Variations & Claims in International Construction Contracts (FIDIC) from Statistical Perspective in MENA Region for the Last Decade

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Posted Date: 1 May 2024

doi: 10.20944/preprints202404.2016.v1

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Article

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Abstract: This study delves into the dynamics of 'Variations' and 'Claims' within construction projects, specifically under the FIDIC-Red Book 1999 (FIDIC 1999) framework. It aims to identify, categorize, and devise mitigation strategies for key types of Variations and Claims, aligning with the FIDIC Conditions of Contract. The research, drawing on inputs from construction industry professionals including Contract Administrators and Project Managers, focuses on the MENA region. This choice is driven by the region's extensive adoption of FIDIC standards and its rapidly growing construction sector. Data collection encompassed a questionnaire distributed to 80 industry experts, predominantly through interviews, focusing on countries like Saudi Arabia, UAE, Kuwait, and Egypt. These locations were chosen to reflect diverse construction practices and the involvement of international firms. Utilizing SPSS-V.25 for statistical analysis, the study uncovers the most prevalent and impactful causes of Variations and Claims, highlighting the critical need for managerial intervention. A key feature of this study is the integration of Scientometric Analysis for a quantitative review of current literature, providing a comprehensive academic context. A significant addition to the methodology is the implementation of a k-means clustering analysis. This advanced statistical technique further classifies the data into distinct clusters, each representing unique combinations of 'Frequency' and 'Impact' of Variations and Claims. The k-means analysis elucidates intricate patterns and potential solutions, offering profound insights into effectively managing these issues. These analytical advancements are crucial in identifying significant and manageable responses to reduce the frequency and impact of Variations and Claims in construction projects.

Keywords construction industry; international contracts; FIDIC 1999 Red Book; variations; claims; scientometric analysis; statistical analysis; relative importance index (RII); K-means clustering

1. Introduction

Construction Industry represents a vital indicator to the countries' economies, its success lead to achieve development and stability, while its failure adversely affects economy. As a result of its complexity, unique nature compared with other industries and the participation of several parties from all market sectors within or outside the country, therefore any event or circumstance affecting the construction industry has the ability to influence the economy as a whole. According to market

 doi:10.20944/preprints202404.2016.v1

research until 2020 for “Construction Industry “worldwide, published in www.MarketReportsStore.com website where the study of the global construction forecasts up to the year 2020 and how the evolution of “Construction Industry “in all the major countries, according to The CIC's (Construction Intelligence Center) Global 50s, This encompasses over 50 of the world's biggest and most significant markets. The Middle East and Africa are expected to have the fastest-growing "Construction Industry" in the coming years, according to a report. This is due in large part to the significant investments made in infrastructure and buildings in these regions, despite fluctuations in oil prices and their vulnerability to economic growth. The report also confirmed that the Asia-Pacific region will account for a growing portion of the global construction industry, rising from 40% in 2010 to nearly 49% in 2020. Variations and Claims are common in Construction industry due to requirements and needs as well as the growing complexity of the processes of construction. However, construction industry contracts of huge funding values undergo many "Variations" during project stages; Design stage, contracting stage and construction stage, Abdelalim, A.M., (2016-2023). The primary objectives of this study are to explore and investigate contractual variants and raised claims in compliance with the employer's FIDIC-Red Book 1999 (FIDIC 1999); Conditions of Contract for Construction of building and engineering works, as well as their underlying reasons. Based on feedback from construction professionals' experience; clients, consultants, contractors, and claim experts through the conducted questionnaire.

1.1. Research Objectives

Research mainly aims to carry out a study of “Variations” and “Claims" in the Conditions of Contract for Construction of building and engineering works designed by the employer (FIDIC 1999) in order to achieve the following objectives:

- Identification and characterization of the significant types of “Variations” and “Claims" in construction projects in accordance with the terms of the Conditions of Contract for Construction (FIDIC-1999).
- Study the significant Causes of the “Variations” and “Claims" in construction projects.
- Suggest recommendations and proposed solutions to benefit from the results of the study and avoid the Causes of “Variations” and “Claims”.

1.1. Research Methodology

The research methodology adopts a multi-faceted approach, essential for comprehensively addressing the intricacies of Variations and Claims in International Contracts, specifically under FIDIC guidelines. The methodology is structured into distinct but interrelated stages, each contributing uniquely towards achieving our research objectives, as shown in Figure 1.

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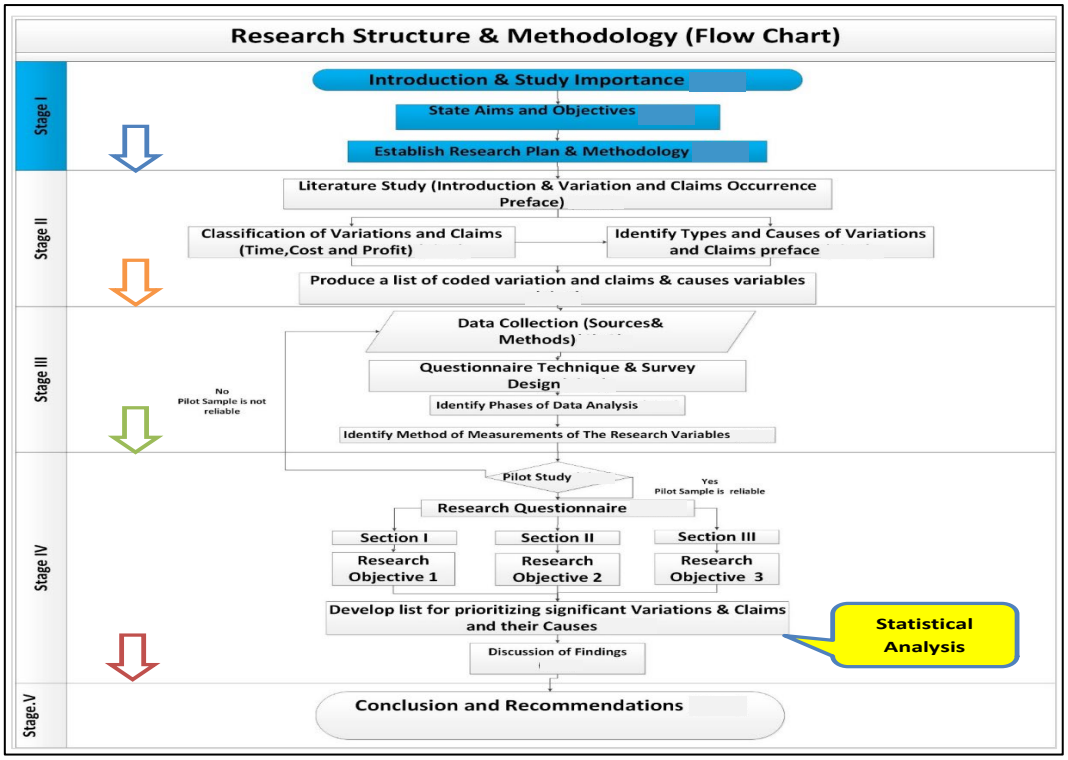

Figure 1. Research Methodology.

1.1. Scientometric Analysis

In the Scientometric Analysis phase of this research, a thorough and systematic examination of the existing scholarly literature on Variations and Claims in International Contracts, with a specific focus on those under the FIDIC framework, is carried out. This examination is pivotal for pinpointing the dominant themes, trends, and notable gaps within this academic field. Utilizing advanced data analysis tools, the research delves into a carefully curated collection of academic journals, conference papers, and industry reports. This process aims to intricately map the scholarly landscape surrounding the topic, thereby affirming the pertinence of the research focus.

To initiate this analysis, Scopus, a comprehensive database known for its wide array of scientific publications and rapid indexing, is selected as the primary source for data retrieval. This choice enhances the likelihood of accessing relevant and recent literature in this field. In December 2023, a specific search query is employed to gather data. The query, formulated as "(TITLE-ABS-KEY ("Construction" AND "FIDIC" AND "Claim") OR TITLE-ABS-KEY ("Construction" AND "FIDIC" AND "Variation")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "ar"))," is designed to capture publications that focus on 'Construction,' 'FIDIC,' along with either 'Claim' or 'Variation.'

Recognizing the enduring significance of 'construction claims' as a topic of research in the construction sector, the authors decide against setting a time restriction for the publications. Initially, 62 articles are retrieved through this process. To ensure the quality and relevance of the review, inclusion and exclusion criteria are established. Articles not in English and those not categorized as either 'journal articles' or 'conference articles' are excluded. This refining process narrows down the selection to 49 manuscripts, which are then downloaded and meticulously reviewed.

For deeper analysis, VOS-viewer software, an open-source tool acclaimed for its capability to construct and visualize bibliometric networks, is utilized. This software applies the visualization of similarities (VOS) technique, as formulated by (van Eck & Waltman, 2010), for this analysis. The process includes examining all keywords found in the selected publications, with a predetermined threshold set to include those appearing at least twice. Among 324 keywords, 54 meet this criterion, revealing six main thematic clusters in the analysis as shown in Figure 2. These clusters are visually

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represented in a keyword co-occurrence network, where each cluster is color-coded, and the size of each node (keyword) indicates its frequency of occurrence. The relationships between keywords are depicted through arcs, with the thickness of each line signifying the strength of the relationship. The clusters identified are: the yellow cluster representing 'contractors,' the red cluster for 'construction industry and EOT,' the green cluster signifying 'construction project management,' the purple cluster for 'civil engineering,' the blue cluster denoting 'construction and FIDIC,' and the sky blue cluster for 'construction contracts.' The most prominent keyword, serving as the central node in this network, is 'construction projects'.

This visualization, despite not being constrained by strict keyword thresholds, highlights a critical observation: previous studies have not extensively explored the causes of claims and variations within the context of FIDIC contracts. This gap in the literature underscores the necessity for this research to delve deeply into these aspects, thereby contributing to a more comprehensive understanding of Variations and Claims in construction contracts under FIDIC regulations.

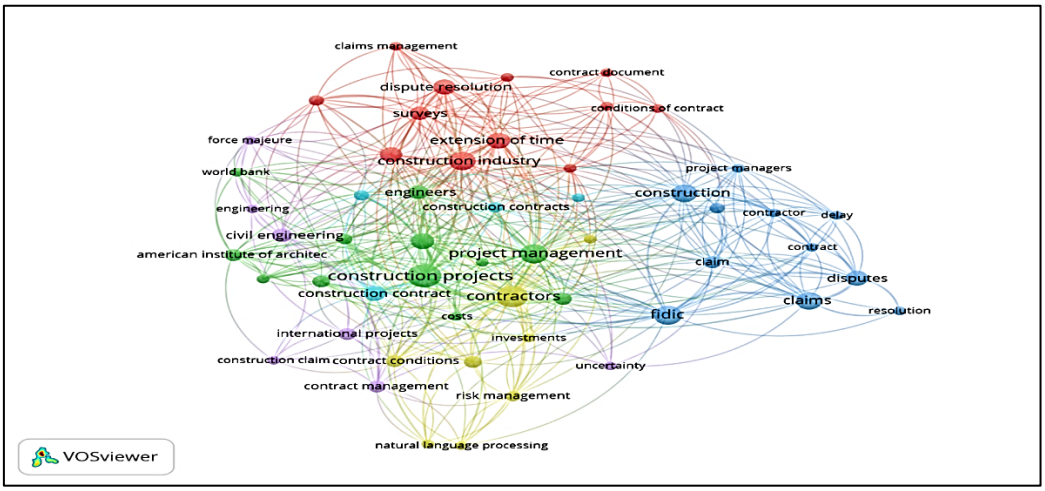

Figure 2. Co-occurrence of the top keywords.

The insights gained from this scientometric analysis not only affirm the significance of the research topic within both academic and industry circles but also provide a foundational guide for the direction and emphasis of subsequent stages of investigation. This ensures that the research approach is both comprehensive and well-informed, addressing the complexities of Variations and Claims in a manner that is grounded in the current state of academic and industry understanding. This stage of the research, therefore, serves as a critical stepping stone in developing a nuanced and contextually relevant exploration of the subject matter, aiming to contribute meaningfully to the field of construction management and contract administration.

Literature Study

Variations and Claims generally arise between the employer and the contractor due to their respective rights and obligations under the Contract Clauses; or due to some events or circumstances. The FIDIC Conditions of Contract tried to ensure the balanced rights of all parties even at the exposure of the employers, engineers and contractors to claims.

1.1. Classification of Variations and Claims

According to the terms of Conditions of Contract for Construction of building and engineering works designed by the employer (FIDIC 1999), Variations and Claims between the Employer and the Contractor, they are classified into: Time Claims, Cost Claims and Profit Claims as per Table 1.

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Table 1. Classification of Claims according to FIDIC 1999.

No.	FIDIC Sub-Clause	Claim Description	Claim Party		Sort of Claim (Additional)		
			Employer (E)	Contractor (C)	Cost (C)	Profit (P)	Time (T)
1	4.2.a	Failure to extend validity of the performance security	E		C		
2	4.2.b	Failure to pay agreed amount due.	E		C		
3	4.14	Avoidance of Interference	E		C		
4	4.16	Damages, losses and expenses resulting from Transport	E		C		
5	4.19	Payment of electricity, water or gas	E		C		
6	4.2	Employer's equipment or free-issue materials	E		C		
7	7.5	Rejection of defective plant and / or materials	E		C		
8	7.6	Contractor's failure to remedy defects	E		C		
9	8.6	Revised methods of working due to poor rate of progress	E		C		
10	8.7	Delay damages	E		C		
11	9.4	Failed tests on completion	E		C		
12	11.4	A failure to rectify defects	E		C		
13	15.4	Termination by employer	E		C		
14	18.1	Contractor's failure to insure	E		C		
15	18.2	Contractor's inability to insure	E		C		
16	1.9	Delayed drawings or instructions		C	C	P	T
17	2.1	Right of access to, or possession of the site		C	C	P	T
18	4.2	Delay of performance security payment after performance certificate issuing		C	C	P	T
19	4.7	Errors in setting out information		C	C	P	T
20	4.12	Unforeseen physical conditions		C	C		T
21	4.24	Fossils, ancient artifacts, archaeological or geological items		C	C		T
22	7.4	Additional tests instructed by the engineer		C	C	P	T
23	8.4.a	A variation or significant change to the quantities		C			T
24	8.4.c	Unusual bad weather		C			T
25	8.4.d	Shortage of personnel or goods		C			T
26	8.4.e	Employer's delay or impediment		C			T
27	8.5	Delays caused by authorities		C			T
28	8.9	Suspension and/or resuming work after suspension		C	C		T
29	10.2	The Employer using part of the works		C	C	P	
30	10.3	Prevention from undertaking tests on completion		C	C	P	T
31	12.4	An omission of works		C	C		T
32	13.2	An adopted value engineering proposal		C	C	P	
33	13.7	Changes in legislation		C	C		T
34	14.8	Delayed payment		C	C		
35	16.1	Suspension initiated by the contractor		C	C	P	T
36	16.4	Termination initiated by the contractor		C	C	P	
37	17.1	Damage or injury caused by Employer's personnel agents		C	C		
38	17.4	Ambiguity in Documents		C	C	P	T

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39	17.4	Loss or damage to the works caused by Employer's Risks (poor design etc.)	C	C	P	T
40	18.1	Insurances supplied by the Employer's	C	C		
41	19.4	Force Majeure	C	C	P	T
42	19.6	Optional payment and release due to termination	C	C	P	
43	5.2	Refusal of contractor objection to nomination	C	C	P	T
44	11.8	An instruction to search for defect	C	C	P	T
45	8.3	Acceleration of Works	C	C	P	T
46	8.10	Payment for plant and material in event of suspension	C	C		
47	16.2	Client's Breach of Contract	C	C	P	
48	16.2	Inflation / Price Escalation	C	C	P	
49	16.2	Currency Fluctuation	C	C	P	
50	5.2	Default of Nominated Subcontractor or Suppliers	C	C	P	T
51	19.6	Rectification of Damage Due to Unexpected Risk	C	C	P	T

1.1. Causes of Variations and Claims

According to the terms of Conditions of Contract for Construction of building and engineering works designed by the employer (FIDIC 1999), causes of variations and claims can be classified as shown in Table 2.

