Project organization
- On the other hand, the most inadequate aspects include:
- Coordination tools
- Design approval processes
- Resources

These findings highlight critical areas for improvement in South African design projects, particularly in resource allocation, approval systems, and coordination tools. Addressing these weaknesses could significantly enhance project efficiency and outcomes. The South African design industry faces significant challenges due to a shortage of skilled professionals, particularly engineers, as well as a lack of modern coordination tools (Lawless, 2007). As a result, the industry struggles to provide essential resources, streamline approval processes, and implement effective coordination tools. These limitations create a ripple effect, leading to delays, frequent revisions, and increased rework within the design process.

Table 8 Frequency scores for key design performance indicator

S/No	Key Design Performance indicator	Rank	Frequency of scores					Mean score	Total
	Frequency		1	2	3	4	5		
1	Drawing Revisions	1	1	11	4	17	10	3.558	43
2	Drawing (Design)Rework	4	nil	14	8	13	8	3.349	43
3	Site Rework due to Design	7	2	12	14	9	6	3.116	43
4	Design Delay	6	1	11	12	14	5	3.256	43
5	Submission Delay	8	1	13	14	12	3	3.070	43
6	Approval Delay	2	nil	8	12	15	8	3.535	43
7	Design Changes	5	nil	12	11	16	4	3.279	43
8	Scope Changes	3	2	9	12	12	8	3.349	43

➢ *Calculation of Mean Scores:*

According to Table 8, the distribution of responses for drawing revision was as follows: one respondent rated it as 1, eleven chose 2, four gave it a 3, seventeen selected 4, and ten assigned it a score of 5. In total, 43 valid responses were recorded for this item.

$$\text{Formula for calculating the mean} = (x) = \frac{\sum(Frequency \times data\ value)}{number\ of\ data\ value}$$

$$\text{Mean score for Drawing revision} = \frac{(1x1) + (11x2) + (4x3) + (17x4) + (10x5)}{43} = 3.5581$$

The mean score for Drawing Revision was calculated to be 3.5581, indicating it was rated above average in terms of frequency or impact. Similar calculations were performed for the remaining factors, and the results are presented in Table 8 above.

Table 9 Key Design Performance indicator in the South African construction industry

S/No	Key Design Performance indicator	RII	Group
1	Drawing Revisions	0.619	Drawing related
2	Drawing (Design)Rework	0.609	Drawing related
3	Site Rework due to Design	0.609	Design related

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4	Design Delay	0.586	Design related
5	Submission Delay	0.581	Time related
6	Approval Delay	0.572	Time related
7	Design Changes	0.572	Design related
8	Scope Changes	0.558	Scope related

The **Relative Importance Index (RII)** method was employed to rank the project characteristics based on their perceived significance, as captured in the questionnaire responses. This approach helps to identify which characteristics are seen as most critical by the participants.

➢ *The RII was calculated using the following formula:*

$$RII = \frac{Er}{A\ x\ N}\ (0 \leq \text{RII} \leq 1)$$

➢ *Where*

E represents the assigned value for each response category. For frequency-based questions (e.g., causes of delay, rework, and revision), the scale ranges from **5 = very often** to **1 = never**. For questions assessing adequacy (e.g., project characteristics), the scale uses **5 = most adequate** down to **1 = not adequate**.

- **R** is the numerical rating selected by the respondent, corresponding to one of the values in the scale (5, 4, 3, 2, or 1).
- **A** refers to the highest possible weight in the scale, which is **5** in this case.
- **N** stands for the total number of respondents included in the analysis (*Chan and Kumaraswamy, 1997*).

$$RII \text{ for Drawing revision} = \frac{(1x1) + (11x2) + (4x3) + (17x4) + (10x5)}{5 \times 43} = 0.7116$$

The Relative Importance Index (RII) for Drawing Revision was calculated as 0.7116, indicating it is one of the most significant factors. Similar calculations were conducted for all other factors, and the results are summarized in Table 8. According to Table 2, the top ten contributors to delay, rework, and revision were identified—most of which are associated with change-related issues, as shown in Table 3, highlighting their dominant role among the highest-ranked causes. Meanwhile, **Table 6** reveals that **Design Documentation** is the only project characteristic rated as adequate. All other characteristics were viewed as insufficient, which may be contributing to recurring challenges such as delays and rework in the design process. This pattern underscores the need for improvements in areas like planning, coordination, and resource management.

