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Application of an Integrated Workmanship Benchmarking Framework to Building Failure in Developing Countries

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Abstract

The construction industry is grappling with significant challenges related to measuring and assessing workmanship performance, which has led to instances of poor workmanship and even building failures. Traditional evaluation methods often fall short, underscoring the urgent need for a more integrated approach to performance assessment. Recent research focused on developing integrated performance assessment techniques and indicators for a comprehensive evaluation of building projects. Key factors contributing to poor workmanship include a lack of standardisation, inadequate assessment frameworks, and limited empirical knowledge. In response, this study proposes implementing an integrated benchmarking framework to evaluate workmanship performance more effectively, employing various data collection methods, including case studies, questionnaires, and checklist surveys, to assess workmanship performance across construction sites throughout the project lifecycle. The questionnaire targeted critical success factors, while checklist surveys identified key failure factors at various project stages. The findings reveal that this integrated benchmarking framework significantly reduces building defects and failures, enhancing overall workmanship quality within Trinidad and Tobago's construction sector. Analysed projects demonstrated a notable decrease in defects and improvements in structural workmanship performance across all phases of the project. These results are expected to facilitate effective workmanship management in construction and promote the development of best practices in developing countries. This integrated benchmarking framework provides a comprehensive tool for evaluating workmanship performance across various building types, considering critical success and failure factors, project structures, and the organisations involved while offering continuous assessments throughout the lifecycle of building projects.

Keywords:

Workmanship;
Performance;
Benchmarking;
Framework;
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1- Introduction

The construction industry is vital for economic development, encompassing various associated sectors [1]. However, it faces challenges related to poor workmanship, which often results from deficiencies in design and implementation [2, 3]. This leads to difficulties in meeting stakeholder expectations and achieving project success. Effective performance measurement is essential for assessing project outcomes, and numerous methods exist for this purpose, such as the Analytical Hierarchy Process (AHP), Multi-Criteria Analysis (MCA), Earned Value Analysis, Regression Analysis, and Structural Equation Models [4-7]. Despite extensive research on project performance, significant challenges remain [8], including the absence of a comprehensive industry-wide performance framework. Other issues include varying project priorities, subjective assessments, data reliability, and a lack of standardised metrics [7, 9].

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Building failures can manifest in various forms and degrees of severity [10], with complete structural collapse being a major concern. A primary challenge contributing to such failures is poor workmanship, which complicates workers' ability to recognize issues and implement necessary quality control measures immediately. This often results in substandard construction practices, flawed designs, and ineffective methodologies, ultimately raising the risk of building collapse.

Globally, especially in developing countries, construction quality frequently fails to meet expectations. Research indicates that quality satisfaction in construction projects remains elusive due to human errors, forgetfulness, and carelessness [11]. Chinwokwu (2000) and Windapo (2006) [12, 13] suggested that a considerable percentage of building failures, approximately 37%, may be connected to carelessness and greed among construction professionals, with design defects accounting for an additional 22%. Makinde [14] identified over fifty cases of building failures between 2000 and 2007, revealing that a significant portion—nearly 40%—of these failures in residential buildings was linked to poor workmanship. Other categories, like commercial (14.3%) and assembly buildings (12.7%), also experienced notable failures attributed to similar root causes [15]. Moreover, about half of the failures linked to poor workmanship can be traced to design defects, while the rest stem from construction and material issues [16]. A survey analysing multiple building projects pointed to inadequate skills, knowledge gaps, and unclear project information as significant contributors to poor quality [17]. These findings highlight that insufficient workmanship leads to significant problems, such as increased costs and project delays, which, if unaddressed, will continue to undermine the quality of construction projects.

The construction industry in countries such as Trinidad and Tobago often relies on Safe To Work (STOW) certification and the International Organization for Standardization (ISO), which does not adequately address workmanship issues. To fill this gap, there is a need for an integrated benchmarking framework that emphasises Workmanship Performance Assessment (WPA) at the upper management level of building projects. This study aims to develop a framework to enhance the quality and reliability of construction outcomes, particularly in developing countries.