Table 2. Causes of Claims according to FIDIC 1999.

No.	List of Causes	No.	List of Causes
01	Inadequate/ Inaccurate Design Information	16	Inappropriate/ Unexpected Cost Control (Target)
02	Inadequate Design Documentation	17	Inappropriate/ Unexpected Quality Control (Target)
03	Inadequate Brief	18	Poor Communications Among Project Participants
04	Unclear & Inadequate Specifications	19	Lack of Information for Decision Making; (Decisiveness)
05	Inappropriate Contract Type (Strategy)	20	Slow Client Response
06	Inappropriate Contract Form	21	Changes by Client
07	Inadequate Contract Administration	22	Lack of Competence of Project Participants
08	Inadequate Contract Documentation	23	Poor Workmanship
09	Incomplete Tender Information	24	Inadequate Site Investigation
10	Inappropriate Contractor Selection	25	Unrealistic Information Expectations (By Contractor)
11	Unrealistic Tender Pricing	26	Lack of Team Spirit Among Participants
12	Unrealistic Client Expectations	27	Personality Clashes Among Project Participants
13	Inappropriate Payment Method	28	Poor Management By One or More Project Participants
14	Inappropriate Document Control	29	Adversarial Culture Among project Participants
15	Inappropriate/ Unexpected Time Control	30	Uncontrollable External Events
		31	Exaggerated Claims

1.1. Significance and Avoid ability

Significance and avoid-ability are two key issues that have been addressed of real strategy for reducing Variations and Claims Causes. The Significance of causes reflects its potentiality to occur and adversely affects the overall performance of construction projects. Avoid-ability is more concerned with the precautions and preventive procedures that can reduce the consequences of

 doi:10.20944/preprints202404.2016.v1

variations and claims. Both of them are essential in studying causes of claims and recommended responses.

Methods and Techniques

1.1. Characteristics of the Survey Targeted Participants and Statistical Investigation

The sample size for the survey was determined with consideration for the limited availability of Claims & Disputes experts. To ensure a statistically representative sample of the population, the following formula was used for the initial calculation:

$$m = \frac{z^2 \times p \times (1-p)}{\varepsilon^2} = \frac{(1.96)^2 \times 0.5 \times (1-0.5)}{(0.05)^2} = 384$$ (1): Sample Size.

This calculation is based on:

A confidence level value (z) of 1.96 indicates a 95% confidence level, an estimated proportion (p) of 0.5, commonly used when the exact proportion is unknown. A margin of error (ε) set at 0.05, equating to 5%.

The initial sample size calculated using this formula was 384. However, due to the finite population of Claims & Disputes experts, a correction was applied to this initial figure. The corrected sample size (n) was determined by the following equation, which accounts for the limited population size:

$$n = \frac{m}{1+\frac{m-1}{N}} = \frac{384}{1+\frac{384-1}{110}} \approx 80$$ *(2): Correction for Limited Sample Population*

In this equation, N represents the total population of Claims & Disputes experts. This adjustment resulted in a final sample size of approximately 80. This methodological approach is critical to ensure that the sample size is adequately representative of the expert population, enhancing the reliability of the survey results.

The characteristics of respondents were classified and denoted into six groups; PC01, PC02, PC03, PC04, PC05 and PC06 as shown in figures 3 and 4. Those are: the role of respondents and managerial level in their firms, personal respondent's experiences and organization's past experiences and finally the business in hand in terms of number of projects operated by company. This information was collected through respondents' profile part in the questionnaire.

1.1. Participant Profiles and Group Classifications in the Survey

- The survey categorized respondents into six distinct groups, each defined by specific criteria that captured various dimensions of their professional profiles. This categorization facilitated a detailed analysis of the data, allowing for nuanced insights into industry practices. The groups were as follows:
- PC01 - Role of the Respondent (Identity): This classification focused on the professional role of each respondent, identifying their specific position or function within their organization.
- PC02 - Detailed Managerial Level: Respondents were classified based on their managerial level within their organizations, offering insights into the decision-making hierarchy and leadership structure.
- PC03 - Years of Experience: This category evaluated the individual professional experience of each respondent, highlighting the depth and range of their expertise in the industry.
- PC04 - Organization/Firm's Experience (Firm's Number of Years in Business): This group focused on the longevity and historical context of the organizations represented, providing an understanding of the firm's experience and stability in the industry.
- PC05 - Organization/Firm's Annual Number of Projects: This classification detailed the scale and scope of operations of the respondents' firms, based on the number of projects managed or undertaken annually.
- PC06 - Organization/Firm's Number of Employees: This group provided insights into the size and human resource capacity of the organizations, highlighting the scale of their operations in terms of personnel.

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The following Figure 3 and Figure 4 provide a visual representation of these classifications, illustrating the diversity and distribution of the participant pool across these varied criteria. This systematic approach to categorizing the respondents enriched the survey's findings, ensuring a comprehensive understanding of the industry as viewed through the diverse perspectives and experiences of professionals across different roles, managerial levels, and organizational contexts.

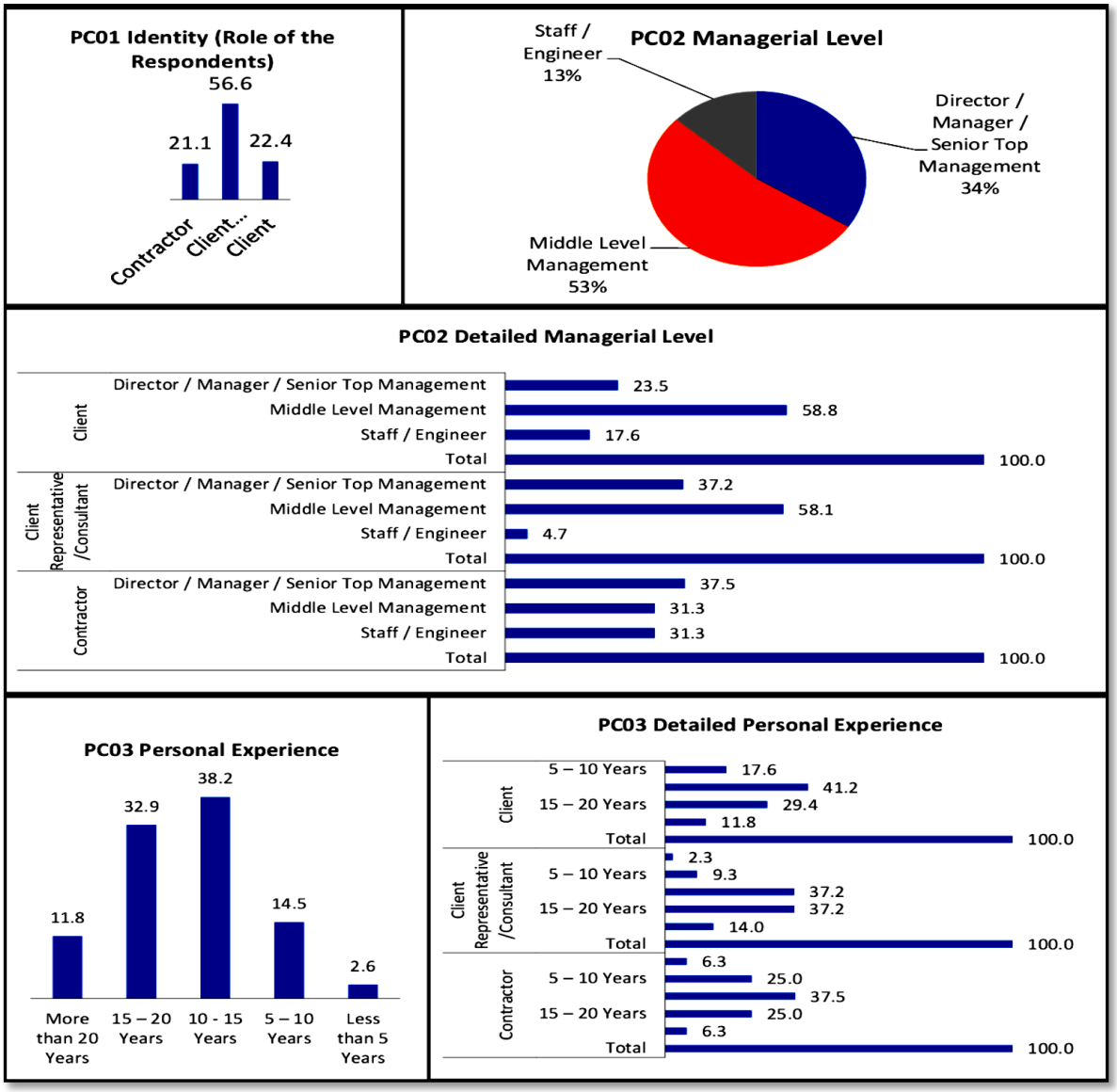

Figure 3. Respondent's Profile (Groups PC01, PC02, PC03).

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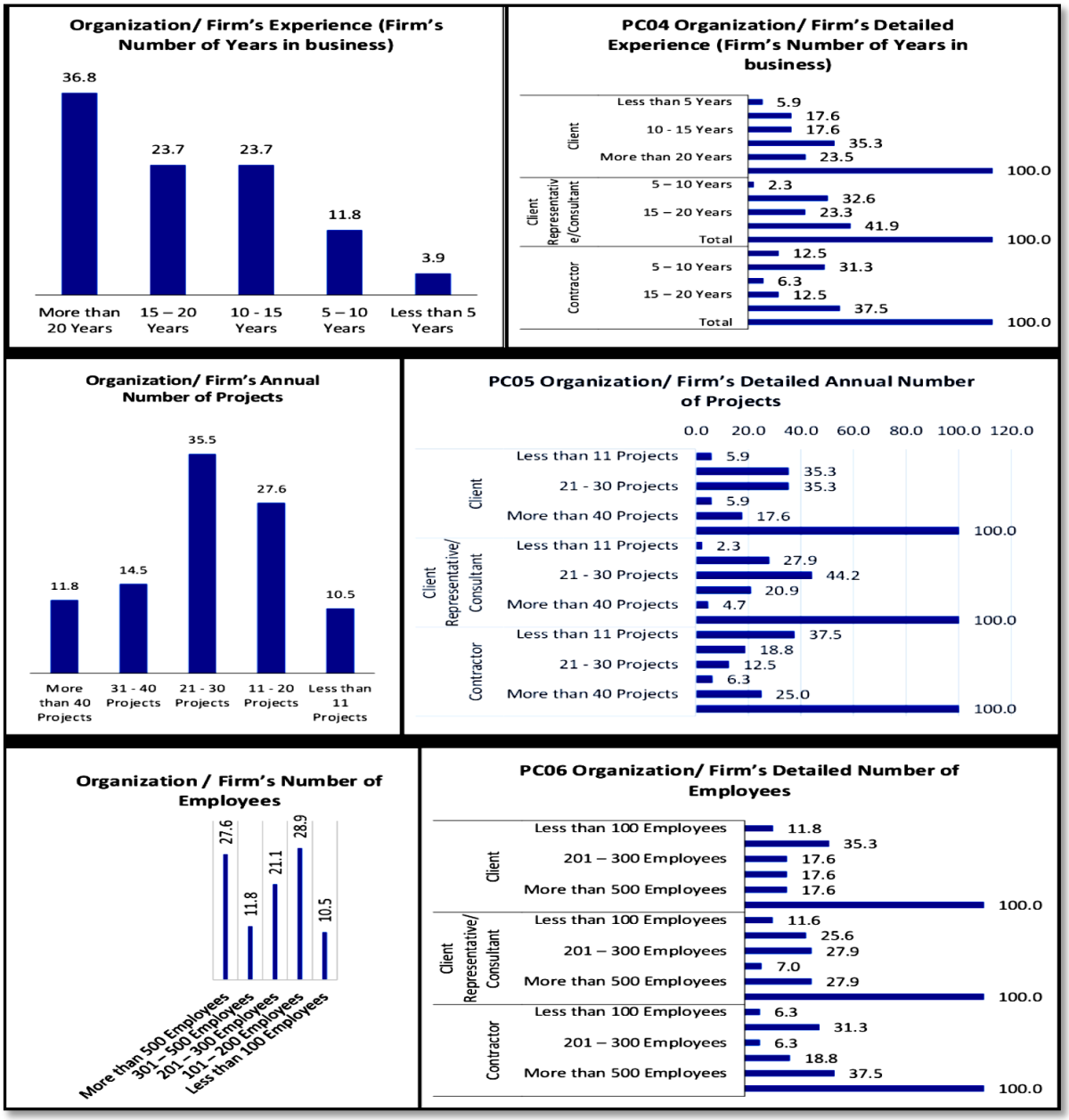

Figure 4. Respondent's Profile (Groups PC04, PC05, PC06).

