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RESEARCH ARTICLE

Causes of Variation Orders in Road Construction Projects in Tanzania

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Abstract:

Background:

Variation order has long been an essential component of road construction projects worldwide, being predominantly observed in Tanzania, where road projects are particularly vulnerable.

Objective:

This study aimed to determine the sources of variation orders in Tanzanian road construction projects and provide a feasible remedy, such as reduction or eradication.

Methods:

A desk study and questionnaire were utilized as the research approach and analyzed using the relative importance index (RII) method.

Results and Discussion:

The results reveal that the most significant circumstances causing variation orders are financial problems, weather conditions, differing site conditions, changes in design, poor scheduling, lack of coordination, delay in approval, unavailability of equipment, and lack of communication.

Conclusion:

Recommended strategies to minimize variation orders were that all involved parties should plan before the commencement of on-site work and perform detailed site investigations. Consultants should ensure that the design and specifications are within the approved budget. All participants were required to spend adequate time in the pretender planning phase. Finally, accurate information and research should be obtained regarding procurement procedures, materials, and plants.

Keywords: Variation order, Relative important index, Road construction, Tanzania, Design, Equipment.

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1. INTRODUCTION

Most of the road construction projects in Tanzania had undergone many variation orders, which increased client expenditures beyond the planned budget. Occasionally, disagreements and excessive postponements occurred. Variation order implies alterations in the margin of task scheduling, blueprint, or agreement files in the construction industry, leading to the postponement of projects and additional payments. Therefore, it is essential to manage the variation orders [1]. Matimbe and Lema discovered significant variations in road project costs beyond the original contract sums in a study assessing the cost and time performance of integrated road projects (IRP) in Tanzania [2]. According to the survey, 95% of the sampled projects experienced cost variations ranging from 19 to 216% of the original contract sum, and 70% experienced time variations ranging from 5 to 733% of the initial completion time. Kimambo also stated that the actual project costs for many initial integrated road projects (IRP) were higher than the original estimates [3]. The local components for most civil work contracts were typically more expensive (up to 30% higher) due to changes in exchange rates. Therefore, it is essential to control the order of variation. Several analyses have been conducted to determine the origins of variation orders in road construction projects. A key reason necessitating a variation order is the preference or flavor for a better-completed result that differs from the quality initially

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agreed upon by the owner in a specific contractual agreement.

Furthermore, owing to consultants, weather, and varying site conditions, changes to an initial design may be required [4]. Burati *et al*. investigated nine key engineering projects with expense-related deviations to encounter obligations [5]; the authors discovered that character variation is described as 12.4% of the agreed rates in the entire nine projects. Ndihokubwayo and Haupt found that 63% of site instructions were used as additional work and recommended that the design team be more careful at the preliminary stage to avoid unnecessary alteration of results [6]. Moreover, Charoenngam *et al*. advised that stakeholders should have good communication in the work environment and that capacity building should be provided to the design team because standard construction technology is changing [7]. Likewise, Chan and Yeong suggested that excellent document keeping, appropriate harmonization, and interaction between professionals remain suitable for intolerance of variation order administration [8].

This study investigated the possible causes of variation orders in road construction projects in Tanzania, especially TARURA and TANROADS, which are agencies dealing with the construction and maintenance of roads in Tanzania. The data were collected from four actual projects conducted in Tanzania and 92 respondents working with one of Tanzania's road agencies.

2. LITERATURE REVIEW

Variation orders arise from various sources, of which some are foreseeable. Many researchers have identified multiple causes for a variation order. Pourrostam and Ismail focused on investigating the causes of variation orders in roadway construction projects and identifying their effects on such projects in southern Iran [9]. Their results showed a low correlation between owners and contractors. Conversely, it showed a good correlation between the employer and contractors, with 97% agreement. It was concluded that employer changes in plans or scope, errors and omissions in design, differing site conditions, and contractors' financial difficulties were some of the critical factors causing variation orders in roadway construction projects.

Halwatura and Ranasinghe also studied road construction projects in Sri Lanka [10]. According to the questionnaire survey, poor estimation was the primary cause of variation order, followed by unexpected site conditions, political pressure during the construction stage, inadequate investigation, and client-initiated variations. The ranking was verified through a case study analysis. Multiple case studies have been conducted by Wu *et al*. to identify the causes of changes in highway projects in Taiwan [11]. The findings showed that differences in engineering properties among embankments, roads, viaducts, and tunnels create differences in the importance of investigating and managing geological concerns. A site survey was developed in the feasibility analysis and planning design stages for similar future projects.