➢ *T-test Analysis of key Performance Indicators*

Table 10 T-test analysis of key Performance Indicators and Ranks

Test Value = 3						
No	**Key Design Performance indicators**	**Mean**	**Sig (P value)**	**Hypothesis Result**	**RII**	**Rank**
1	Drawing Revisions	3.558	0.003	H0- rejected	0.7116	1
2	Drawing (Design)Rework	3.349	0.050	H0- accepted	0.6697	4
3	Site Rework due to Design	3.116	0.499	H0- accepted	0.6232	7
4	Design Delay	3.256	0.117	H0- accepted	0.6511	6
5	Submission Delay	3.070	0.645	H0- accepted	0.6139	8
6	Approval Delay	3.535	0.001	H0- rejected	0.7069	2
7	Design Changes	3.279	0.070	H0- accepted	0.6558	5
8	Scope Changes	3.3489	0.054	H0- accepted	0.6697	3

**. Correlation is significant at the 0.05 level (2-tailed).

D. Null Hypothesis (H_0): The population mean (μ) is equal to 3.

➢ *Alternative Hypothesis (H_a): The population mean (μ) is not equal to 3.*

When the p-value is less than 0.05, this indicates a statistically significant difference, and we reject the null hypothesis. If the p-value is greater than 0.05, there is no significant difference, so we fail to reject the null hypothesis, meaning the sample mean is not significantly different from the assumed average.

A t-test analysis was conducted to determine whether the sample mean differs from the hypothesized population mean of 3. The first row of Table 10 presents this hypothesized population mean, which serves as the benchmark for comparison. In this case, a one-sample t-test was applied, using a hypothesized mean of 3, since this value represents an "average" rating on the 5-point Likert scale used in the survey.

The significance level, commonly referred to as "Sig. (2-tailed)," is set at 0.05, which is the standard threshold used in t-tests to assess whether a result is statistically meaningful, if the p-value is less than 0.05, it indicates a significant difference between the sample mean and the hypothesized mean. As a result, the null hypothesis is rejected in favor of the alternative hypothesis.

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Conversely, if the p-value is greater than 0.05, the result is not statistically significant, and we therefore fail to reject the null hypothesis, indicating that the sample mean does not differ significantly from the hypothesized value.

Based on the results presented in Table 10, we can conclude with 95% confidence that the observed outcomes are unlikely to be the result of random variation. The analysis shows that, for most variables, no statistically significant difference was found between the sample mean and the hypothesized population mean. significant. However, “drawing revisions” and “approval delays” stand out as exceptions, where the differences were found to be statistically significant.

Almost all key design performance indicators have an actual mean greater than the hypothesized mean of 3, suggesting that these factors occur frequently. The most common issues in South African design projects, based on Table 10, are “drawing revisions,” “approval delays,” and “scope changes.” Conversely, “submission delay,” “site rework due to design,” and “design delay” are among the least frequent occurrences.

The findings highlight that the South African design industry faces significant challenges in managing drawing revisions, approval processes, and scope changes. These inefficiencies result in delays, rework, and revisions, ultimately disrupting the design process and extending project timelines

➢ *Hypothesis 1*

Null Hypothesis (H_0): There is no significant relationship between the top 10 causes of delay, rework, and revisions and drawing (design) rework.

Table 11 presents the Results of a Correlation Analysis Conducted to Examine the Association between the ten most Critical Contributing factors and the Occurrence of Drawing (design) Rework.

ANOVA[a]						
Model		**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
1	Regression	22.125	10	2.213	2.198	.046[b]
	Residual	31.208	31	1.007		
	Total	53.333	43			
a. Dependent Variable: "Redesign or modification of drawings (design rework)"						
b. Predictors: (Constant), "inadequate design details," "limited resources," "changes in project scope," "modifications initiated by the project owner," "design revisions," "unclear scope definition," "unrealistic project timelines," "insufficient input information," "delays in approvals," and "ineffective information flow."						