1.1. Evaluation of Survey Validity and Reliability

The survey underwent a rigorous evaluation for validity and reliability, focusing on types of variations and claims in terms of frequency, impact, and their underlying causes. The validity was quantitatively established with a Cronbach's alpha value of 0.97, indicating a high level of internal consistency since this value notably surpasses the commonly accepted threshold of 0.70. Furthermore, the lowest item-total statistic in the survey did not fall below 0.969, reinforcing the validity of the findings. In terms of reliability, the corrected item-total correlation for all survey factors, both dependent and independent, exceeded 0.30. This statistical affirmation underscores that the survey elements were both reliable and consistent, providing a solid foundation for the study's conclusions.

 doi:10.20944/preprints202404.2016.v1

1.1. Relative Importance Index Test (RII)

The survey incorporated the Relative Importance Index (RII) to analyze participants' perceptions of various factors. Respondents were requested to assign a rating to each factor, ranging from 1 ('very rare') to 5 ('very high'). Absent responses were not assigned any weight in the RII calculation. This rating system facilitated the categorization of responses into five distinct levels of importance: extremely rare (very low), rare (low), average, high, and very high. The application of RII in analyzing the survey results enabled a nuanced understanding of how different factors were perceived in terms of their importance and frequency within the context of the study.

1.1. Assessment of Frequency for Types of Variations and Claims

In assessing the frequency of different types of variations and claims, responses from clients, consultants, and contractors were collectively evaluated, as summarized in Table 3. This comprehensive analysis identified a total of fifty-one distinct types of variations and claims, initially detailed in Table 1. Among these, ten types emerged as the most frequently encountered in projects, as consistently reported across all respondent groups. The remaining forty-one types were notably less frequent, indicating a lower occurrence rate in construction projects.

Table 3. Classification of Claims according to Respondents.

Code#	Type	Type Frequency					Type Frequency Index		
		Very Low	Low	Average	High	Very High	Mean	RII	Rank
T16	Delayed drawings or instructions	1	5	48	16	6	3.28	65.53	1
T23	A variation or significant change to the quantities	3	4	44	19	6	3.28	65.53	2
T38	Ambiguity in Documents	5	13	43	11	4	2.95	58.95	3
T45	Acceleration of Works	3	10	54	9	0	2.91	58.16	4
T31	An omission of work forming	3	18	48	7	0	2.78	55.53	5
T34	Delayed payment	2	25	43	4	2	2.72	54.47	6
T25	Shortage of personnel or goods	2	38	29	4	3	2.58	51.58	7
T07	Rejection of defective plant and / or materials	3	36	30	7	0	2.54	50.79	8
T09	Revised methods of working due to slow progress	3	38	28	6	1	2.53	50.53	9
T10	Delay damages	3	36	33	2	2	2.53	50.53	10

1.1. Assessment of Impact for Types of Variations and Claims

The impact assessment of variations and claims, based on the collective feedback from clients, consultants, and contractors, is presented in Table 4. This evaluation aimed to understand the severity of different types of variations and claims as experienced in the industry. The analysis revealed that thirty-two types of variations and claims were frequently identified as having a significant impact on construction projects. In contrast, nineteen types were perceived to have a less severe impact, suggesting that their occurrence typically results in less disruption or fewer consequences for the projects involved.

Table 4. Causes of Claims according to Respondents.

Code#	Type	Type Impact					Type Impact Index		
		Very Low	Low	Average	High	Very High	Mean	RII	Rank
T39	Loss or damage to the works caused Employer's Risks (War, riots, munitions, poor design ..	6	2	4	18	46	4.26	85.26	1

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T47	Client's Breach of Contract	4	5	2	21	44	4.26	85.26	2
T16	Delayed drawings or instructions	1	3	7	34	31	4.20	83.95	3
T41	Force Majeure	3	7	7	24	35	4.07	81.32	4
T27	Delays caused by authorities	2	4	3	46	21	4.05	81.05	5
T38	Ambiguity in Documents	1	4	7	42	22	4.05	81.05	6
T33	Changes in legislation	7	3	2	40	24	3.93	78.68	7
T23	A variation or change of the quantities	2	1	16	42	15	3.88	77.63	8
T26	Employer's delay or impediment	4	1	23	41	7	3.61	72.11	9
T48	Inflation / Price Escalation	3	2	27	34	10	3.61	72.11	10

1.1. Causes of Variations and Claims (Perceived Agreement Assessment)

Every replying group affirmed to the possibility that the majority of the causes listed above could result in claims and variances in construction projects. With varying degrees of agreement, each group concurred that there are 31 possible causes that could lead to these kinds of construction variations and claims. This illustrates the disparities in agreement as each group perceived it. The assessment of the cause by the different responding groups (i.e., clients, consultants, and contractors) was compared using Table 5. The generation of different kinds of construction variations and claims can be attributed to these thirty-one proposed causes. Furthermore, based on their experiences and backgrounds, the respondents were evidently biased in some way, according to the data. But this bias is not unexpected—in fact, other people have already noted it such as Kumaraswamy (1997).

Table 5. Causes of Claims Assessment according to Respondents.

Code	Cause Description	Clients	Consultants	Contractors	Overall
C01	Inadequate/ Inaccurate Design Information	100.00%	100.00%	93.80%	98.68%
C21	Changes by Client	100.00%	97.70%	87.50%	96.05%
C19	Lack of Information for Decision Making; (Decisiveness)	100.00%	93.00%	93.80%	94.74%
C23	Poor Workmanship	100.00%	90.70%	100.00%	94.74%
C30	Uncontrollable External Events	100.00%	93.00%	93.80%	94.74%
C02	Inadequate Design Documentation	94.10%	95.30%	87.50%	93.42%
C04	Unclear & Inadequate Specifications	94.10%	97.70%	81.30%	93.42%
C16	Inappropriate/ Unexpected Cost Control (Target)	100.00%	93.00%	87.50%	93.42%
C09	Incomplete Tender Information	88.20%	95.30%	87.50%	92.11%
C15	Inappropriate/ Unexpected Time Control (Target)	100.00%	93.00%	81.30%	92.11%
C22	Lack of Competence of Project Participants	94.10%	93.00%	81.30%	92.11%
C05	Inappropriate Contract Type (Strategy)	88.20%	95.30%	81.30%	90.79%
C08	Inadequate Contract Documentation	94.10%	93.00%	81.30%	90.79%
C18	Poor Communications Among Project Participants	100.00%	90.70%	81.30%	90.79%

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C20	Slow Client Response	100.00%	90.70%	81.30%	90.79%
C31	Exaggerated Claims	100.00%	93.00%	75.00%	90.79%
C07	Inadequate Contract Administration	88.20%	95.30%	75.00%	89.47%
C11	Unrealistic Tender Pricing	100.00%	86.00%	87.50%	89.47%
C14	Inappropriate Document Control	100.00%	86.00%	87.50%	89.47%
C24	Inadequate Site Investigation	94.10%	88.40%	87.50%	89.47%
C03	Inadequate Brief	94.10%	88.40%	81.30%	88.16%
C12	Unrealistic Client Expectations	100.00%	86.00%	81.30%	88.16%
C17	Inappropriate/ Unexpected Quality Control (Target)	100.00%	81.40%	93.80%	88.16%
C26	Lack of Team Spirit Among Participants	94.1%	90.70%	75.00%	88.16%
C28	Poor Management By One or More Project Participants	94.1%	86.00%	87.50%	88.16%
C10	Inappropriate Contractor Selection	94.1%	88.40%	75.00%	86.84%
C06	Inappropriate Contract Form	88.20%	88.40%	75.00%	85.53%
C25	Unrealistic Information Expectations (By the Contractor)	94.10%	86.00%	75.00%	85.53%
C27	Personality Clashes Among Project Participants	94.10%	86.00%	75.00%	85.53%
C29	Adversarial (industry) Culture Among project Participants	94.10%	86.00%	75.00%	85.53%
C13	Inappropriate Payment Method	94.10%	86.00%	68.80%	84.21%

1.1. Causes of Variations and Claims (Perceived Significance Assessment)

The responses for the cause's significant assessment from the viewpoint of all respondents, for the first 10 categories of variations and claims, are shown in Table 6.

Table 6. Assessment of Claims Significance according to Respondents (Top Ten).

Code #	Cause Description	Cause Significance					Cause Significance Index		
		Very Low	Low	Average	High	Very High	Mean	RII	Rank
C15	Inappropriate/ Unexpected Time Control (Target)	3	3	7	16	47	4.33	86.58	1
C10	Inappropriate Contractor Selection	1	3	8	23	41	4.32	86.32	2
C05	Inappropriate Contract Type	4	3	8	12	49	4.30	86.05	3
C16	Inappropriate/ Unexpected Cost Control (Target)	3	4	7	15	47	4.30	86.05	3
C21	Changes by Client	3	3	6	20	44	4.30	86.05	3
C19	Lack of (Decisiveness)	2	6	5	18	45	4.29	85.79	4

 doi:10.20944/preprints202404.2016.v1

C20	Slow Client Response	2	5	5	28	36	4.20	83.95	5
C17	Inappropriate/ Unexpected QC	5	2	10	22	37	4.11	82.11	6
C01	Inadequate/ Inaccurate Design	2	3	7	38	26	4.09	81.84	7
C06	Inappropriate Contract Form	5	4	6	25	36	4.09	81.84	7

1.1. Causes of Variations and Claims (Perceived Avoid ability Assessment)

Analysis was done on the responses from the different groups about the Avoidability of factors that can lead to or "trigger" the kinds of variations and claims. Nonetheless, the analysis of the total response data is presented in this section. The answers for the top ten avoidable causes of variations and claims are shown in Table 7.

Table 7. The Top Ten Avoidable Causes of Variations and Claims.

Code #	**Cause Description**	**Cause Avoid-ability**					**Cause Avoid-ability Index**		
		Very Low	**Low**	**Average**	**High**	**Very High**	**Mean**	**RII**	**Rank**
C10	Inappropriate Contractor Selection	2	5	23	41	5	3.55	71.05	1
C13	Inappropriate Payment Method	4	3	20	47	2	3.53	70.53	2
C06	Inappropriate Contract Form	3	7	25	31	10	3.50	70.00	3
C05	Inappropriate Contract Type (Strategy)	3	6	31	24	12	3.47	69.47	4
C01	Inadequate/ Inaccurate Design Information	2	5	34	31	4	3.39	67.89	5
C24	Inadequate Site Investigation	1	5	39	26	5	3.38	67.63	6
C04	Unclear & Inadequate Specifications	1	7	40	25	3	3.29	65.79	7
C02	Inadequate Design Documentation	1	8	44	19	4	3.22	64.47	8
C08	Inadequate Contract Documentation	1	10	42	21	2	3.17	63.42	9
C07	Inadequate Contract Administration	4	4	51	15	2	3.09	61.84	10
C09	Incomplete Tender Information	1	8	53	11	3	3.09	61.84	10

Results and Discussion

In this study, the employment of various statistical analysis methods was pivotal for a comprehensive understanding of the intricate dynamics of Variations and Claims in FIDIC contracts in the MENA region. Each method contributed uniquely to unraveling different facets of the data. Starting with descriptive and inferential statistics allowed for establishing a foundational understanding of the data distribution and relationships among variables. Advancing to more complex analyses like the Relative Importance Index (RII) and Spearman's Correlation, deeper insights into the significance and interconnectedness of factors influencing Variations and Claims were obtained. The culmination of the analysis with k-means clustering, a robust unsupervised machine learning technique, enabled the classification of vast and complex data into meaningful categories. This facilitated the identification of distinct patterns and trends, which might not have been discernible through simpler analytical methods. By concluding with k-means clustering, the study provided actionable insights and targeted recommendations, ensuring that findings were not only statistically significant but also practically relevant to industry stakeholders.

1.1. Analysis of the findings (Statistical Hypothesis- Kruskal Wallis Test)

Nothing presumptive exists in the Kruskal-Wallis Test. The alternative hypothesis states that the samples originate from distinct populations, while the null hypothesis states that the samples are from the same populations. The p-value was compared to the significance level in order to evaluate the null hypothesis and determine whether any of the differences between the medians are

 doi:10.20944/preprints202404.2016.v1

statistically significant. According to the null hypothesis, each population median is equal. Typically, a significance threshold of 0.05 (represented as α or alpha) is effective. A 5% chance of determining that a difference exists when there isn't one is indicated by a significance level of 0.05. P-value < α indicates statistical significance in the discrepancies between some of the medians. The null hypothesis is true if the p-value is less than or equal to the significance level.

The majority of the six group respondents to this statistical test said that, with the exception of T12, which is statistically significant in relation to Personal Experience (PC03) with a p-value of less than 0.05, the differences between the medians are not statistically significant. As a result, not all group medians are equal and the null hypothesis was rejected. Furthermore, T14's relationship to Organization/Firm's Experience (Firm's Number of Years in Business) (PC04) was determined to be statistically significant with a p-value of 0.01. The null hypothesis was rejected, indicating that not all item medians are identical, and T16 was also statistically significant in relation to Organization/Firm's Experience (Firm's Number of Years in Business) (PC04), with a p-value of =0.009 (lower than 0.05). T39 showed statistical significance in relation to the organization's or firm's Annual Number of Projects (PC05) with p-value =0.007. In terms of frequency, it is evident that the majority of variations and claims have no disparities between the medians that are statistically significant, refer to Table 8.

Table 8. Kruskal Wallis Test & P-Value (Types of Variations and Claims – in terms of Frequency).

Code	Type	Role of the Respondents (PC01)		Managerial Level (PC02)		Personal Experience (PC03)		Organization/ Firm's Experience (Years) (PC04)		Organization/ Firm's Annual Number of Projects (PC05)		Organization/ Firm's Number of Employees (PC06)	
		Kr us kal	(P-Val	Kr us kal	(P-Val	Kr us kal	(P-Val	Kr us kal -	(P-Val	Kr us kal	(P-Val	Kr us kal	(P-Val
T12	A failure to rectify defects	3.757	0.153	0.880	0.644	10.716	0.030	.0.27	0.866	1.495	0.828	1.233	0.873
T14	Contractor's failure to insure	0.389	0.823	1.935	0.380	4.351	0.361	12.058	0.017	6.596	0.159	2.853	0.583
T16	Delayed drawings or instructions	0.741	0.690	2.696	0.260	1.402	0.844	13.614	0.009	6.451	0.168	1.103	0.894
T36	Termination initiated by the contractor	5.676	0.059	2.776	0.250	3.372	0.498	10.077	0.039	2.345	0.673	15.413	0.004
T39	Loss or damage to the works caused Employer's Risks	1.232	0.540	0.949	0.622	6.340	0.175	7.578	0.108	14.220	0.007	6.147	0.188

1.1. Kruskal Wallis Test (Types of Variations and Claims – Impact)

For this statistical test, most of the group respondents (PC01, PC02, PC03, PC04, PC05, PC06) responded that the differences between the medians are not statistically significant except for PC01 group we find that T11, T49, T02, T21, T45, T27, T38 and T43 with p-value of 0.002,0.005,0.007,0.035,0.040,0.041,0.042 and 0.049 respectively. In addition, for the Managerial level; PC02 group, was found that T32, T29, T22 and T25 are statistically significant with p-value = 0.026, 0.028, 0.038 and 0.046 respectively. Also, for PC03 group note that only one type T49 is statistically

 doi:10.20944/preprints202404.2016.v1

significant with p-value =0.0.044. For PC04 group the two types T02, T11 are statistically significant with p-value =0.012 and 0.021 respectively For PC05 group the two types T16, T39 are statistically significant with p-value =0.009 and 0.013 respectively. Finally, PC06 group there are three types T16, T47 and T26 are statistically significant with p-value =0.032, 0.040 and 0.040. It is clear that the most of types of variations and claims in terms of impact have no differences between the group respondents' medians which are not statistically significant as shown in Table 9.