2- Building Failure and Collapse in Developing Countries

Building failure refers to a structure's inability to fulfil its intended role of providing comfort, safety, and stability [18-20]. This can lead to varying degrees of structural damage, culminating in complete collapse [21, 22]. Failures can be classified into cosmetic, which affects appearance without compromising stability, and structural, which endangers integrity and aesthetics [23]. These issues are particularly prevalent in developing countries, where socio-economic, political, and environmental challenges exacerbate the situation.

The rise in building failures and collapses globally, especially in developing regions, highlights significant concerns despite advancements in construction materials and standards [24]. Root causes in these countries often stem from human factors such as design errors and negligence rather than environmental stresses or terrorist acts, which tend to be more prevalent in developed nations [24]. This points to a pressing need for re-evaluation of the processes surrounding building planning, construction, and management to address the fundamental issues leading to structural failures.

Developing countries are especially vulnerable to natural disasters like earthquakes, hurricanes, and floods, which can disrupt social and economic stability [25]. Poorly planned informal settlements, which make up a considerable portion of populations in places like the Caribbean [26], are especially prone to collapse due to lax enforcement of building codes. With as much as 70% of construction occurring unregulated [27], the importance of stringent building regulations cannot be overstated. Ensuring compliance with safety standards is vital for protecting both buildings and the communities they serve from the impacts of natural hazards [25]. However, key contributors to building failures include unqualified personnel, inadequate soil investigations, poor oversight, and insufficient legislation [28, 29]. The role of building professionals is critical since deficiencies in their duties can lead to disastrous outcomes. A harrowing example is the Rana Plaza disaster in Bangladesh (Figure 1), where a nine-story garment factory collapsed in 2013, resulting in over 1,000 deaths and thousands of injuries [30]. Investigations revealed serious violations of building codes, construction on unstable land, and lack of structural integrity, emphasising the profound consequences of negligence in building practices [30].

Recent incidents highlighted significant regulatory issues and widespread violations of building codes, particularly in urban areas vulnerable to natural disasters. Although some efforts are being made to tackle these challenges, there is still a pressing need for stricter enforcement of regulations, improved construction practices, and addressing socio-economic disparities. It has been suggested that by adopting more robust building codes and investing in infrastructure designed to withstand disasters, developing countries could significantly decrease the frequency and severity of building collapses.

Figure 1. Building Collapse in Rana Plaza, a Nine-Story Building in Bangladesh

Findings attribute approximately 50%, 40%, and 10% of the causes of building failures to faulty design, construction site deficiencies, and material product failures, respectively [24, 31]. Flaws can occur at any stage, leading to structural failures primarily due to errors in planning, design, construction, and usage rather than the inherent load-bearing capacity of structures [31, 32]. To effectively mitigate the risk of building failures, a comprehensive evaluation framework focused on all lifecycle phases is needed. This framework should consider the roles of various stakeholders to identify gaps and inefficiencies, highlighting the importance of robust planning, regulation, legislation, and adherence to codes and standards in ensuring the quality of building projects.

3- Integrated Workmanship Benchmarking Framework

The framework developed aims to evaluate building workmanship performance throughout its project life cycle by identifying key success and failure factors, ultimately promoting sustainability in the construction industry. It integrates various assessment methods to address workmanship performance comprehensively, focusing on eliminating defects, enhancing quality, and improving efficiency. The overarching goal is to increase customer satisfaction through continual improvements that prevent building failures.