Sunday examined the impact of variations in construction projects [12]. Variation orders are the most disruptive and unpleasant events of projects because of their implications for the cost and completion date of the project. Msallam *et al*. focused on the causes of variation in highway projects in Jordan [13]. According to the results, the ten important causes were the change in schedule, ambiguous design details, change of plan or scope, a conflict between contract documents, lack of coordination, safety considerations, client financial problems, change in design by consultants, socio-cultural factors, and changes in government regulations. The analysis revealed that the tasks handled by the consultants were more prone to variation orders than those handled by in-house professionals. The consultants' reasons were unclear drawings, design discrepancies, and conflicts between contract documents.

Additionally, the owners' most contributing causes of variation orders were changes in scope, slow decision processes, and insufficient project shortages. Contractors' reasons included lack of skilled labor, different site conditions, and contractors' desired profitability. The following are the causes of the variation order based on the reviewed literature (Table **1**).

Table 1. Causes of the variation order.

S.No	Variation orders	No	Variation orders
1	Inaccurate estimations	13	Expertise transformation
2	Unforeseen site conditions	14	Welfare concerns
3	Poor investigations	15	Shortage of skilled workforce
4	Modification of drawings	16	Substandard project presented
5	Extra preliminaries because of time extension	17	Impractical completion time proposed by the owner
6	Owner's modifying tasks	18	Scarcity of contractor knowledge
7	Insufficient scope of work for the contractor	19	Change in economic conditions
8	Unsatisfactory designing	20	Lack of coordination
9	Inhabitants	21	Owner's financial problems
10	Material replacement and other procurement processes	22	Weather conditions
11	Scarcity of resources	23	Delay in approval
12	Disputes among agreement files	24	Changes in government regulations

3. METHODS

Data were collected through a desk study and a questionnaire survey. According to Kothari, a research methodology is an approach to solving a research problem analytically [14]. Various phases can be examined using research methodologies by studying their research problems and reasoning. Desk research refers to secondary data collected without fieldwork. A desk study was conducted on selected road construction projects to identify the causes of a variation order. Data were obtained from project disbursement diplomas and regular development statements to provide information on the stated problem, which aids in comprehending the correlation between the hypotheses and fundamental habits in construction projects. All projects discussed in the four case studies used the design-bid-build delivery technique, in which the client hires a design consultant and then chooses a contractor through a tendering process.

A series of questionnaires were distributed to various respondents to collect data by one of the authors (Roziana Saki). The project management team, consultants, and contractors were also led. It is divided into three sections. The first section included respondents' personal information such as their name, agency name, address, education level, and experience with road construction projects. Furthermore, the second section included questions regarding the causes of the variation order in the road construction field. Finally, the third section focuses on the preventive measures that should be taken to eliminate variation orders. A total of 120 questionnaires were sent electronically in a Google survey (70 from TANRODS and TARURA and 50 from contractors and consultants). The questionnaires were mailed between August 4 and September 2, 2021, and respondents were requested to respond within 28 days.

4. ANALYSIS

4.1. Case Study

The desk study and questionnaire data were analyzed quantitatively using the relative importance index (RII). Through a desk study, four road construction projects in Tanzania with approved variation orders (VO) were chosen to thoroughly understand the causes of variation orders and represent the occurrence of variation orders.

In Project No. 1, the scope of the work included the construction of an engineering office and laboratory and the construction of government city roads according to bitumen standards. It includes paving government city roads, constructing drainage systems (side drains, bridges, and culverts), and installing traffic lights. Variation order No. 1 was declared to cover the expenses of design changes owing to the provision of equipment at the temporary office of the engineer and laboratory because the original quantity was underdesigned. Variation order No. 2 was also caused by changes in the design. Consequently, the excavation amount increased. The addition of crushed stone from a commercial source was also required because of the soft material at the site. Perforated UPVC pipes were used to remove water from the subsurface.

Furthermore, variation order No. 3 was due to omitted pesticides in the art termite nest works. Moreover, variation orders No. 4 and 5 were due to changes in the specification of the service ducts (300 mm diameter PVC class PN 4), service ducts (150 mm diameter PVC class PN 4), and binder type PG70/10 grade for asphalt concrete surfacing. Variation order No. 6 was due to omitted asphalt concrete surfacing (active filler) work, and variation order No. 7 was due to additional work on supplying, installing, and testing street rights. Additionally, weather conditions and local community meetings caused a variation in time. These variations were calculated under clauses 47 and 48 of the general condition of the contract.