Table 9. Kruskal Wallis Test & P-Value (Types of Variations and Claims – in terms of Impact).

Code	Type	Role of the Respondents (PC01)		Managerial Level (PC02)		Personal Experience (PC03)		Firm's Experience in business) (PC04)		Firm's Annual Number of Projects (PC05)		Firm's Number of Employees (PC06)	
		Kr	(P-Val	Kr	(P-Val	Kr	(P-Val	Kr	(P-Val	Kr	(P-Val	Kr	(P-Val
T02	Failure to pay agreed amount due.	9.810	**0.007**	0.853	0.653	5.711	0.222	12.868	**0.012**	1.668	0.797	0.941	0.919
T11	Failed tests on completions	12.143	**0.002**	0.980	0.613	1.286	0.864	11.567	**0.021**	4.106	0.392	1.291	0.863
T16	Delayed drawings or instructions	4.236	0.120	1.286	0.526	6.177	0.186	5.823	0.213	13.615	**0.009**	10.538	**0.032**
T21	Fossils, archaeological or geological	6.722	**0.035**	0.806	0.668	0.793	0.939	7.127	0.129	1.836	0.766	4.559	0.336
T22	Additional tests by the engineer	4.437	0.109	6.532	**0.038**	4.671	0.323	1.841	0.765	3.470	0.482	1.201	0.878
T25	Shortage of personnel or goods	4.334	0.115	6.174	**0.046**	6.841	0.145	2.121	0.713	2.726	0.605	1.870	0.760
T26	Employer's delay or impediment	2.120	0.346	4.185	0.123	0.414	0.981	1.632	0.803	2.038	0.729	10.035	**0.040**
T27	Delays caused by authorities	6.376	**0.041**	1.003	0.606	1.882	0.757	4.640	0.326	11.746	0.019	5.343	0.254
T29	Employer using works partially	0.105	0.949	7.149	**0.028**	3.864	0.425	4.435	0.350	5.405	0.248	2.994	0.559
T32	Adopt value engineering proposal	2.326	0.312	7.327	**0.026**	0.248	0.993	2.123	0.713	3.247	0.517	0.491	0.974
T38	Ambiguity in Documents	6.357	**0.042**	0.663	0.718	2.917	0.572	1.028	0.906	0.964	0.915	4.404	0.354
T39	Loss or damage to the works caused Employer's Risks	3.103	0.212	2.344	0.310	5.551	0.235	3.117	0.538	12.596	0.013	9.185	0.057
T43	Refusal of contractor objection to nomination	6.020	**0.049**	2.210	0.331	6.101	0.192	3.929	0.416	2.498	0.645	1.374	0.849
T45	Acceleration of Works	6.446	**0.040**	1.929	0.381	7.492	0.112	4.239	0.375	3.131	0.536	2.153	0.708
T47	Client's Breach of Contract	4.435	0.109	0.294	0.863	1.745	0.783	5.417	0.247	8.780	0.067	10.051	**0.040**
T49	Currency Fluctuation	10.413	**0.005**	2.801	0.246	9.776	**0.044**	6.154	0.188	2.455	0.653	3.481	0.481

1.1. Kruskal Wallis Test (Cause of Variations and Claims – Agreement)

For this statistical test, most of the group respondents (PC01, PC02, PC03, PC04, PC05, and PC06) responded that the differences between the medians are not statistically significant except for PC01 group; it was found that one cause C31 with p-value of 0.029. In addition, PC02 group we found that no causes are statistically significant. Although, for PC03 group note that only one type C12, C11, C19, C20, C30, C14 and C10 are statistically significant with p-value equals 0.006, 0.009, 0.021, 0.024, 0.026, 0.026 and 0.027 respectively. For PC04 group C04, C06, C08, C10, C14, C07, C12, C29, C11, C17, C20, C25, C13, C28, C24, C03, C27 and C2 are statistically significant with p-value =0.00, 0.00, 0.001, 0.003, 0.005, 0.005, 0.005, 0.010, 0.011, 0.019, 0.021, 0.027, 0.027, 0.039, 0.041, 0.044, 0.048, 0.050 respectively. Too, PC05 group C06, C05, C12, C03, C11, C25, C09 and C29 are statistically significant

 doi:10.20944/preprints202404.2016.v1

with p-value =0.002, 0.003, 0.004, 0.011, 0.015, 0.023, 0.025 and 0.042 respectively. Finally, PC06 group C27, C24, C29, C25, C17, C14, C13, C03, C06, C16, C02, C20, C28, C18, C11, C09, C30, C19 are statistically significant with p-value lower than 0.05. It is clear that the most of causes of variations and claims in terms of agreement have no differences between the group respondents' medians which were not statistically significant as shown in Table 10.

Table 10. Kruskal Wallis Test & P-Value (Types of Variations and Claims – in terms of Agreement**).**

Code	Cause	Role of the Respondents (PC01)		Managerial Level (PC02)		Personal Experience (PC03)		Organization / Firm's Experience (PC04)		Organization / Firm's Annual Number of Projects (PC05)		Organization/ Firm's Number of Employees (PC06)	
		Kruskal	(P-Value)	Kruskal	(P-Value)	Kruskal	(P-Value)	Kruskal	(P-Value)	Kruskal	(P-Value)	Kruskal	(P-Value)
C02	Inadequate Design.	1.221	0.543	2.181	0.336	5.071	0.280	4.855	0.303	6.433	0.169	13.818	**0.008**
C03	Inadequate Brief	0.997	0.608	0.045	0.978	4.924	0.295	9.823	**0.044**	12.967	**0.011**	14.055	**0.007**
C04	Unclear & Inadequate Specs.	4.941	0.085	1.826	0.401	2.462	0.651	21.749	**0.000**	5.655	0.226	5.367	0.252
C05	Inappropriate Contract Type	2.773	0.250	1.178	0.555	7.109	0.130	7.520	0.111	16.349	**0.003**	4.917	0.296
C06	Inappropriate Contract Form	2.015	0.365	2.237	0.327	6.817	0.146	20.442	**0.000**	17.144	**0.002**	14.043	**0.007**
C07	Inadequate Contract Administration	5.267	0.072	1.334	0.513	2.020	0.732	14.674	**0.005**	4.553	0.336	0.854	0.931
C08	Inadequate Contract Documents	2.433	0.296	2.508	0.285	8.510	0.075	18.180	**0.001**	8.729	0.068	9.314	0.054
C09	Incomplete Tender Information	1.577	0.455	0.046	0.977	5.389	0.250	6.898	0.141	11.187	**0.025**	11.288	**0.024**
C10	Inappropriate Contractor Selection	2.707	0.258	3.805	0.149	10.949	0.027	15.995	0.003	7.654	0.105	6.037	0.196
C11	Unrealistic Tender Pricing	2.557	0.278	3.768	0.152	13.541	**0.009**	13.012	0.011	12.290	**0.015**	11.334	**0.023**
C12	Unrealistic Client Expectations	3.224	0.199	2.811	0.245	14.404	**0.006**	14.668	0.005	15.187	0.004	7.866	0.097
C13	Inappropriate Payment Method	4.218	0.121	1.526	0.466	6.919	0.140	10.975	**0.027**	9.080	0.059	16.076	**0.003**
C14	Inappropriate Document Control	2.581	0.275	1.700	0.427	11.051	0.026	15.091	**0.005**	7.038	0.134	16.094	**0.003**
C16	Inappropriate/ Unexpected Cost Control (Target)	2.024	0.364	1.731	0.421	7.469	0.113	5.733	0.220	5.949	0.203	13.823	**0.008**
C17	Inappropriate/ Unexpected Quality Control (Target)	4.758	0.093	0.106	0.948	8.535	0.074	11.844	0.019	9.188	0.057	19.021	**0.001**
C18	Poor Communications	3.506	0.173	0.358	0.836	6.813	0.146	4.159	0.385	2.665	0.615	13.069	**0.011**
C19	Lack of (Decisiveness)	1.221	0.543	0.804	0.669	11.500	**0.021**	7.138	0.129	7.686	0.104	10.905	**0.028**
C20	Slow Client Response	3.472	0.176	4.648	0.098	11.252	**0.024**	11.589	**0.021**	8.602	0.072	13.742	**0.008**
C21	Changes by Client	3.959	0.138	1.537	0.464	6.285	0.179	9.489	**0.050**	5.426	0.246	4.777	0.311
C24	Inadequate Site Investigations	0.464	0.793	0.011	0.995	6.324	0.176	9.965	0.041	7.853	0.097	23.056	**0.000**
C25	Unrealistic Expectations (By the Contractor)	2.574	0.276	0.726	0.696	6.848	0.144	10.994	0.027	11.313	0.023	19.155	**0.001**
C27	Personality Clashes of Participants	2.463	0.292	0.866	0.648	5.909	0.206	9.581	0.048	9.259	0.055	25.707	**0.000**
C28	Poor Management By Participants	0.738	0.692	0.047	0.977	8.442	0.077	10.064	**0.039**	5.525	0.238	13.343	**0.010**
C29	Adversarial Cultural Affairs	2.141	0.343	0.640	0.726	6.980	0.137	13.252	**0.010**	9.925	**0.042**	19.660	**0.001**

 doi:10.20944/preprints202404.2016.v1

C30	Uncontrollable External Events	1.213	0.545	0.857	0.651	11.095	**0.026**	7.143	0.129	3.248	0.517	10.913	**0.028**
C31	Exaggerated Claims	7.108	**0.029**	1.228	0.541	7.047	0.133	7.527	0.111	7.732	0.102	4.664	0.324

1.1. Kruskal Wallis Test (Cause of Variations and Claims – Significance)

Similarly, most of the group respondents (PC01, PC02, PC03, PC04, PC05, PC06) responded that the differences between the medians are not statistically significant except for PC01 group we found that causes C29, C20, C12, C03, C01, C07, C23, C15, C28, C05, C11, C18 and C09 with p-value of 0.001, 0.004, 0.009, 0.011, 0.012, 0.012, 0.019, 0.025, 0.031, 0.0310, 035, 0.037 and 0.046 respectively. In addition, PC02 group has no causes are statistically significant. Although, for PC03 group have three types C04, C10 and C20 are statistically significant with p-value =0.025, 0.039, and 0.043 respectively. As well PC04 group has three causes C04, C11 and C18 are statistically significant with p-value =0.014, 0.020 and 0.039 respectively. Too, PC05 group C20, C15, C21, C10, C05, C01, C29, C16 and C29 are statistically significant with p-value =0.003, 0.006, 0.009, 0.009, 0.012, 0.013, 0.027, 0.027 and 0.048 respectively. Finally, for PC06 group; C17, C15, C05, C07, C10, C19, C21, C16, C08, C24, C13, C06 and C29 are statistically significant with p-value lower than 0.05. It is clear that most of the causes of variations and claims in terms of significance have no differences between the group respondents' medians which are not statistically significant, Table 11.

Table 11. Kruskal Wallis Test & P-Value (Types of Variations and Claims – in terms of Significance).

Code	Cause	Role of the Respondents (PC01)		Managerial Level (PC02)		Personal Experience (PC03)		Organization/ Firm's Experience (Firm's Number of Years) (PC04)		Organization/ Firm's Annual Number of Projects (PC05)		Organization/ Firm's Number of Employees (PC06)	
		Kruskal -	P-Val	Kruskal -	P-Val	Kruskal -	P-Val	Kruskal -	P-Val	Kruskal -	P-Val	Kruskal -	P-Val
C01	Inadequate/ Inaccurate Design	8.92	**0.012**	0.372	0.830	2.069	0.723	4.038	0.401	12.699	**0.013**	8.493	0.075
C03	Inadequate Brief	9.09	**0.01**	1.894	0.388	7.387	0.117	7.114	0.130	3.263	0.515	6.746	0.150
C04	Unclear & Inadequate Specifications	5.04	0.080	2.802	0.246	11.111	**0.025**	12.551	**0.014**	6.064	0.194	7.515	0.111
C05	Inappropriate Contract Type	6.95	**0.031**	0.702	0.704	7.852	0.097	7.395	0.116	12.882	**0.012**	18.944	**0.001**
C06	Inappropriate Contract Form	3.002	0.223	2.110	0.348	5.036	0.284	3.565	0.468	9.563	**0.048**	11.976	**0.018**
C07	Inadequate Contract Administration	8.91	**0.012**	0.579	0.749	3.059	0.548	4.436	0.350	7.796	0.099	17.400	**0.002**
C08	Inadequate Contract Docs.	1.83	0.400	2.267	0.322	4.009	0.405	4.619	0.329	4.800	0.308	12.948	**0.012**
C09	Incomplete Tender Information	6.14	**0.046**	2.411	0.300	6.970	0.138	7.981	0.092	3.713	0.446	4.670	0.323
C10	Inappropriate Contractor Selection	2.00	0.367	2.025	0.363	10.113	**0.039**	8.103	0.088	13.516	**0.009**	16.415	**0.003**
C11	Unrealistic Tender Pricing	6.71	**0.035**	0.233	0.890	8.069	0.089	11.710	**0.020**	2.540	0.637	8.474	0.076
C12	Unrealistic Client Expectations	9.49	**0.009**	1.183	0.554	1.880	0.758	5.153	0.272	5.957	0.202	9.015	0.061
C13	Inappropriate Payment Method	4.63	0.099	0.846	0.655	3.483	0.480	2.253	0.689	7.175	0.127	12.042	**0.017**
C14	Inappropriate Document Control	1.72	0.421	0.108	0.947	4.141	0.387	1.238	0.872	5.515	0.238	4.552	0.336
C15	Inappropriate/ Unexpected Time Control (Target)	7.34	**0.025**	0.011	0.995	7.869	0.096	7.247	0.123	14.352	**0.006**	21.28	**0.000**
C16	Inappropriate/ Unexpected Cost Control (Target)	4.14	0.126	1.456	0.483	5.846	0.211	5.821	0.213	10.956	**0.027**	13.44	**0.009**
C17	Inappropriate/ Unexpected Quality Control (Target)	4.85	0.088	2.925	0.232	5.286	0.259	7.227	0.124	7.661	0.105	21.705	**0.000**
C18	Poor Communications	6.59	**0.037**	1.379	0.502	3.132	0.536	10.064	**0.039**	3.327	0.505	2.739	0.602
C19	Lack of Decisiveness	4.63	0.099	2.345	0.310	3.896	0.420	4.594	0.332	8.482	0.075	15.25	**0.004**
C20	Slow Client Response	10.96	**0.004**	0.819	0.664	9.864	**0.043**	4.353	0.360	16.149	**0.003**	6.914	0.140
C21	Changes by Client	4.271	0.118	1.245	0.536	6.882	0.142	7.331	0.119	13.584	**0.009**	15.214	**0.004**
C23	Poor Workmanship	7.948	**0.019**	0.668	0.716	3.692	0.449	7.843	0.098	4.764	0.312	1.142	0.888
C24	Inadequate Site Investigation	0.837	0.658	0.320	0.852	1.904	0.753	8.113	0.088	5.419	0.247	12.387	**0.015**
C28	Poor Management	6.953	**0.031**	0.240	0.887	8.590	0.072	3.515	0.476	2.022	0.732	6.483	0.166
C29	Adversarial Cultural Affairs	15.06	**0.001**	0.075	0.963	4.051	0.399	7.528	0.110	10.968	**0.027**	10.025	**0.040**