The survey data was analyzed through Pearson’s correlation test, with three key findings summarized in Table 4.6.

The results reveal a clear association between the top ten causes of delay, rework, and revisions, and the occurrence of drawing (design) rework. This relationship is supported by a significance level of p = 0.046, which is below the 0.05 threshold for a 95% confidence level. Practically, this indicates there is only a 4.6% likelihood that these findings occurred by chance. Consequently, the null hypothesis is rejected. This outcome underscores that the identified factors collectively have a significant impact on drawing (design) rework, confirming their role as key contributors to delays, rework, and revisions in South African multidisciplinary projects.

➢ *Hypothesis 2:*

H_0: Information-related issues do not have a significant impact on design delays.

Table 12 Correlation Analysis Between Information-Related Issues and Design Delays This table illustrates the correlation between information-related issues and the occurrence of design delays, highlighting the key parameters involved.

Information related issues vs design delay	**Pearson Correlation Sig. (2-tailed)**	**Correlation significance level**
Poor Information Flow vs Design Delay	0.414^{**} 0.006	**. Correlation is significant at the 0.01 level (2-tailed).
Lack of input Information vs Design Delay	0.370^{*} 0.016	*. Correlation is significant at the 0.05 level (2-tailed).
Inappropriate Assumptions vs Design Delay	0.411^{**} 0.006	**. Correlation is significant at the 0.01 level (2-tailed).

The survey data was analyzed using Pearson’s correlation test, revealing three significant findings, as shown in Table 12. The results indicate a strong connection between “poor information flow” and “design delay,” with a correlation coefficient of 0.414 and a p-value of 0.006. Since this p-value is below the 0.05 threshold for a 95% confidence level, there is only a 0.6% probability that this result occurred by random chance. Similarly, there is a notable relationship

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between "lack of input information" and "design delay," with a correlation coefficient of 0.370 and a p-value of 0.016, meaning there is a 1.6% chance of this result happening randomly.

Additionally, "inappropriate assumptions" also show a significant link to "design delay," with a correlation coefficient of 0.411 and a p-value of 0.006. The positive correlation indicates a strong association, reinforcing that issues related to information management contribute to delays in the design process for South African projects.

Given these findings, the null hypothesis is rejected, confirming that poor information flow, lack of input data, and incorrect assumptions are key factors that increase the likelihood of design delays in the industry.

➢ *Hypothesis 3:*

H_0: Changes do not have a significant impact on drawing (design) rework.

Table 13 Correlation Between Change-Related Issues and Drawing (Design) Rework This table presents the relationship between change-related issues and drawing (design) rework, focusing on the relevant parameters.

Changes issues vs Drawing (Design) Rework	**Pearson Correlation Sig. (2-tailed)**	**Correlation significance level**
Scope Change vs Drawing (Design) Rework	0.418** 0.005	**. Correlation is significant at the 0.01 level (2-tailed).
Design Change vs Drawing (Design) Rework	0.337* 0.027	*. Correlation is significant at the 0.05 level (2-tailed).
Owners Initiated change vs Drawing (Design) Rework	0.414** 0.006	**. Correlation is significant at the 0.01 level (2-tailed).

The data obtained from the survey administered was analyzed using the Pearson's correlation test and three significant results are shown in Table 13.

The analysis reveals a strong and significant relationship between "scope change" and "drawing (design) rework," with a correlation coefficient of 0.418 and a p-value of 0.005. Since the correlation is positive, it indicates that as scope changes increase, the amount of design rework also rises. With a p-value below 0.01 at a 95% confidence level, the likelihood of this result occurring by random chance is just 0.5%.

Similarly, there is a notable connection between "design change" and "drawing (design) rework," with a correlation coefficient of 0.337 and a p-value of 0.027. This positive correlation suggests that frequent design modifications contribute to increased rework. Since the p-value is below 0.05, there is only a 2.7% probability that this result happened by chance.

Additionally, "owner-initiated changes" also show a strong positive correlation with "drawing (design) rework," with a correlation coefficient of 0.414 and a p-value of 0.006. Again, since the p-value is below 0.01, there is only a 0.6% chance of this finding being random.