To achieve these objectives, the Lean Construction (LC) approach was adopted for its effectiveness in enhancing workmanship and reducing waste. By implementing LC principles, such as Total Quality Management (TQM), Business Process Re-Engineering (BPR), Concurrent Engineering (CE), Last Planner System (LPS), teamwork, Value-Based Management (VBM), and OHSAS 18001, the framework seeks to lower construction costs while optimizing material usage [33]. TQM was selected due to its focus on continuous improvement, management commitment, quality culture, employee empowerment, and customer satisfaction, making it a suitable foundation for the integrated workmanship framework. Furthermore, to ensure sustainable performance in building projects, the TQM framework was placed within a wider sustainability context that evaluates technical, social, economic, and environmental factors throughout the project's life cycle (Figure 2). However, an analysis of current literature and quality techniques revealed gaps in TQM implementation, particularly in performance assessment concerning life cycle costs and environmental impacts. To address these shortcomings, additional performance assessment methodologies were integrated into the TQM framework, including Six Sigma, Safety Management Systems (SMS), Environmental Management Systems (EMS), and Value-Based Management Systems. A blended framework is proposed, integrating key concepts from various sustainability domains—technical, economic, environmental, and social (Figure 2).

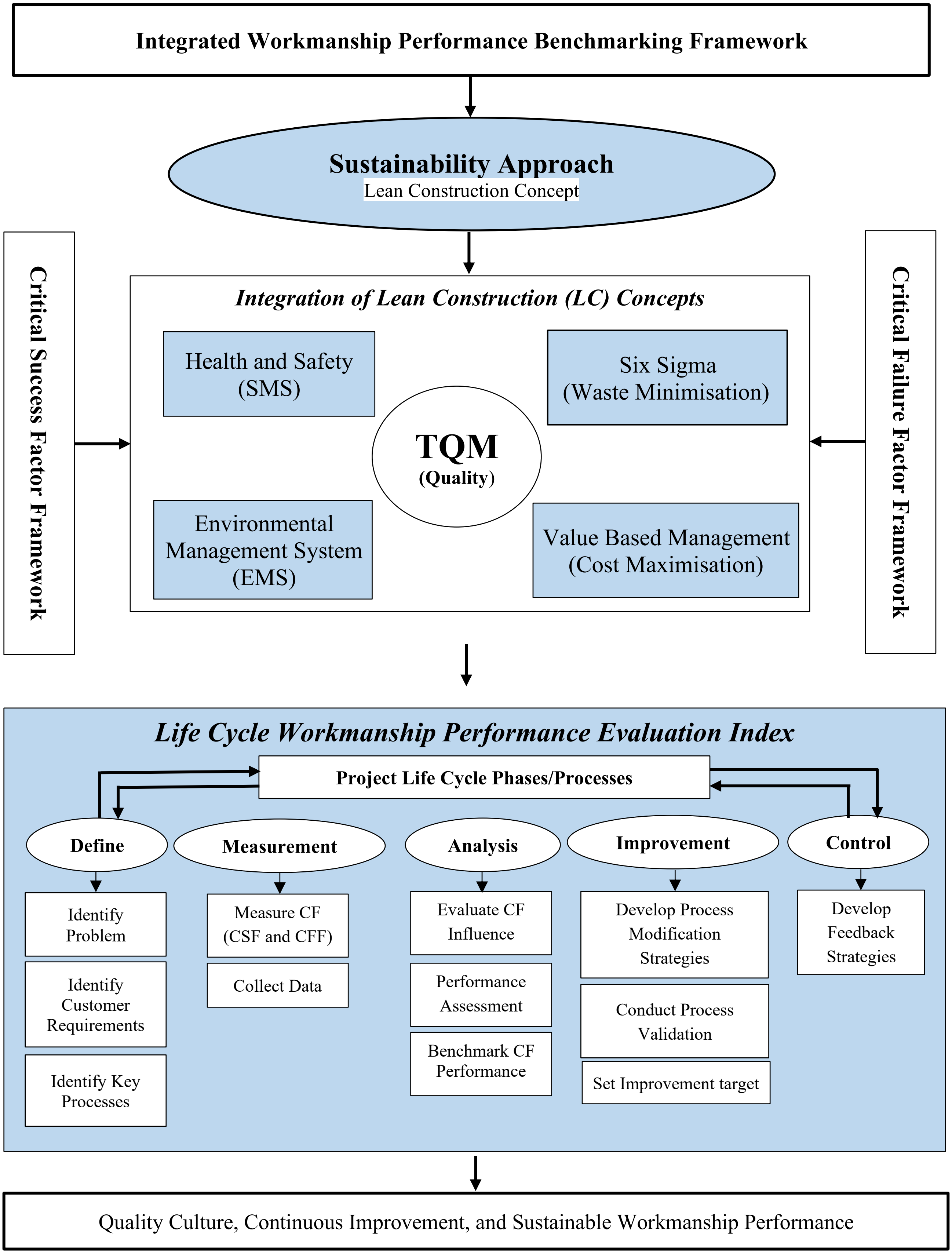

Figure 2. Integrated Workmanship Performance Benchmarking Framework

The framework emphasises the continuous assessment of workmanship performance throughout the entire life cycle of building projects. It utilises a life cycle workmanship performance evaluation index to monitor both Critical Success Factors (CSF) and Critical Failure Factors (CFF), ensuring a comprehensive analysis of project performance for the individual project and the overarching organisation. The assessment of CSFs in building projects revealed that technical sustainability is important, highlighting the necessity of emphasising quality, management, performance measurement, planning processes, documentation, supervision, training, and project management.

3-1- Integrating Critical Success Factors for Sustainable WPA

An analysis of existing TQM frameworks [33-35] revealed that a majority share common CSFs, which include top management commitment, supplier quality management, and employee empowerment. Notably, while strategic and design quality management CSFs were prevalent, the quality culture CSF was less frequently observed, indicating a need for enhancement in the organization's cultural initiatives. Furthermore, it was found that the TQM and Six Sigma frameworks do not comprehensively cover all the critical factors necessary for a WPA. However, these frameworks can synergistically complement each other. A combined approach that leverages the strengths of the frameworks is recommended for effectively establishing key factors in construction quality management [36].