In Project No. 2, the original project was called for reconstruction work that included widening the road to a 7m wide carriageway and 2m broad shoulders on each side for an overall road width of 11m and improving vertical and horizontal alignments of the existing pavement structure. The significant difficulties encountered during construction are summarized below.

The original design drawings lacked details for some components of the work, notably the One-Stop Border Post documents, which contained excessive, missing, or mismatched design information. These missing pieces of information were later obtained from the designer via time-consuming correspondences involving the employer. Some were provided by the supervision consultant site staff and caused variation orders 3 and 4. During construction, frequent overtopping and damage were caused by flash floods, demonstrating the inadequacy of drainage structures at some road locations. The design consultant reviewed the design documents and discovered deficiencies in some drainage structures. Consequently, revised drawings were prepared and issued, leading to variations in Order No. 6. The stone required to construct grouted stone pitching side drains was not readily available in the project area. Therefore, the contractor proposed modifying the design and using cast-in-situ concrete, which was evaluated and approved by the engineer, leading to variation order No. 3.

Some work was frequently rejected and rebuilt because of poor project organization and the lack of experienced personnel to maintain proper quality control. The most severe quality control issues were discovered during the cement-stabilized work, and bituminous surface construction led to variation orders 1 and 5.

In Project No. 3, the project was named after the construction of the Uyovu-Bwanga road (45 km) with the bitumen standard. The significant difficulties encountered during construction and completion are summarized below. During the design review, the consultants discovered some deficiencies or mismatches in the specifications, drawings, and bill of quantity concerning the actual site conditions, resulting in additional work in the earthworks and pavement layers of gravel or crushed stone (variation order no. 1). During the implementation of this work, the timely relocation of utilities was a critical issue. Various utilities owned by the BUKOMBE district water authority, TANESCO, VODACOM, and TTCL were presented in the Uyovu area. It somehow contributed to the project's variation over time. The employer also delayed paying compensation, causing an interruption in construction activities and time variations.

The project began on November 28, 2012, lasting 21 months. Consequently, the project was scheduled to be completed on August 27, 2014. However, the contractor halted the work from October 14, 2014, to July 1, 2016. The work was resumed on August 1, 2016, and the project was completed in October 2017 after being suspended. Consequently, the project was completed in 59 months, which led to a variation in Order No. 2. As the project was expected to be in 2013 and took four more years, it needed price adjustment in materials and human resources, as the results led to a variation in Order No. 3.

Table 2. Summary of the causes of variation orders for each case study [15].

Project	Causes of Variation Order
Project 1	Design change
	Omission of works in the contract
	Specification change
	Addition work
	Differing in weather condition
	Land acquisition (local people community meeting issue)
	Financial issue
Project 2	Preliminary design (design detail inadequacy)
	Change in design
	Deficiency of material (stones)
	Poor construction and work rejection
Project 3	Inadequate design
	Delayed Relocation of Utilities
	Compensation events
	Increase price and payment of interest
	Change in government policy
	Improper schedule
Project 4	Inadequate design
	Change in Climatic Conditions
	Lack of coordination
	Poor soil conditions