1.1. Kruskal Wallis Test (Cause of Variations and Claims – Avoid-ability)

Similarly, most of the group respondents (PC01, PC02, PC03, PC04, PC05 and PC06) responded that the differences between the medians are not statistically significant except for PC01 group; it was

 doi:10.20944/preprints202404.2016.v1

found that three causes C06, C08 and C21 with p-value of 0.011, 0.017 and 0.034 respectively. In addition, PC02 group has no causes statistically significant. Although, for PC03 group have three types C09, C30 and C10 are statistically significant with p-value =0.010, 0.036, and 0.044 respectively. As well PC04 group has three causes; C06, C13 and C02 are statistically significant with p-value =0.020, 0.029 and 0.032 respectively. But, PC05 group has no statistically significant causes. Finally, PC06 group has one statistically significant cause C13 with p-value lower than 0.05 which = 0.008. It is clear that the most causes of variations and claims in terms of avoid-ability have no differences between the group respondents' medians which were not statistically significant, Table 12.

Table 12. Kruskal Wallis Test & P-Value (Types of Variations and Claims – in terms of Avoid ability).

Code	Cause	Kruskal-Wallis H Rol e	(P-Value) e	Kruskal-Wallis H M a n	(P-Value) a n	Kruskal-Wallis H P er s	(P-Value) s	Kruskal-Wallis H O r g a n	(P-Value) a n	Kruskal-Wallis H O r g	(P-Value) g	Kruskal-Wallis H O r g	(P-Value) g a n
C02	Inadequate Design	0.336	0.845	0.989	0.610	3.995	0.407	10.590	**0.032**	9.109	0.058	2.490	0.646
C06	Inappropriate Contract Form	9.055	**0.011**	5.086	0.079	5.691	0.223	11.693	**0.020**	6.923	0.140	6.264	0.180
C08	Inadequate Contract Documents	8.158	**0.017**	1.232	0.540	3.889	0.421	1.588	0.811	2.193	0.700	5.175	0.270
C09	Incomplete Tender Information	2.093	0.351	2.717	0.257	13.175	**0.010**	4.111	0.391	1.753	0.781	2.316	0.678
C10	Inappropriate Contractor Selection	2.769	0.250	2.121	0.346	9.798	**0.044**	1.463	0.833	3.212	0.523	2.881	0.578
C13	Inappropriate Payment Method	1.031	0.597	0.153	0.927	5.576	0.233	10.797	**0.029**	7.427	0.115	13.673	**0.008**
C21	Changes by Client	6.743	**0.034**	4.693	0.096	1.210	0.876	1.191	0.880	2.101	0.717	5.204	0.267
C30	Uncontrollable External Events	0.378	0.828	1.468	0.480	10.300	**0.036**	2.847	0.584	2.727	0.604	3.585	0.465

1.1. Spearman's Correlation Test

The next step was to measure the correlation between the top ten frequented types and top ten significant causes to summarize the strength of relationship between each variable of the two groups. As known that the relationship appears in 3 phases; first phase was that (- r < 0); it means that There is a negative relationship between the two variables. Second phase is that (+ r > 0) which means that there is a positive relationship between the two variables. Third phase is that (r = 0) which means that there is no relationship between the two variables.

To understand spearman correlation coefficient, if the correlation coefficient value (r) = 0 that means no relationship between variables. While if the correlation coefficient value (0.0 < r < 0.25) that indicated a weak positive relationship. For the correlation coefficient value (0.25 ≤ r < 0.75) that indicated an average positive relationship. But if the correlation coefficient value (0.75 ≤ r < 1) that means there was a strong positive relationship. While if the correlation coefficient value equals 1(r = 1) means that the relationship is complete positive relationship.

Regarding the correlation hypothesis if r = 0 there is no relation between the two variables and accepting the zero hypothesis (H0), but if r not equal to 0 there is a relation between the two variables and rejecting the zero hypothesis (H0) and accept the alternative hypothesis (H1).While if sig. > 0.05 then accepting the zero hypothesis (H0), but if sig. < 0.05 the zero hypothesis (H0) will be refused.

1.1.1. Spearman's Correlation Test (Types-Frequency) & (Causes -Significance)

 doi:10.20944/preprints202404.2016.v1

For this statistical test, the correlation between the most frequented types and the most significant causes was conducted by spearman's test. In Table 13, it was appearing that there is a highly positive correlation denoted by red color, related to the p-value. And also those denoted by the green color revealed the correlation relationship between significant causes; C21, C10, C05 and frequent types T16, T23, T38 and T31. While it was lower than 0.05 so, the H0 hypothesis was not accept and accepting the H1 hypothesis alternatively. Similarly, for significant causes C15, C16, C17 had a correlation relationship with frequented types T16, T23, T31.Also significant cause C19 has a correlation with frequent types T16, T23, T45 and T31. In addition, the significant cause C20 had a correlation relationship with frequent types T16, T23, T38 and T31. The same for significant cause C01 had a correlation relationship with frequent types T16, T38, T31, T07 and T09 .Finally, significant cause C06 had a correlation relationship with frequent types T16, T23, T38, T31, T34 and T10. For the correlation hypothesis while significance is lower than 0.05 to reject the H0 zero hypotheses and accept the H1 alternative hypothesis, Table 13.

Table 13. Spearman's Coefficient & Sig. values between the Most Frequented: types of variations/claims & causes.

TYPE (Frequency)			T16	T23	T38	T45	T31	T34	T25	T07	T09	T10
CAUSE (SIGNIF	Correlation (Coefficients)		Delayed drawing	A variatio	Ambiguity in	Acceleration of	An omissio´	Delayed payment	Shortage of	Rejection of	Revised methods	of Delay damages
C21	Changes by Client	Correlation	.397**	.242*	.280*	.148	.366**	.046	.033	.054	-.025	.114
		Sig. (2-tailed)	.000	.035	.014	.202	.001	.694	.780	.644	.830	.325
C10	Significance Inappropriate Contractor Selection	Correlation	.346**	.279*	.236*	.126	.411**	.018	.070	-.002	-.005	.179
		Sig. (2-tailed)	.002	.015	.041	.277	.000	.880	.546	.984	.969	.122
C05	Significance Inappropriate Contract Type (Strategy)	Correlation	.291*	.328**	.251*	.102	.460**	.034	-.038	.066	.049	.140
		Sig. (2-tailed)	.011	.004	.028	.382	.000	.768	.742	.574	.674	.227
C15	Significance Inappropriate/ Unexpected Time Control	Correlation	.229*	.258*	.146	.135	.320**	.037	-.005	.140	.093	.187
		Sig. (2-tailed)	.046	.025	.209	.244	.005	.748	.968	.229	.423	.106
C16	Significance Inappropriate/ Unexpected Cost Control	Correlation	.268*	.306**	.133	.220	.426**	.157	.084	.200	.204	.240*
		Sig. (2-tailed)	.019	.007	.253	.056	.000	.175	.472	.083	.078	.037
C19	Significance Lack of Decisiveness	Correlation	.320**	.333**	.179	.266*	.426**	.019	-.036	.125	.147	.119
		Sig. (2-tailed)	.005	.003	.123	.020	.000	.868	.760	.281	.206	.306
C17	Significance Inappropriate/ Unexpected QC (Target)	Correlation	.304**	.250*	.142	.077	.297**	.021	-.085	.051	.039	.096
		Sig. (2-tailed)	.008	.029	.223	.507	.009	.855	.463	.662	.736	.408
C20	Significance Slow Client Response	Correlation	.389**	.321**	.334**	.099	.457**	.211	.132	.142	-.016	.196
		Sig. (2-tailed)	.001	.005	.003	.393	.000	.067	.256	.222	.890	.089
C01	Significance Inadequate/ Inaccurate Design Information	Correlation	.297**	.192	.237*	.062	.317**	.177	.168	.236*	.240*	.207
		Sig. (2-tailed)	.009	.096	.039	.595	.005	.127	.146	.040	.037	.073
C06	Significance Inappropriate Contract Form	Correlation	.263*	.291*	.265*	.197	.440**	.259*	.004	-.015	-.025	.246*
		Sig. (2-tailed)	.022	.011	.021	.088	.000	.024	.975	.897	.827	.032

1.1.1. Spearman's Correlation Test (Types-Impact) & (Causes -Significance)

Similarly, the correlation between the most impacted types and significant causes was investigated by spearman's test. It is appearing that there is a highly positive correlation for mentioned correlation coefficient by red color, related to p-value (sig.). The green color reveals that there was a correlation relationship between significant causes C21, C16, C17, C20, C01 and Impacted types T39, T47, T16, T41, T27, T38, T33, T23, T26 while it is lower than 0.05. Therefore, rejecting the H0 and accept the H1 hypothesis alternatively. Similarly, for significant cause C10 which had a

 doi:10.20944/preprints202404.2016.v1

correlation relationship with Impacted types T39, T47, T16, T41, T27, T38, T33 and T26. Also, significant causes C05, C15 have a correlation relationship with impacted types T39, T47, T16, T41, T27, T38, T33, T23, T26 and T48. In addition, the significant cause C19 had a correlation relationship with Impacted types T39, T47, T16, T41,T27,T38,T33,T26,T48.Finally for significant cause C06 has a correlation relationship with Impacted types T39, T47, T16, T41, T27, T38, T33 and T26. For the correlation hypothesis, while significance was lower than 0.05, we will not accept the H0 zero hypothesis and accept the H1 alternative hypothesis, Table 14.

Table 14. Spearman's Coefficient & Significant Value between Frequented: Types of Variations/ Claims and Causes.

	TYPE (Impact)		T39	T47	T16	T41	T27	T38	T33	T23	T26	T48
CAUSE (SIGNIF	Correlation (Coefficients)		Loss or damage	Client' s Breach	Delayed drawing	Force Majeure	Delays caused	Ambiguity in	Changes in	A variatio	Employer's	Inflation / Price
C21	Changes by Client	Correlation	.447**	.424**	.470**	.389**	.548**	.468**	.529**	.252*	.392**	.136
		Sig. (2-tailed)	.000	0.000	.000	.001	.000	.000	.000	.028	.000	.240
C10	Inappropriate Contractor Selection	Correlation	.559**	.417**	.385**	.462**	.595**	.490**	.432**	.174	.479**	.189
		Sig. (2-tailed)	.000	.000	.001	.000	.000	.000	.000	.133	.000	.102
C05	Inappropriate Contract Type	Correlation	.501**	.481**	.433**	.438**	.560**	.507**	.542**	.295**	.457**	.276*
		Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.010	.000	.016
C15	Inappropriate/ Unexpected Time Control	Correlation	.461**	.492**	.487**	.398**	.581**	.391**	.410**	.256*	.383**	.313**
		Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.026	.001	.006
C16	Inappropriate/ Unexpected Cost Control	Correlation	.438**	.453**	.453**	.390**	.539**	.469**	.519**	.345**	.357**	.136
		Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.002	.002	.243
C19	Lack of Information for (Decisiveness)	Correlation	.556**	.561**	.377**	.309**	.538**	.448**	.486**	.207	.462**	.336**
		Sig. (2-tailed)	.000	.000	.001	.007	.000	.000	.000	.073	.000	.003
C17	Inappropriate/ Unexpected QC	Correlation	.447**	.413**	.489**	.412**	.455**	.457**	.474**	.287*	.404**	.098
		Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.012	.000	.402
C20	Slow Client Response	Correlation	.360**	.398**	.438**	.331**	.539**	.503**	.445**	.280*	.451**	.162
		Sig. (2-tailed)	.001	.000	.000	.004	.000	.000	.000	.014	.000	.162
C01	Inadequate/ Inaccurate Design Information	Correlation	.402**	.473**	.312**	.420**	.486**	.355**	.418**	.273*	.417**	.224
		Sig. (2-tailed)	.000	.000	.006	.000	.000	.002	.000	.017	.000	.052
C06	Inappropriate Contract Form	Correlation	.566**	.414**	.443**	.304**	.557**	.585**	.499**	.182	.455**	.115
		Sig. (2-tailed)	.000	.000	.000	.008	.000	.000	.000	.116	.000	.324

1.1.1. Spearman's Correlation Test (Types-Frequency) & (Causes –Avoid-ability)

Similarly, there was a highly positive correlation for mentioned correlation coefficients by red color, related to p-value (significant) which had green color revealing a correlation relationship between avoidable cause C10 and frequent types T23, T38. Also, for avoidable cause C13 which had a correlation relationship with frequented types T38, T45, T31. Also avoidable cause C06 had a correlation with frequented types T16, T23, T38, and T31. In addition, the avoidable cause C05 had a correlation with frequented types T16, T31, T09. Moreover, for avoidable causes C01, C04 and C09

 doi:10.20944/preprints202404.2016.v1

have a correlation with frequented type T09. On the other hand, the avoidable cause C05 had a correlation with frequent types T38, T09. However the avoidable cause C02 had a correlation relationship with frequented types T38, T07, T09 and T10. Meanwhile, the avoidable cause C07 had no correlation with any frequent types. Finally the avoidable cause C08 had a correlation with frequent types T38, T09, T45 and T10. For the correlation hypothesis while significance was lower than 0.05 to exclude the H0 zero hypotheses and accept the H1 alternative hypothesis, Table 15.