In exploring SMS implementation within the construction sector, 24 important CSFs were identified [37, 38] and categorized into five groups: safety commitment, competency profile, safety climate, project management, and safety requirements. Among these, safety commitment, particularly top management involvement [39, 40], was highlighted as vital for successful SMS implementation. The significance of these CSFs was further evaluated through expert assessments, considering different life cycle phases (Figure 3).

Integrated Workmanship Critical Success Factor Metrics

Design, Planning, and Construction Phase

- Top management commitment
- Process planning
- Project management skills
- Safety training
- Performance measurement system
- Employee quality initiatives
- Project selection
- Process documentation
- Operational control
- Economic investment
- Effective supervisions
- Proper communication

Operation and Phase-Out Phase

- Use of the right tools
- Availability of tools
- Impact on customer and user
- Impact on the team
- Business organisational success
- Preparing for the future
- Customer satisfaction
- Business results
- Safety commitment
- Leadership and commitment
- Funding
- Education and training
- Material efficiency and quality
- Data collection and measurement
- Process documentation
- Performance measurement system
- Supply chain management

Figure 3. Integrated Critical Success Factor Metrics for Sustainable WPA

3-2- Integrating Critical Failure Factors (CFF) for WPA

Management's ability to provide adequate supervision and maintain quality is crucial for enhancing employee productivity and workmanship performance. Hewage & Ruwanpura [41] indicates that lack of experience and competence can contribute to subpar workmanship, leading to project failures. Other significant factors include inadequate project management, poor supervision, and language barriers can result in miscommunication on-site [42, 43]. The factors affecting workmanship performance differ widely across regions, underscoring the necessity for deeper investigation into the causes of poor workmanship and project failures, especially in developing countries. This study aims to assess the significance of these failure factors through expert evaluations. The Critical Failure Factor Metrics (Figure 4) were evaluated and organized by their relative importance index. The findings suggest that many critical failure factors relate to technical sustainability, advocating for a focused approach to quality management, performance measurement, process planning, documentation, supervision, training, and project management throughout building project lifecycles.