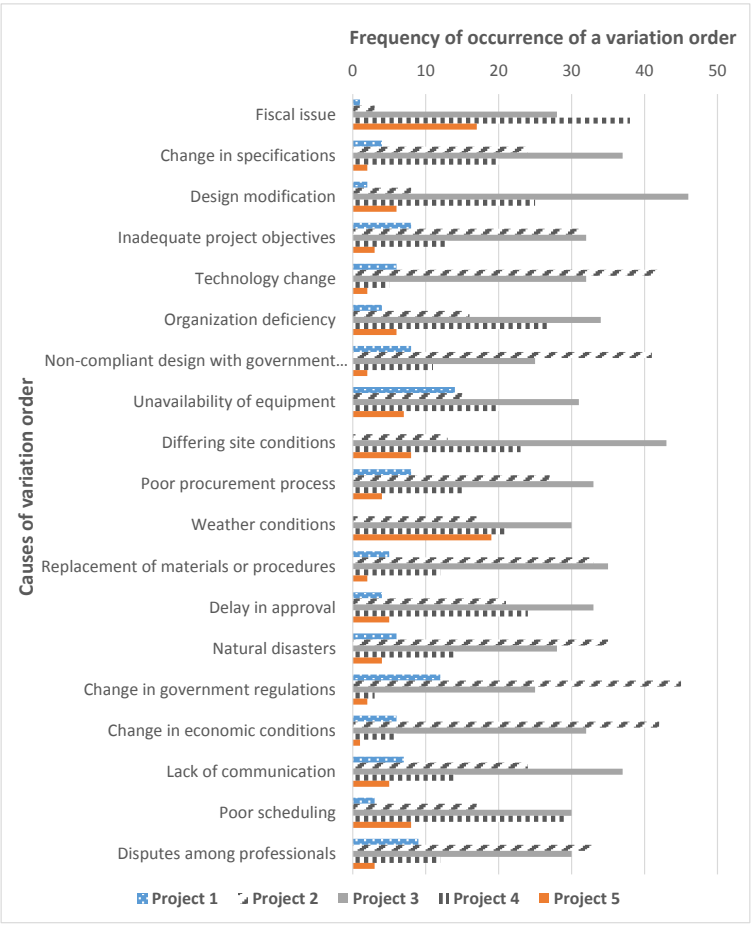

Fig. (1). Frequency of occurrence of causes of variation order based on data collected.

In Project No. 4, the project's name was the supervision of rectifying substandard work and the defect notification period from Nangurukuru to the Mbwemkuru road project. The significant difficulties encountered from construction to completion were summarized. There was a need to change 13 bridges to box culverts; this was justified from a technical and hydrological perspective after the final design review, resulting in variation order 2. Additionally, during the implementation stage, a variation in the design of shoulder construction occurred. Changes in climatic conditions, lack of coordination, and poor soil conditions contribute to variations in time and cost (Table **2**).

3.2.. Questionnaire survey

This segment evaluated respondents' personal characteristics. A total of 92 people responded and successfully returned the questionnaire, resulting in a response rate of 76.7%. A numerical examination was performed using the RII method. Many respondents were working in the agency with 66 respondents (71.7%), in consulting offices with 13 respondents (14.1%), and 13 respondents (14.1%) were working in contractor's offices (Fig. **1**).

In a job description, 60% of the respondents were categorized as normal engineers (project and road engineers), 33% as managers (regional coordinators, heads of units, and chief executive officers), and 7% as site inspectors, land surveyors, civil technicians, and trainees.

The working experience of respondents in road construction projects was one of the demands to describe the differences in rank among respondents with varying experience in projects. The respondents' years of experience were subjectively grouped into three categories: those with less than five to ten and ten years and above. Only five had never worked on a road construction project with the variation order based on the respondents' information. The survey did not allow them to continue with the next question. Therefore, the remaining respondents in this study had a good understanding and could provide reliable answers to the questionnaire. According to the analysis, 45.7% had more than ten years of experience, 33.7% had 5–10 years of experience, and 20.7% had less than five years of work experience. The frequency of outcomes of variation orders regarding their causes was ranked using a 5-point Likert scale: never = 1, very rarely = 2, sometimes = 3, often = 4, and always = 5.

Next, the causes of variation orders were calculated by the scale value, and the obtained value was used to calculate the relative importance index using the formula presented below:

$$RII = \frac{\Sigma W}{A*N} = \frac{1n_1*2n_2*3n_3*4n_{4*}5n_5}{A*N} \quad \textbf{(1)}$$

In the equation,

RII = relative importance index

W = weight assigned to each attribute factor by the respondents; it ranges from 1 to 5 (1 = strongly disagree and 5 = strongly agree)

ΣW = summation of all weights of each attribute
A = the highest score (5 in this case)

N = total number of respondents

5. RESULTS

Results obtained after calculation were ranked as shown in (Table **3**). The results reveal that the most significant circumstances causing variation orders are financial problems, weather conditions, differing site conditions, changes in design, poor scheduling, lack of coordination, delay in approval, unavailability of equipment, and lack of communication.

Table 3. Results of the causes of variation order.