Table 15. Spearman's Coefficient & Sig. value between the Most Frequented: Types of Variations / Claims & Causes.

TYPE (Frequency)			T16	T23	T38	T45	T31	T34	T25	T07	T09	T10
CAUSE AVOIDAB	CORRELATION (Coefficients)		Delayed drawings	A variation or	Ambiguity in	Acceleration of Works	An omission of	Delayed payment	Shortage of personnel	Rejection of defective	Revised methods of	Delay
C10	Inappropriate Contractor Selection	Correlation	.066	.231*	.283*	.064	.100	-.075	-.034	.141	.127	.114
		Sig. (2-tailed)	.570	.045	.013	.584	.390	.521	.772	.225	.273	.325
C13	Inappropriate Payment Method	Correlation	.096	.084	.268*	.334**	.405**	-.022	.208	.101	.133	.136
		Sig. (2-tailed)	.411	.473	.019	.003	.000	.852	.072	.385	.251	.243
C06	Inappropriate Contract Form	Correlation	.229*	.318**	.294**	.142	.458**	.083	-.010	.082	.173	.286*
		Sig. (2-tailed)	.046	.005	.010	.221	.000	.478	.933	.479	.135	.012
C05	Inappropriate Contract Type	Correlation	.333**	.170	.168	.157	.264*	.096	-.081	.046	.348**	.192
		Sig. (2-tailed)	.003	.142	.147	.175	.021	.412	.489	.695	.002	.097
C01	Inadequate/ Inaccurate Design	Correlation	-.067	.020	.149	.162	.109	.077	.024	.198	.262*	.173
		Sig. (2-tailed)	.566	.863	.198	.163	.348	.509	.834	.086	.022	.136
C24	Inadequate Site Investigation	Correlation	.055	.197	.250*	.012	.162	-.080	-.076	.214	.259*	.212
		Sig. (2-tailed)	.635	.088	.029	.920	.161	.494	.513	.064	.024	.066
C04	Unclear & Inadequate Specifications	Correlation	-.041	.027	.068	.035	-.025	.012	-.067	.117	.235*	.070
		Sig. (2-tailed)	.724	.814	.560	.765	.831	.915	.567	.313	.041	.546
C02	Inadequate/ Inaccurate Design Information	Correlation	.148	.175	.290*	.091	.181	.109	.032	.393**	.361**	.373**
		Sig. (2-tailed)	.202	.131	.011	.432	.117	.350	.782	.000	.001	.001
C08	Inadequate Contract Documentation	Correlation	.139	.162	.227*	.276*	.176	.170	.008	.211	.397**	.335**
		Sig. (2-tailed)	.230	.163	.048	.016	.129	.141	.945	.068	.000	.003
C07	Inadequate Contract Administration	Correlation	.055	-.163	.148	-.062	.201	.010	.022	.169	.094	-.032
		Sig. (2-tailed)	.639	.158	.203	.597	.082	.930	.852	.145	.421	.782
C09	Incomplete Tender Information	Correlation	.101	.216	.051	.192	.180	.022	.056	.164	.329**	.167
		Sig. (2-tailed)	.387	.060	.664	.096	.120	.851	.629	.156	.004	.150

** indicates the statistically highly positive correlation.

1.1.1. Spearman's Correlation Test (Types-Impact) & (Causes –Avoid-ability)

In Table 16, the correlation between the most impacted types and the most avoidable causes by spearman's test was investigated. It is appearing that there was highly positive correlation for

 doi:10.20944/preprints202404.2016.v1

denoted by red color, related to p-value (sig.) which has green color reveals that there is a correlation relationship between avoidable cause C10 and impacted types T47, T16, T41, T27 while significant was lower than 0.05 , so we will not accept the H0 and accept the H1 alternative hypothesis. For avoidable cause C13 which had a correlation with impacted types T47, T41, T27 and T38. Also avoidable cause C06 had a correlation with impacted types T39, T47, T18, T41, T27, T38, T33 and T26. In addition, avoidable cause C05 had a correlation with impact types T39, T47, T16, T27, T38, T33 and T26.

Moreover, for avoidable causes C01, it had a correlation with impacted types T47 and T33.On the other hand, the avoidable cause C24 had a correlation with impacted types T47, T27, T38, T33, T23, T26 and T48. However, the avoidable cause C02 had a correlation with impacted types T41, T27, T38, T33 and T26 .In contrast, the avoidable cause C04 and C09 have no correlation with any impacted types. And, the avoidable cause C08 had a correlation with impacted types T47, T16, T27, T38, T33, T26 and T48. Finally, the avoidable cause C07 had a correlation with impacted type T33. For the correlation hypothesis while significance was lower than 0.05 we will not accept the H0 zero hypothesis and accept the H1 alternative hypothesis.

Table 16. Spearman's Coefficient & Significant value between the Most Impacted Types of Variations/ Claims & Most Avoid ability Causes**.**

CAUSE	TYPE (IMPACT)		T39	T47	T16	T41	T27	T38	T33	T23	T26	T48
	CORRELATION		Loss of Cl ie	De la	Fo rce	De la	A m	Ch an	A va ria	E m	In fla	
C10	Inappropriate Contractor Selection	Correlation Coefficient	.222	.307**	.305**	.244*	.308**	.185	.359**	.227*	.179	.294**
		Sig. (2-tailed)	.054	.007	.007	.034	.007	.109	.001	.048	.121	.010
C13	Inappropriate Payment Method	Correlation Coefficient	.143	.370**	.206	.240*	.271*	.360**	.226*	.205	.190	.042
		Sig. (2-tailed)	.216	.001	.074	.037	.018	.001	.050	.076	.099	.717
C06	Inappropriate Contract Form	Correlation Coefficient	.301**	.354**	.330**	.237*	.510**	.520**	.434**	.186	.459**	.150
		Sig. (2-tailed)	.008	.002	.004	.039	.000	.000	.000	.109	.000	.195
C05	Inappropriate Contract Type (Strategy)	Correlation	.251*	.275*	.295**	.183	.388**	.298**	.352**	.145	.258*	.198
		Sig. (2-tailed)	.029	.016	.010	.113	.001	.009	.002	.212	.025	.087
C01	Inadequate/ Inaccurate Design Information	Correlation	.070	.295**	.055	.066	.073	.176	.299**	.132	.165	.088
		Sig. (2-tailed)	.548	.010	.635	.572	.533	.128	.009	.256	.153	.449
C24	Inadequate Site Investigation	Correlation	.164	.266*	.222	.184	.302**	.254*	.306**	.303**	.248*	.241*
		Sig. (2-tailed)	.156	.020	.054	.111	.008	.027	.007	.008	.030	.036
C04	Unclear & Inadequate Specifications	Correlation	.043	.166	.006	-.008	.073	.064	.160	.210	.063	.104
		Sig. (2-tailed)	.712	.151	.957	.949	.531	.580	.169	.069	.590	.369
C02	Inadequate/ Inaccurate Design Information	Correlation	.178	.183	.142	.325**	.381**	.229*	.415**	.145	.344**	.116
		Sig. (2-tailed)	.125	.115	.221	.004	.001	.046	.000	.212	.002	.318
C08	Inadequate Contract Documentation	Correlation	.219	.310**	.227*	.191	.434**	.278*	.483**	.193	.305**	.342**
		Sig. (2-tailed)	.058	.006	.048	.099	.000	.015	.000	.094	.007	.003
C07		Correlation	.016	.190	.086	.048	.152	.127	.277*	.071	.171	.183

 doi:10.20944/preprints202404.2016.v1

	Inadequate Contract Administration	Sig. (2-tailed)	.893	.099	.458	.679	.190	.276	.015	.540	.140	.113
C09	Incomplete Tender Information	Correlation	.097	.095	.062	.176	.116	-.033	.164	.214	.135	.115
		Sig. (2-tailed)	.403	.414	.592	.128	.317	.779	.157	.063	.247	.322

** indicates the statistically highly positive correlation.

1.1. Overall Questionnaire Participant's Assessment

Respondents were asked to score the questionnaire's overall coverage in this area, as well as the variables under each section. Additionally, to provide any other remarks on the parts of the variable and any related issues. Table 17 presents respondents' responses regarding the types of variations and claims and its significance, where, 94.1 % of the clients think that the common types of variations and claims are significant, for the consultants 88.4 % think that it was significant and 93.8% for the contractors.

Table 17. Respondents' Responses regarding the Types of Variations and Claims and its Significance.

Identity (Role of the Respondents)		Frequency	Percent	Valid %	Cumulative %
Client	Not Sure	1	5.9	5.9	5.9
	Yes	16	94.1	94.1	100.0
	Total	17	100.0	100.0	
Client Representative/Consultant	No	3	7.0	7.0	7.0
	Not Sure	2	4.7	4.7	11.6
	Yes	38	88.4	88.4	100.0
	Total	43	100.0	100.0	
Contractor	No	1	6.3	6.3	6.3
	Yes	15	93.8	93.8	100.0
	Total	**16**	**100.0**	**100.0**	

Table 18 presents respondents' responses regarding the causes of variations and claims and its significance, where 88.2 % of the clients think that the common types of variations and claims are significant, for the consultants 95.3 % think that it was significant; finally for the contractors 93.8 think that it was significant.

Table 18. Respondents' Responses regarding the Causes of Variations and Claims and its Significance.

Identity (Role of the Respondents)		Frequency	Percent	Valid %	Cumulative %
Client	No	1	5.9	5.9	5.9
	Not Sure	1	5.9	5.9	11.8
	Yes	15	88.2	88.2	100.0
	Total	17	100.0	100.0	
Client Representative/Consultant	No	1	2.3	2.3	2.3
	Not Sure	1	2.3	2.3	4.7
	Yes	41	95.3	95.3	100.0
	Total	43	100.0	100.0	
Contractor	No	1	6.3	6.3	6.3
	Yes	15	93.8	93.8	100.0
	Total	16	100.0	100.0	

Table 19 presents respondents' responses regarding The Questionnaire; will questions help managers to predict the significance of types & causes of variations and claims? Where, 94.1 % of the clients think that The survey questions will help managers to predict the significance types & causes

 doi:10.20944/preprints202404.2016.v1

of variations and claims, For the consultants 83.7 % think that it will help, finally for the contractors 93.8 think that it will help positively.

Table 19. Will Questions Help Managers to Predict the Types & Causes of Variations and Claims?

Identity (Role of the Respondents)		Frequency	Valid %	Cumulative %
Client	No	1	5.9	5.9
	Yes	16	94.1	100.0
	Total	17	100.0	
Client Representative/Consultant	No	1	2.3	2.3
	Not Sure	6	14.0	16.3
	Yes	36	83.7	100.0
	Total	43	100.0	
Contractor	Not Sure	1	6.3	6.3
	Yes	15	93.8	100.0
	Total	16	100.0	

The responses to the questionnaire, which is shown in Table 20 below, will assist managers in forecasting and suggesting tactics to prevent or lessen variations and claims. Whereas 76.5% of clients believe that managers would be able to anticipate and provide ways to prevent or lessen variations and claims, Seventy-nine percent of consultants believe it will be helpful, and eighty-seven percent of contractors believe it will be beneficial.

Table 20. Will Questions Help Managers to Predict Strategies to Reduce Variations and Claims?

Identity (Role of the Respondents)		Frequency	Valid %	Cumulative %
Client	No	2	11.8	11.8
	Not Sure	**2**	**11.8**	**23.5**
	Yes	13	76.5	100.0
	Total	**17**	**100.0**	
Client Representative/Consultant	No	1	2.3	2.3
	Not Sure	**8**	**18.6**	**20.9**
	Yes	34	79.1	100.0
	Total	**43**	**100.0**	
Contractor	Not Sure	2	12.5	12.5
	Yes	**14**	**87.5**	**100.0**
	Total	**16**	**100.0**	

1.1. K-means Analysis

Having explored the various factors influencing variations and claims in construction contracts through initial statistical methods, it's now the turn to a more nuanced analysis. In this section, we delve into the K-means clustering algorithm, a pivotal tool in data analytics, renowned for its simplicity and efficiency. This method is particularly valuable for the study as it complements the Spearman's Correlation and Kruskal Wallis tests previously discussed, offering a unique perspective in understanding the dynamics of factors influencing variations and claims in construction contracts. The delineation of clusters representing groups of causes sharing similar characteristics provides a structured and nuanced understanding of the diverse factors contributing to claims, enabling stakeholders to prioritize and address them more effectively.

As per (Ostrovsky, R., and et.al. 2013) K-means clustering stands as a widely embraced and substantiated technique in clustering. It operates on a centroid-oriented principle, aiming to allocate objects into a predefined set of clusters by optimizing the centroids' positions, such as minimizing squared distances to these centroids.

To determine the appropriate number of clusters (k), various methodologies such as the Hubert statistic, Davies Bouldin index, Dunn index, score function, elbow plot, and silhouette plot have been

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devised (Pai, S. G. and et.al. (2021). In this study, the elbow plot method, known for its reliability, Yuan, C., & Yang, H. (2019), was employed for cluster count determination.