Workmanship Critical Failure Factor Metrics

Design and Planning Phase

- Design error
- Design omission
- Design changes by the owner
- Lack of design standards
- Inadequate structural design
- Incomplete detail drawing
- Use of wrong techniques
- Use of inferior materials
- Inadequate assessment of exposure
- Lack of proper structural analysis
- Communication gap
- Project location
- Project supervision
- Soil geology
- Quality control
- Workforce selection

Construction and Implementation Phase

- Delayed payment
- Inadequate funding
- Poor material procurement processes
- Defects in various stages of construction
- Poor communication
- Poor site supervisions
- Poor project management
- Inexperienced subcontractors
- Inadequate time to complete the project
- Inadequate training of employees
- Defective construction materials
- Poor quality control on sites
- Lack of proper reinforcement in concrete
- Lack of workmanship skills
- Lack of construction standards
- Scope changes
- Inappropriate designs for construction

Operation and Phase-Out Phase

- Decay and break up of mortar
- Crack on building walls
- Roof leaking
- Dampness
- Poorly constructed and maintained roofs
- Exposed reinforcement
- Leaking through walls
- Flooring damaged by leaks
- Lack of skilled and trained personnel
- Poor communication
- Inadequate information sharing or sourcing
- Forgetfulness and carelessness
- Low productivity
- Poor supervision of work
- Material availability
- Labour availability
- Equipment availability and failure
- Use of inferior materials
- Technical challenges of the project
- Poor funding
- Irregular controls of activities

Figure 4. Integrated Critical Failure Factor Metrics for Sustainable WPA

4- Methodology/Research Approach

The questionnaires and checklist surveys were instrumental in gathering data regarding workmanship performance at various sites. Experts were randomly selected to ensure unbiased opinions.

4-1- Questionnaire Survey Technique

The study on workmanship performance in residential building projects highlighted the importance of expert opinion data since not all critical factors could be directly evaluated on-site due to various project stages at different levels of completion. The research explored workmanship performance across the entire project life cycle, considering both completed and ongoing projects, as well as the organisations involved [10, 44-48]. To facilitate this, an interview guide was developed based on critical success factors relevant to the life cycle phases: design and planning, construction and implementation, and closeout. This guide consisted of two sections: the respondents' characteristics and the critical factors influencing workmanship in each project phase.

4-2- Checklist Survey Technique

A checklist technique was employed, categorising critical failure factors by project phases. Three experienced professionals are: contractors, engineers, and consultants. They were selected for assessment at various construction sites, utilising their expertise and willingness to participate as third-party experts. The checklist allows for direct observations of different case studies. This checklist mirrored the structure of the interview guide, with one section addressing project characteristics and the other relating to critical failure factors associated with poor workmanship.

4-3- Case Study Approach and Sample Size

A case study approach was adopted to evaluate workmanship performance across 140 residential building projects involving 420 professionals from design and construction sectors in Guyana, Jamaica, Suriname, and Trinidad. Performance assessments included interviews and observations conducted at each site using the proposed survey instruments, with opinions gathered on critical success and failure factors. Given that contractors, engineers, and consultants play pivotal roles in driving construction activities and monitoring each project phase [10, 47], they constituted the primary respondents for the study. The selection of case studies spanned different strata (Tables 1 and 2)

Table 1. Project Size and Sample Strata

Project size	Sample size	Guyana	Jamaica	Suriname	Trinidad	
Small	25	5	5	5	10	Three (3) participants considered per project, resulting in 420 participants
Medium	70	10	20	10	30	
Large	45	10	10	5	20	
Total	**140**	**25**	**35**	**20**	**60**	

Table 2. Residential Project Sample Summary

Projects	Project Strata Assessed
Sample #1	Residential-Ongoing-Small-New-Projects
Sample #2	Residential-Ongoing-Small-Renovated Projects
Sample #3	Residential-Ongoing-Medium-New Projects
Sample #4	Residential-Ongoing-Medium-Renovated Projects
Sample #5	Residential-Ongoing-Large-New Projects
Sample #6	Residential-Completed-Small-New Projects
Sample #7	Residential-Completed-Small-Renovated Projects
Sample #8	Residential-Completed-Medium-New Projects
Sample #9	Residential-Completed-Medium-Renovated Projects
Sample #10	Residential-Completed-Large-New Projects
Sample #11	Residential-Completed-Large-Renovated Projects

5- Data Analysis and Discussion

A life cycle assessment represents a reliable method for evaluating durability, quality, and sustainability by analysing both success and failure factors. The data collected were integrated into a Workmanship Performance Benchmarking Framework Index, which facilitated the modeling of workmanship performance across selected case studies (Figures 3 and 4). The benchmarking framework assessment methodology and mechanism are explained in Figure 2.