Causes of Variation order	RII	Ranks
Financial problems	0.7540	1
Weather conditions	0.6966	2
Differing site conditions	0.6598	3
design modification	0.6575	4
Poor scheduling	0.6506	5
organization deficiency	0.6345	6
delay in approval	0.6115	7
Change in specifications	0.5816	8
Unavailability of equipment	0.5793	9
Lack of communication	0.5678	10
Poor procurement process	0.5540	11
Natural disasters	0.5425	12
Replacement of materials or procedures	0.5379	13
Inadequate project objectives	0.5356	14
Disputes among professionals	0.5241	15
Non-compliant design with government regulations	0.5034	16
Technology change	0.4966	17
Change in economic conditions	0.4943	18
Change in government regulations	0.4575	19

Table 4. Summary of the causes of variation orders for each case study.

No	Causes of Variation Orders
1	Design change
2	Omission of works in the contract
3	Specification change
4	Change in government policy
5	Differing in weather condition
6	Land acquisition
7	Financial issue
8	Inadequacy detail design
9	Changes in climatic conditions
10	Deficiency of material
11	Poor construction and work rejection
12	Poor soil conditions
13	Lack of coordination

6. DISCUSSION

The findings of the desk study revealed 19 causes of a variation order in answering the primary aim. It was blended to 13 from most of the minor repetitive causes of variation orders to be used in the questionnaire for the verification and validation process to evaluate their degree of importance. However, all 13 causes were previously identified within the field of variables in the literature review. The document study summarizes the causes of variation in order from the four project contract documents, as presented in (Table **4**).

Based on the data analyzed using the RII method, the financial problem was ranked according to the overall respondents as the first position with RII = 0.7540, which seriously impacts the project and may cause deferral completion. This result was also aligned with Ssegawa *et al*. (2002), who observed that the client and architect initiated most of the variations due to financial reasons, design, and drawing changes. Weather conditions (RII = 0.6966) were ranked as the second most important cause of variation in Tanzania. It is supported by Ismail *et al*. (2012), Wu *et al*. (2015), and Msallam *et al*. (2015). Differing site conditions were ranked as the third cause with RII=0.6598, change in design as the fourth cause of variation order in a road construction project in Tanzania with an RII of 0.6575, and poor scheduling as the fifth cause of variation with an RII of 0.6506. Changes in government regulations (RI=0.4575) and economic conditions (RI=0.4943) were the minimum-ranked causes of variation orders in road construction projects in Tanzania.

Based on the questionnaire findings, the respondents' proposed recommendations were that all involved parties should plan properly before work starts on site. The purpose was to assist in reducing the occurrence of variations during the construction phase, where the impact of variations can be severe on the project. Detailed site investigations, including detailed soil investigations, and considering it during the tendering stage were also suggested because the design and construction of the road project approach vary due to differences in site conditions. The third recommendation was for consultants to ensure that the design/specifications fall within the approved budget to avoid unnecessary variations. The fourth was to spend adequate time in the pretender planning phase, and the fifth was to obtain accurate information and research regarding procurement procedures, materials, and plants.

CONCLUSION

This study focuses on weighing the key causes of variation orders in road construction projects in Tanzania by distributing questionnaires among TANROADS and TARURA workers, contractors, and consulting firms. A typical index analysis of the collected information through a survey revealed the top ten causes of variation orders in road construction projects in Tanzania: financial problems, weather conditions, differing site conditions, changes in design, poor scheduling, lack of coordination, delay in approval, unavailability of equipment, lack of communication, and schedule.

Suggestions to minimize variation order incidence were stated as follows:

1. All participating partners must prepare sufficiently before the site commencement. To avoid conflicts, other groups such as water, electricity, and communication should be involved during the design stage.

2. All parties must perform thorough site analysis and geotechnical studies and scrutinize at the bidding stage.

3. Consultants must ensure the blueprints/specifications plunge in authorized fund allocation. Before entering the tender, both parts should be financially prepared to avoid variation in order.

4. Devote sufficient time in the devising stage. Before filling in the bidding document and estimating, contractors must conduct an effective site visit to see all obstacles and consider them in the bid.

5. Investigate and obtain accurate data concerning procurement transactions, materials, and plants. If possible, contractors are advised to obtain the entire amount of specific material to avoid a shortage of material at the site.

LIST OF ABBREVIATIONS

RII	=	Relative Importance Index
IRP	=	Integrated Road Projects
VO	=	Variation Orders

CONSENT FOR PUBLICATION

Not applicable.

STANDARDS OF REPORTING

Coreq guidelines were followed.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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