These results indicate that changes—whether related to scope, design, or owner decisions—significantly contribute to increased rework in South African design projects. Based on this evidence, the null hypothesis is rejected, confirming that uncontrolled changes in project parameters are a key driver of design rework.

➢ *Hypothesis 4:*

Ho: "Scope change" will have no significant effect on site rework due to design

Table 14 Tests of between-Subjects Effects Dependent Variable: Site Rework due to Design

Source	**Type III Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Corrected Model	29.485[a]	14	2.106	2.571	.016
Intercept	193.499	1	193.499	236.248	.000
Scope change	9.399	4	2.350	2.869	.041
Poor information flow	14.027	4	3.507	4.282	.008
Scope change * Poor Information flow	9.275	6	1.546	1.887	.118
Error	22.933	28	.819		
Total	470.000	43			
Corrected Total	52.419	42			
a. R Squared =0.562 (Adjusted R Squared = .344) b. H_0: Poor **. Correlation is significant at the 0.05 level (2-tailed).					

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- Information flow has no significant impact on site rework due to design.
- H_0: The interaction between scope change and poor information flow has no significant impact on site rework due to design

The survey data was analyzed using Pearson's correlation test, and three key findings are highlighted in Table 14. First, a significant relationship was found between scope change and site rework due to design, with a p-value of 0.041. Since this is below the 0.05 threshold for a 95% confidence level, there is only a 4.1% probability that this result occurred by chance. Based on this, the null hypothesis is rejected.

Similarly, poor information flow was found to have a significant relationship with site rework due to design, with a p-value of 0.008. As this is also below the 0.05 significance level, the likelihood of this result occurring randomly is just 0.8%. Therefore, the null hypothesis is again rejected.

However, when examining the interaction between scope change and poor information flow in relation to site rework due to design, the significance level was 0.118—above the 0.05 threshold. This indicates that their combined effect is not statistically significant, and we fail to reject the null hypothesis in this case.

These findings suggest that while both scope changes and poor information flow individually contribute to site rework due to design, their combined influence does not have a statistically significant impact.

➢ *Study Overview*

This study aimed to identify the primary causes of delays, rework, and revisions in multidisciplinary projects in South Africa. Through an extensive review of existing literature, 20 potential causes of delays were identified. To validate these findings, key project characteristics and design performance indicators were also examined. A questionnaire based on these identified factors was distributed to industry experts, and the collected data was analyzed using:

- Cronbach's Alpha coefficient
- Mean analysis
- Relative Importance Index
- One sample t-test
- Pearson correlation coefficient

➢ *Key Findings*

The study revealed that among the top ten causes of delays, rework, and revisions, four were related to changes, two stemmed from information deficiencies, two were time-related, one was due to scope deficiencies, one resulted from resource shortages, and one was linked to design deficiencies. Notably, there were no experience-related or complexity-related delay factors among the top ten, which included:

- Scope Modifications
- Delays in Approval Processes
- Revisions to Design Elements
- Changes Initiated by the Project Owner
- Inadequate Definition of Project Scope
- Shortages in Required Resources
- Inefficient Flow of Information
- Absence or Insufficiency of Input Data
- Unrealistic Estimates of Project Timelines
- Insufficient Detail in Design Documentation

The study further revealed a statistically significant correlation between these top ten factors and key design performance indicators. Additionally, a strong relationship was observed between information-related issues and design delays, as well as between change-related issues and drawing rework.

IV. RECOMMENDATIONS FOR MITIGATING KEY ISSUES

A. Scope Changes

Scope changes, often caused by poor scope definition and design modifications, can lead to worker demotivation, staff turnover, disputes, and overall project instability. Reducing these changes is crucial to minimizing their cascading effects.

➢ *Strategies to Mitigate Scope Changes:*

- Conduct routine trainings on change and transition management.
- Perform recurring assessments of change initiatives.
- Ensure timely communication of any modifications.
- Implement an effective change in management and control system.
- Ensure scope freezing and deadline enforcement are led by experienced designers to maintain project Stability..
- Clearly define client responsibilities for changes and document them in writing to avoid disputes.

B. Approval Delays

Approval processes can sometimes be unnecessarily long and bureaucratic, leading to avoidable delays, rework, and revisions. A more efficient approval system can help mitigate these issues.