The k-means clustering utilized in this study was instantiated through the programming language Python, widely recognized within the realms of scientific computing, engineering, data science, and machine learning due to its pervasive adoption and robust functionality. The k-means algorithm is characterized by a sequential execution involving three primary steps: initial centroid establishment for cluster initialization, assignment of data points to their closest centroids, and subsequent recalibration of centroids based on updated assignments, accompanied by the computation of discrepancies between the new and former centroids. This iterative process continues until centroid movements reach a level of insignificance below a predetermined threshold, thus signaling convergence,

The primary aim of the k-means algorithm is to minimize cluster inertia or the within-cluster sum-of-squares criterion, as delineated by Equation 3, wherein X_i represents samples and U_j stands for the mean of samples within each cluster. The determination of the suitable number of clusters is validated through the elbow plot, displaying distortion scores for selected number of clusters as per Equation 3. The "elbow" point designates the cluster count at which further additions do not lead to a significant reduction in WCSS. Notably, in this analysis, the optimal number of clusters was identified as four, evident in Figure 5.

$$\boldsymbol{WCSS = \sum_{i=0}^{n} min_{U_j \in C} \left(\|X_i - U_j\|^2 \right)} \qquad (3)$$

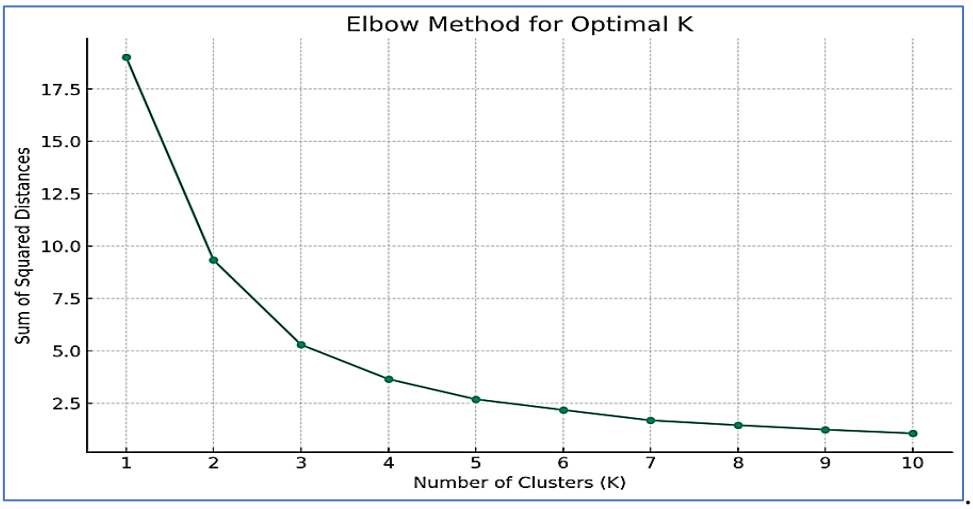

Figure 5. Elbow Plot for the Distortion Score for the Number of Clusters.

The k-means clustering analysis, applied to assess the causes of claims and variations in FIDIC 1999 contracts, effectively categorized these factors into four distinct clusters. Each cluster represents a unique combination of 'Frequency' and 'Impact', revealing the multifaceted nature of the causes influencing project outcomes. This robust statistical approach transcends conventional categorization methods, unveiling intricate relationships and associations between these factors.

Cluster 0 - Selective High Impact Causes: Includes causes T45, T40, T35, T25, and T24. This cluster is characterized by a significant impact with fewer occurrences, demanding focused attention due to their potential substantial effect on projects.

Cluster 1 - Diverse Low Impact Causes: With 17 causes (T1, T49, T44, T42, T41, T27, T50, T20, T18, T26, T51, T6, T5, T4, T3, T15, T14), this cluster represents varied and numerous issues of lower individual impact but requiring broad management strategies due to their collective presence.

Cluster 2 - Frequent Mid Impact Causes: The largest cluster with 26 causes (T47, T48, T34, T2, T7, T39, T38, T37, T8, T46, T43, T33, T31, T17, T19, T13, T21, T22, T32, T12, T10, T9, T28, T29, T30, T11), posing a consistent challenge and requiring regular monitoring.

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Cluster 3 - Critical High Impact and High Frequency Causes: Comprising T23, T36, and T16, these issues are both high in impact and frequency, pivotal in the project lifecycle and necessitating strategic management.

Figure 6 and Figure 7 visually support this analysis by showing the network model colored by cluster and detailing the causes of claims within each cluster, respectively. Table 21 illustrates these findings, providing a granular view of each cluster's characteristics.

Table 21. Causes of Claims and/or Variations Assigned to K-means Clusters.

Cluster	Cause	Count
0	T45, T40, T35, T25, T24	5
1	**T1, T49, T44, T42, T41, T27, T50, T20, T18, T26, T51, T6, T5, T4, T3, T15, T14**	**17**
2	T47, T48, T34, T2, T7, T39, T38, T37, T8, T46, T43, T33, T31, T17, T19, T13, T21, T22, T32, T12, T10, T9, T28, T29, T30, T11	26
3	**T23, T36, T16**	**3**

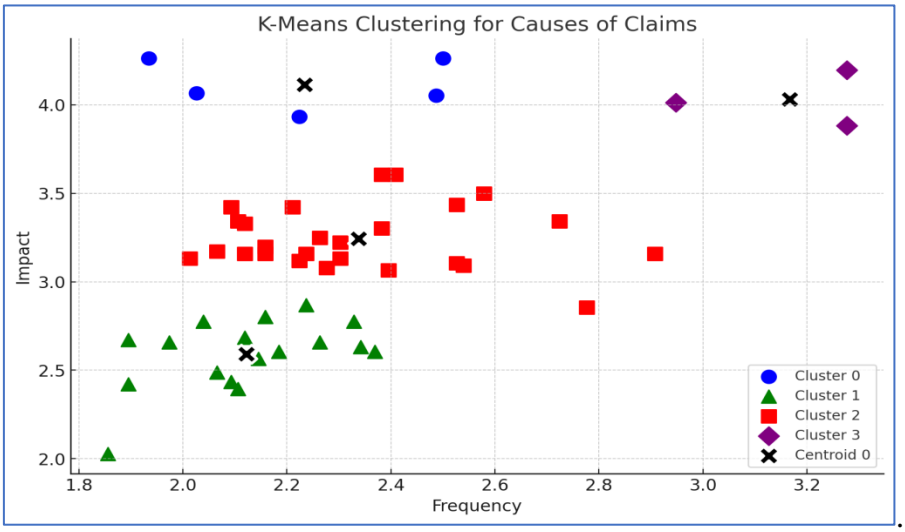

Figure 6. K-Means Clustering for Causes of Claims.

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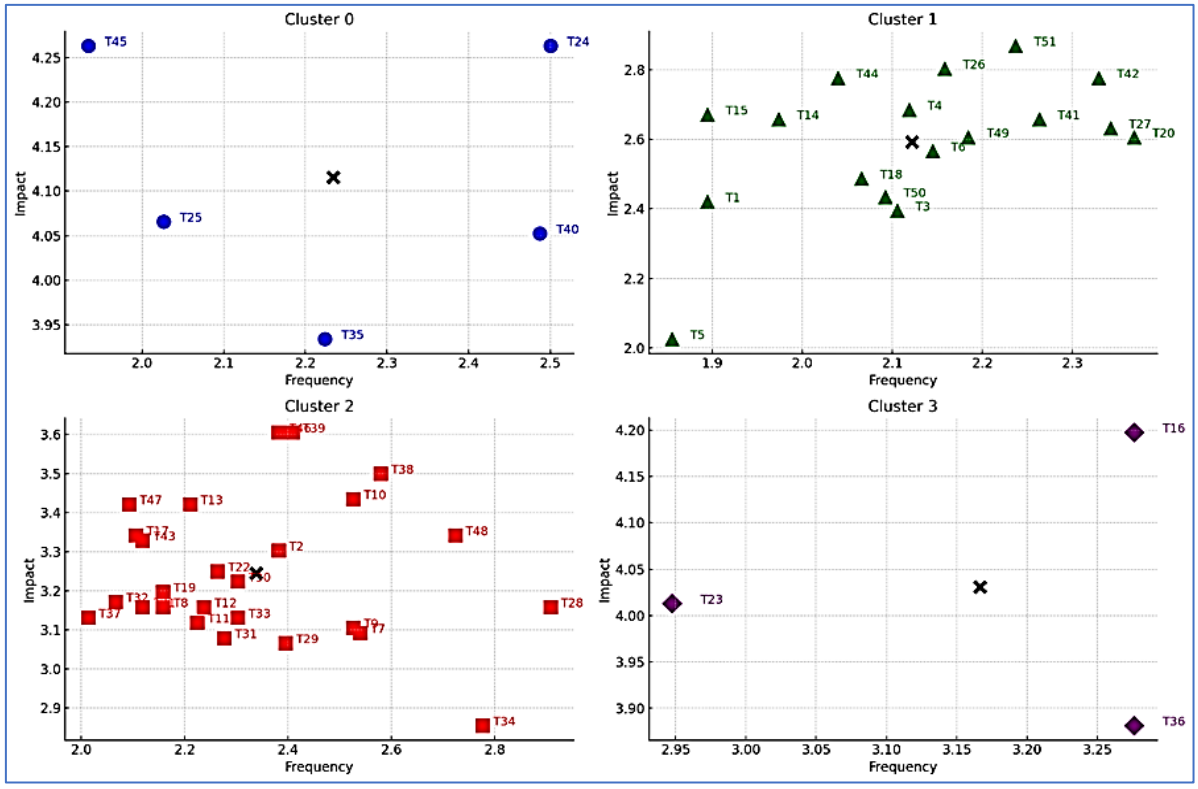

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Figure 7. Assigned Causes of Claims for the Four Analyzed K-Means Clusters.

Conclusions

The presented interim results and conclusions in the research were derived from observations and analysis of the detailed data collected from designed questionnaire with 80 experts who were intensively involved in variations and claims management. Hence, recommended strategies to project managers on methods to mitigate the avoidable causes of variations and claims as the last stage of research will be shown below.

1.1. Frequent Types of Variations and Claims:

Using the types and causes RII applied in this research, for construction industry workers. 51 types of variations and claims have been identified in section 1-part 2 based on a questionnaire survey of 80 respondents. These 51 significant types have been ranked as per respondent's perception; the top frequented ten types which are frequent and severe. Thus, these types require managerial attention and focus, in order to avoid their frequencies, consequently, providing positive benefits in managing construction projects, Table 22 and Table 23.

Table 22. Frequent Types of Variations and Claims.

No.	Frequent Types of Variations and Claims	No.	List of Causes
01	Delayed drawings or instructions	01	Loss or damage to the works caused Employer's Risks munitions, poor design etc.) (T39)
02	A variation or significant change to the quantities	02	Client's Breach of Contract
03	Ambiguity in documents	03	Delayed drawings or instructions
04	Acceleration of Works	04	Force Majeure
05	Omission of work forming	05	Delays caused by authorities
06	Delayed payment	06	Ambiguity in Documents
07	Shortage of personnel or goods	07	Changes in legislation

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08	Rejection of defective plant and / materials	08	A variation or significant change to the quantities.
09	Revised methods of working due to poor rate of progress (T09)	09	Employer's delay or impediment
10	Delay damages	10	Inflation / Price Escalation

Table 23. Causes of Claims and Variations.

No.	Significant Causes of Variations and Claims	No.	Avoidable Causes of Variations and Claims
01	Changes by Client (C21)	01	Inappropriate Contractor Selection (C10)
02	Inappropriate Contractor Selection (C10)	02	Inappropriate Payment Method (C13)
03	Inappropriate Contract Type (Strategy) (C05)	03	Inappropriate Contract Form (C06)
04	Inappropriate/ Unexpected Time Control (Target) (C15)	04	Inappropriate Contract Type (Strategy) (C05)
05	Inappropriate/ Unexpected Cost Control (Target) (C16)	05	Inadequate/ Inaccurate Design Information (C01)
06	Lack of Information for Decision Making; (Decisiveness) (C19)	06	Inadequate Site Investigation (C24)
07	Inappropriate/ Unexpected Quality Control (Target) (C17)	07	Unclear & Inadequate Specifications (C04)
08	Slow Client Response (C20)	08	Inadequate Design Documentation (C02)
09	Inadequate/ Inaccurate Design Information (C01)	09	Inadequate Contract Documentation (C08)
10	Inappropriate Contract Form (C06)	10	Inadequate Contract Administration (C07)

1.1. Concluding Remarks

Based on the presented results, it is recommended that special consideration should be given to contract clauses dealing with such issues. The best way to cope with risk of construction variations and claims is to reduce or avoid them altogether. There are certain fundamental ways and methods of reducing the number of encountered variations and claims, Table 24. The essential steps a client can take to minimize risks and deal with the abovementioned identified causes are to:

- Contract in terms of a standard Form, not a bespoke contract, to mitigate and avoid claims, such as- but not limited- FIDIC FORMS, while it helps contracts parties to have balanced rights and clear procedures for any variations and claims.
- Allow reasonable time for producing clear and complete drawings and specifications by the design team;
- Implement constructability review during the various stages of the project.
- Develop proper procedures for processing and evaluating variations.
- Develop proper procedures for processing and evaluating claims.
- The use of Critical Path Method (CPM) scheduling, cost control, and productivity analysis to control and monitor progress and productivity.

However, there is no guarantee that variations and claims can be avoided entirely. Avoiding variations and claims requires understanding their causes, understanding contractual terms and obligations, and early and continued communication. Therefore, it is expected that the findings of this research will assist all parties to a contract to reduce liability by resolving variations and claims through reference to existing records of fact and clear interpretation of contract terms. It will also help them avoid the main causes of variations and claims and; hence, minimize delays and cost overruns in construction projects. The author believes the suggested comments are essential for proper project management, which is far more advantageous and profitable than seeking advice of a construction claim consultants after the dispute is entrenched. The latter course often takes place too late and is too costly.

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Table 24. Guidelines & Techniques to Control Significant and Avoidable Causes of Claims and Variations.

#	Avoidable Causes of Variations and Claims	Recommended Mitigation/ Response Strategy
1	**Changes by Client (C21)**	• Ensure that the Project brief is comprehensive & Clear / Ensure agreement on the project brief • Ensure the early discussion with other authorities to anticipate their requirements • Spend adequate time in project planning • Ensure & Approve the full Development & Coordination of the design • Identify allocated risks & adopt suitable criteria like value for money to evaluate & manage risk • Adopt change control procedures & try to minimize changes as possible.
2	**Inappropriate Contractor Selection (C10)**	• Selection of the contractor should be based on a set of multiple decision criteria; both price and non-price related. • Consider financial ability, past performance, experiences and key personnel availability. • Consider contractor's current workload, past experience in terms of size of completed projects, management resources in terms of formal training regime, past performance. • Consider technical ability, management capability, and health and safety performance. • Consider Contractor's reputation including claims & Disputes.
3	**Inappropriate Contract Type/ Strategy - C05**	• (Feasibility) Link strategic business goals to initial project goals and justify facility. • (Concept) Translate the business objectives to initial scope of work and select alternatives (project delivery, contracting). • (Detailed Scope) Design decisions and delivery & contracting strategy. • (Design) Full determined project delivery & contracting strategy and control plans. • (Construction) Explain construction methodology, operations, contracting strategy and procedures. • (Commissioning, start-up & operate) Finalize commissioning, start-up and update operations contracts and handover of operations. • Consider attributes of optimal contracts: - Align (owner and contractor) objectives - Value for money contractor - Quality (valued or truthful) Information/ Trust and Relationship management Long term commitment and renegotiation/ - Optimal risks sharing. - Optimal wage scheduling/ optimal incentive contracting.
4	**Inappropriate/ Unexpected Time Control (Target)- (C15)**	• Establish Schedule Control Procedures/System • Establish a Time Border : by fixing the overall project duration either by specific constraints or by contract strategy to use it as a key parameter • Assure Time Auditing System : Monitor actual time spent on each activity against planned time • In case of any exceeds of time allowance: - Allow the re-sequencing of later activities - Allow the shortening of time by increasing the resource (Crashing will result in extra cost) - Allow the program for the time impacts of identified risks occurring - Assess & Revise Contractor's Program of Work
		• Run efficient planning of strategies and management of site and supervision of the project.