5-1- Residential Ongoing Small Building Projects

The findings reveal a notable trend in the workmanship performance of small ongoing building projects (Figures 5 and 6), highlighting that the weighted scores were significantly higher during the operation and phase-out (WPC) and planning and design (WPA) phases compared to the construction and implementation phase (WPB). This indicates a more frequent occurrence of defects in the WPC and WPA phases, leading to lower overall performance ratings.

According to Othuman Mydin et al. [42], most construction defects arise from human errors related to defective workmanship, attributing 90% of these errors to the construction team's performance. This challenge often relates to compliance issues with contract agreements concerning project specifications, quality, and other factors affecting customer satisfaction, such as durability and design defects [49]. This emphasises the crucial role of workmanship in project decisions and designs to achieve successful construction outcomes and customer satisfaction. The workmanship performance scale (Table 3) developed from the collected data indicated that the average weighted poor workmanship performance scores for the assessed projects were below 50 points, with the WPA scoring 45.82, WPB 44.29, and WPC 49.09. These scores reflect a comparatively higher level of workmanship performance, ranging from 60 to 70 points.

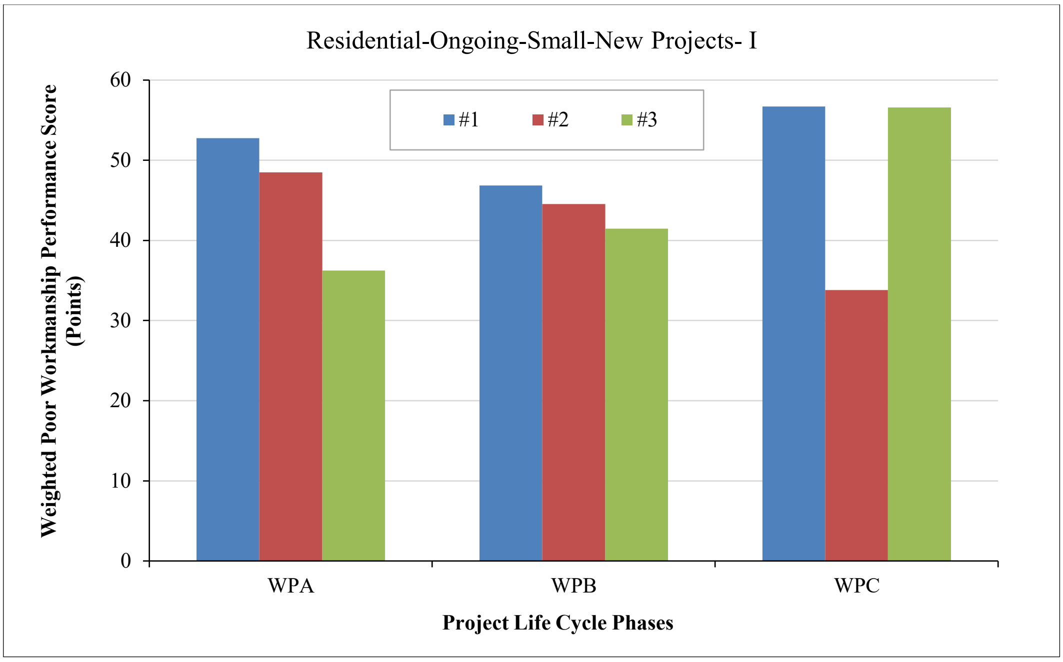

Figure 5. Residential Ongoing Small New Projects–I

Table 3. Project Workmanship Performance Scale

Performance Levels	Weighted Poor Workmanship Performance Score (Defect Occurrence)		Workmanship Performance Scale
	Project Phase Level	**Whole Project Level**	**Measure (Point)**
1	10	100	100
2	20	200	90
3	30	300	80
4	40	400	70
5	50	500	60