➢ *Strategies to Mitigate Approval Delays:*

- Submit documents for approval as early as possible.
- Establish written agreements on submission and approval deadlines.
- Keep clients informed of approval delays and their consequences.
- Plan efficiently to maximize waiting periods.
- Allow sufficient lead time for approvals.
- Avoid last-minute submission of drawings.
- Encourage subcontractors to submit drawings early to prevent bottlenecks.

C. Design Changes

Design changes often stem from insufficient design details, poor scope definition, unforeseen site conditions, or regulatory changes. These alterations can lead to disputes, project overruns, and coordination errors.

➢ *Strategies to Mitigate Design Changes:*

- Conduct thorough design reviews and verifications.
- Implement structured and expert-led design management practices
- Encourage early design commitments.
- Implement controlled changes—allow flexibility early in the design phase but tighten control as more details emerge.
- Use incentive-based contracts with shared risks and rewards.
- Establish a structured change control program.
- Audit designs to ensure quality and compliance.
- Provide early warnings of changes to mechanical and electrical (M&E) contractors.
- Improve collaboration and coordination between design consultants.
- Ensure full understanding and compliance with the client's project brief.

➢ *Owner-Initiated Changes*

Frequent modifications by project owners can result from resource considerations, buildability improvements, or a lack of technical knowledge. While some changes may be necessary, limiting them after the project scope is finalized is essential.

➢ *Strategies to Mitigate Owner-Initiated Changes:*

- Strengthen design coordination.
- Implement controlled change limits—allow more flexibility in the early design stages but tighten restrictions as the project progresses.
- Establish scope-freezing policies.
- Clearly outline the client's responsibility for changes and document all modifications to avoid disputes.
- Notify M&E contractors of potential changes in advance to minimize rework.

➢ *Poor Scope Definition*

A poorly defined scope often results from inadequate information flow, missing input data, or the owner's lack of technical knowledge. This can cause time and cost overruns, disputes, and even project abandonment.

➢ *Strategies to Mitigate Poor Scope Definition:*

- Ensure designers and owners communicate project status and potential changes early, as suggested by Love et al. (2006).
- Implement professional design management practices.
- Involve end users in scope development.
- Resolve scope-related issues in meetings before project execution (Love et al., 2004).

➢ *Poor Information Flow*

Smooth information flow is vital for project success. Poor communication can lead to design changes, poor scope definition, project complexity, and lack of integration, causing delays, rework, and revisions.

➢ *Strategies to Improve Information Flow:*

- Develop a well-defined information-sharing plan at the project's onset.
- Conduct regular coordination meetings.
- Use effective coordination and communication tools.
- Promote timely collaboration and integration among all stakeholders.
- Encourage structured team roles and shared responsibilities to improve communication.

➢ *Lack of Input Information*

A lack of necessary project data can lead to design flaws, project complexity, and staff turnover—ultimately delaying progress.

➢ *Strategies to Address Lack of Input Information:*

- Establish a clear and structured information plan at the project's beginning.
- Schedule consistent coordination meetings.
- Utilize proper project coordination tools.
- Ensure prompt collaboration and integration among team members.
- Appoint an experienced project leader specialized in the domain.

➢ *Unrealistic Project Time Estimates*

Overly optimistic timelines can lead to rushed work, compromised quality, and extended project durations.

➢ *Strategies to Ensure Realistic Project Timelines:*

- Avoid excessive risk-taking with unrealistic deadlines.
- Negotiate practical and achievable project schedules.
- Ensure professional design management and time allocation.

➢ *Insufficient Design Details*

Lack of detail in project designs can result in rework, delays, and contract disputes.

➢ *Strategies to Improve Design Details:*

- Communicate design status clearly to contractors, as recommended by Love et al. (2006).
- Conduct design clarification meetings before project execution.
- Strengthen professional design management practices.

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V. CONCLUSION

Regardless of the specific cause of delays, rework, or revisions, it is crucial to minimize their impact by continuously reassessing the critical path and employing fast-tracking techniques where necessary. Proactive planning, structured change management, and efficient communication can significantly reduce disruptions, ensuring smoother project execution and improved design performance.

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