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5	**Inappropriate/ Unexpected Cost Control (Target)-C16**	• Keep organized regulatory mechanism; and using proper methods for construction, the organizational strategies include: - Appropriate prominence on previous experience; - Regular coordination between the associated parties; - Increasing human resources in the industry; and - Conduct administration of contracts - Regular meetings on development, - Employ proficient subcontractors and suppliers, attributing less weight to prices, and more weight to abilities and earlier performance of contractors to improve the contracts and their reactive and organizational strategies/ procedures. • Use channels for perfect information and communication. • Utilization of latest technology is a proactive and reactive strategy. • Undertake a preconstruction planning regarding the procedures and resources of project.
6	**Lack of Information for Decision-Making; Decisiveness-(C19)**	• Define and clarify the issue - does it warrant action? If so, now? Is the matter urgent, important or both? • Gather all the facts and understand their causes. • Think about or brainstorm possible options and solutions. • Consider and compare the 'advantages and disadvantages ' of each option - consult others if necessary or useful - and for bigger complex decisions where there are several options, create a template which enables measurements according to different strategic factors. • Select the best option - avoid vagueness and weak compromises in trying to please everyone. • Explain your decision to those involved and affected, and follow up to ensure proper and effective implementation.
7	**Inappropriate /Unexpected Quality Control (Target)-(C17)**	• Improve interactions and processes between the Project knowledge areas • Ensure project objectives are met • Reduce expenses due to avoidance of mistakes • Less rework is necessary which leads to save time • Result in better working conditions and wellbeing of the workforce • Improve communication between team members through well-defined processes • Lead to good quality of products as it becomes a company minimal requirement
8	**Slow Client Response- (C20)**	• Develop Project Monitoring Mechanism • Establish regular Meetings. • Seek assistance to obtain information from others and experts to expedite the response.
	Inadequate/ Inaccurate Design Information-(C01)	• Planning: Describe who does what, when, at what cost & with what specification? • Final Design Kick-Off Meeting to review: Project requirements; Project Schedule; All Project significant Decisions & Assure that all parties clearly understand issues indicated by the approved Preliminary Design • Assure Completeness of All Drawings & fully define the work as required. • Assure Coordination of All Drawings with the specifications required. • Incorporate all Adjustments as per the approved design drawings. • All Drawings should be Drafted Clearly. • Include all Composite Drawings for clarifications. • Assure inclusion of Borings & other subsurface / Geotechnical information in the drawings. • Use Graphic & Alphanumeric Scales to avoid confusion on reduced prints & appropriate drafting scale and include symbols, legends and abbreviations. • Assure Preparation of Final Specifications including: Format of Specifications, Coordination of Specifications, Revision of final submission and commissioning specifications for HVAC, Plumbing & electrical system …

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9		• Insure Conformity of final Design Drawings & Specification with requirements in terms of: Drawing Format, Conformity with comments, Stamps, Signatures, Approvals of Regulatory Agency & clarity & Completeness of Specifications. • Insure the production & Review of Final Cost Estimate. • Develop, review & follow Final Design Procedures such as: submittal & Reviews; Utility & Regulatory Agency Approval; Resolution of Questions. • Prepare the Bid Form, General Condition & Special condition of contract, and include any contractor special experience requirements. • Conduct A Constructability Review to facilitate production of contract documents including technical Specification that are clear, coordinated and complete • Conduct a Design Review to plans, specifications, bid booklet &Addendums
10	**Inappropriate Contract Form-(C06)**	• The contract should describe the following: - What will be done/ How long it will take to complete/ How much it will cost and the payment terms; - What will be done if either party defaults; - The extent to which the common law, which would usually apply, is adhered to. • Determine the construction contract parties: - Employer: Requires the construction work and provides payment - Employer's Representative: Acts on behalf of the employer and may be referred to as engineer, project manager, principal agent, etc. - Contractor: Commissioned to construct the works - Subcontractor: Appointed by the contractor to perform a part of the construction works under a subcontract - Adjudicator/ Arbitrator/ Court: Settles disputes between the parties • Decide contract form: - Bespoke contract/ Standard form contracts • identify way of contracting: - Main contractor/ Joint venture partner/ Subcontractor • Decide Construction contract arrangement: - Pure construction contract/ Design-build/ Engineer, procure and construct • Define contract party's rights: - Timeous payments/ Extensions of time/ Access to site/ Upon termination of the contract/ Appointment of subcontractors • Draw contract party's responsibilities: - Completing works/ Guarantees / Insurances/ Administrative procedures/ compliance with all applicable laws - Response to communications/ Substantiation of claims/ Subcontracts • Balance contract party's risks: - Errors in calculations/ Poor management/ Delays/ Penalties/ Insolvency of employer
11	**Inappropriate Payment Method-(C13)**	• Define the stakeholders & supply chain • Identify project program • Define the project process mapping, Responsibility Assignment Matrix. • Define the products, services, management, design, engineering and prefab & assembly needed to a project. • Approve a common framework for managing and controlling project in order to meet the client's business needs. • Refine and improve continually such processes (framework for managing and controlling). • Detail all the required actions that must be taken under the common framework of a process map.

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		• Analyze such a detailed process map to simulate the payment requirements within design and construction stages in order to analyze the effect of using alternative payment mechanisms on the cash flow of the stakeholders and supply chain members. • Note that the concept of the stakeholders & supply chain is emerging as a significant performance enabler for construction industry. • After payment mechanism was defined, start plan your cash flow lifecycle, • Compare your payment mechanism with preferable forms of payment: • reimbursable cost-plus a percentage-fee/ reimbursable cost-plus a fixed-fee/ target cost (shared over-run and/or under run)/ unit-rate (including re-measure)/guaranteed maximum price/ lump-sum services and materials with reimbursable construction/ Lump-sum (i.e. wholly lump-sum)/ open-book accounting/ stage payments/ incentive contracting/ direct payment/ trust accounts/funds/ mobilization advance payment
12	**Inadequate Site Investigations-(C24)**	• Define building Design Concept/ Set Terms of Reference • Describe Preliminary Site Characterization • Test Holes and Sampling/ Test Hole Number and Depth/ Test Hole Stratigraphic Description and Sampling • Laboratory Testing/ Soil Classifications/ Take Photographs/ Ground Temperature Measurement • Determine Report including: - Restate project definition; - Characterize the site so that surrounding conditions that may impact on the design and performance of the building foundation are understood and designed for; - State the present and the projected end of the building service life, climate and ground temperatures; - Classify the soil strata according to recognized ASTM Standards, based on quantitative laboratory results; • Identify foundation options appropriate for the proposed service life of the building; and • Provide guidance for the construction scheduling of the foundation for the building/ Peer Review.
13	**Unclear & Inadequate Specifications-(C04)**	• Be aware of Different Type of Specifications including; Output Based, Performance or Prescriptive • Developing the Project Specifications According to; Scope of Users Requirement; Quality & Performance Characteristics; Technical Characteristics. • Apply Value Management • Proper Structuring of the Project Specifications • Assess the Whole Life Cost Implications of Specifications • Obtain Final Approval of the Specifications • Proper Coordination with other contract documents.
		• Establishment of well-defined client brief comprising key drivers and parameters such as: budgets, functions, quality, sustainability, urban issues and commercial returns. • Better articulation of requirements by the client equates to better consultant response. • Client brief to include any requirements for document checking and coordination. • Client may require additional advice in brief preparation, budgeting and programming and engage specialists' expertise, as in the case of highly complex projects. This may include engagement of facilities planners and/or independent cost advisors that may not necessarily be part of the project team. • Clearly articulate client expectations of the consultant in the request for proposal and state criteria for selection. • Clearly articulate the conditions of contract and obligations on the consultant i.e. quality control, assurances. • Consultant Selection based on technical abilities and past experiences in addition to financial offers.

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14	**Inadequate Design Documentation-(C02)**	• Clients may insist on demonstrable quality control consultants. Consultant Obligations and Functions • Consultants to articulate the project methodologies including design approaches and quality controls in response to invitations to submit proposals. • Primary consultants should select any secondary consultants on a value for money basis and submit with their proposals the rationale for selection of their consultant team. • Team Formation and Project Integration • At the commencement of the project, client and project team should ensure that roles, responsibilities and obligations of all parties are clearly understood. • Establish and agree a design and documentation review process including review points and agree milestones for client and project team sign-off. • Develop a quality plan including procedures for communication, document control and coordination. • Client may create obligations on consultants to report on risk and options for managing risk. • Obtain approvals and sign off progressively throughout the project. • Encourage project teams and clients to utilize tools to assist e.g. value management. • Encourage establishment of integrated teams and articulate procedures for problem resolution. • Encourage design and documentation teams to bring construction expertise to the team to provide greater confidence e.g. early use of contractors on build-ability decisions. • Quality Management Incorporating Project Implementation, Design and Documentation. • Actively consider total cost of project (over the life cycle) as part of the design and documentation process. • Develop a range of Quality Management Tools including checklists, review procedures and audit processes. • The client and project team to consider the role of independent reviewer or value management. • Consultants to provide advice on the quality of documentation that could be reasonably expected from the agreed resources allocated and timelines established for the period. • Consultants to warrant that they have undertaken the design and documentation consistent with the quality plan. • Use of technology by consultants to assist in documentation control and coordination. • Project team to agree upon and nominate an experienced person responsible for documentation coordination. • Obtain approvals and segmental sign off. • Advise the client on the adequacy of the brief and the risks associated with any inadequate allowance for proper documentation in both budgets and programs. • Coordinate secondary consultants, obtain their sign-off on completeness of their documentation, and provide overall sign-off to the client that project documentation is comprehensive. • Ensure version control of documents to secondary consultants. • Create design and documentation coordination roles within project team.
15	**Inadequate Contract Documentation-(C08)**	• Clearly Define Contract Documentations • Assure that the Contract conveys a clear Understanding of the Scope of the Project • Carefully Define the Responsibilities, Authorities, Roles & line of Communications of the contract parties • Develop & Monitor progress according to preset monitoring • Assure adequacy & accuracy of Design Information • Assure adequacy & accuracy& Consistency of Tender Information • Conduct Constructability Review • Review Contract Documentation for consistency & clear ambiguities before tendering

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		• Correct ambiguities & Inconsistencies when discovered during tender stage by issuing addenda • Use Clear words when defining terms especially the terms "Works" & "Approved • Carefully draft the definitions section of the contract • Assure Completion of all final contract Documentation.
16	**Inadequate Contract Administration-(C07)**	• Project Management Discipline: All work to be performed should be appropriately led, planned, scheduled, coordinated, communicated, tracked, evaluated, reported and corrected, as necessary. • Contract Analysis and Planning: Before contract award, each party should develop a contract administration plan and assign the responsibility of administering the contract to a contract manager. • Kick-off Meeting or Pre-performance Conference: Before performance begins. • Performance Measuring and Reporting: During contract performance; the project manager, contract manager, and responsible business managers all must observe performance, collect information, and measure actual progress. • Payment Process: Every contract must establish a clear invoicing and payment process. • Contract Change Management Process: As a rule, any party that can make a contract can agree to change it. Changes are usually inevitable in contracts for complex undertakings. • Dispute Resolution Process. • Contract Closeout Process: Contract closeout refers to verification that all administrative matters are concluded on a contract that is otherwise physically complete.
17	**Incomplete Tender Information-(C09)**	• Perform careful review/audit of all tender documents prior to tendering to avoid ambiguities & discrepancies • Assure Clarity, consistency & completeness • Adequate information for Solicitation such as: Project brief; place of collecting & reviewing bids; bid security requirements; bid due date, time & location • Ensure adequate Instructions' information to bidders such as: Type of bid; Preparation of the bid; bid bonds & Security; Permits; bid's opening • Arrange a Pre-tender site visit for potential bidders • Ensure adequate bid Response forms' information such as: Project Identification; To whom the bid is directed; Person submitting the bid; validity of the bid Acknowledgments; Pricing; Start & completion date • Provide Specifications; Drawings; Contract forms; General & Specific Conditions & Bill of Quantities • Identify the award Criteria and the essential requirements of a complete bid • Clarify areas of concerns within the tender document • Send all clarified questions and answer, to all bidders • Avoid all unofficial communication with bidders • All communication should be in writing. • Make a written notice of award after the evaluation • Keep accurate records of the tender process in case.

Declarations

6.1. Author Contributions

Conceptualization, Ahmed Mohamed Abdelalim; Data curation, Ahmed Mohamed Abdelalim, Mohammed Ramadan , AlJawharah A.AL Nasser and Mohamed Tantawy ; Formal analysis, Ahmed Mohamed Abdelalim, Mohammed Ramadan , AlJawharah A.AL Nasser and Mohamed Tantawy ; Funding acquisition, AlJawharah A.AL Nasser, Ahmed Mohammed Abdelalim ; Investigation, Ahmed Mohamed Abdelalim, Mohammed Ramadan , AlJawharah A.AL Nasser and Mohamed Tantawy ; Methodology, Ahmed Mohamed Abdelalim, Mohammed Ramadan , AlJawharah A.AL Nasser and Mohamed Tantawy ; Project administration, Ahmed Mohamed Abdelalim; Resources,

Ahmed Mohamed Abdelalim, Mohammed Ramadan and AlJawharah A.AL Nasser ; Software, Ahmed Mohamed Abdelalim, Mohammed Ramadan and Mohamed Tantawy ; Supervision, Ahmed Mohamed Abdelalim; Validation, Ahmed Mohamed Abdelalim, Mohammed Ramadan , AlJawharah A.AL Nasser , Rawan Alwahaibi and Mohamed Tantawy ; Visualization, Ahmed Mohamed Abdelalim and Mohamed Tantawy ; Writing – original draft, Ahmed Mohamed Abdelalim and Mohammed Ramadan ; Writing – review & editing, Ahmed Mohamed Abdelalim, AlJawharah A.AL Nasser and Mohamed Tantawy .. All authors have read and agreed to the published version of the manuscript.

6.1. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

6.1. Funding

The authors extend their appreciation to the Researchers Supporting Project number (RSPD2024R590), King Saud University, Riyadh, Saudi Arabia.

6.1. Conflicts of Interest:

The authors declare no conflict of interest.

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