6	60	600	50
7	70	700	40
8	80	800	30
9	90	900	20
10	100	1000	10
Based on the Critical Failure Factor Performance			
Performance Levels	**Weighted Workmanship Performance Score Success Achievement**		**Workmanship Performance Scale**
	Project Phase Level	**Whole Project Level**	**Measure (Point)**
1	10	100	10
2	20	200	20
3	30	300	30
4	40	400	40
5	50	500	50
6	60	600	60
7	70	700	70
8	80	800	80
9	90	900	90
10	100	1000	100
Based on the Critical Success Factor Performance			

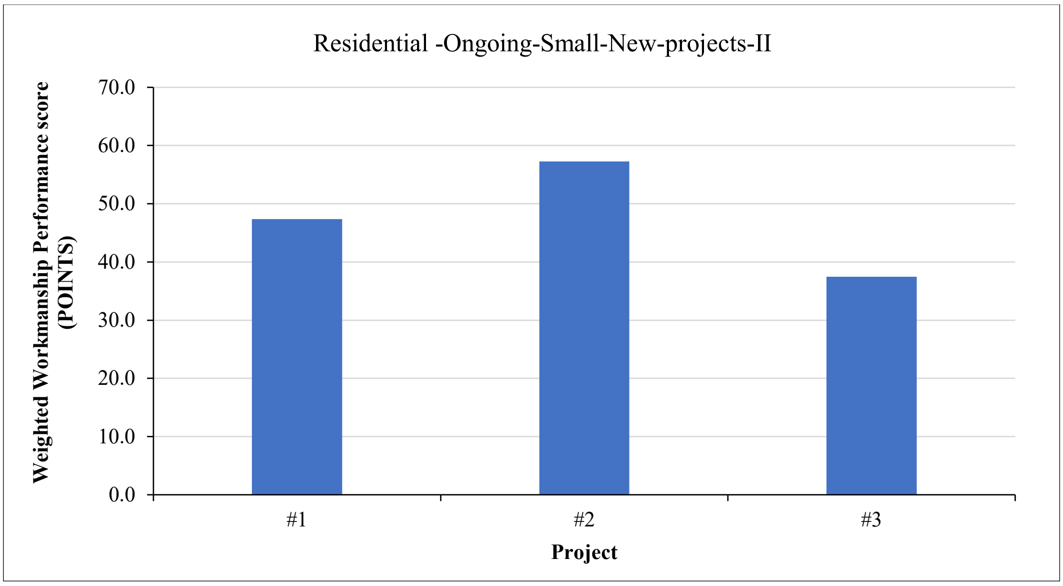

Figure 6. Residential Ongoing Small New Projects–II

Analyzing project performance (Figure 6), project #2 emerged with the highest workmanship performance score, exceeding 50, indicating a range of 60 to 70 on the workmanship scale based on critical success factors. This performance highlights an overall trend of reduced defects across all phases of ongoing small residential projects, indicating an average workmanship performance score below 50 points. According to Abdul Rahman et al. [50], the quality of construction projects has been declining due to an increase in major defects attributed to poor workmanship, underscoring the relationship between lower defect rates and higher workmanship performance.

5-2- Residential Ongoing Medium Building Projects

Data presented on the weighted poor workmanship performance scores reveal that the average score for the planning and design phase (WPA) was significantly higher at 69.80, in contrast to scores of 50.32 for the construction phase (WPB) and 52.96 for the operation and phase-out phase (WPC). This suggests that defects are more prominent during the initial phases of a project. Despite this, all assessed projects reported scores above 50, indicating a relatively low workmanship performance between 40 and 50 points.

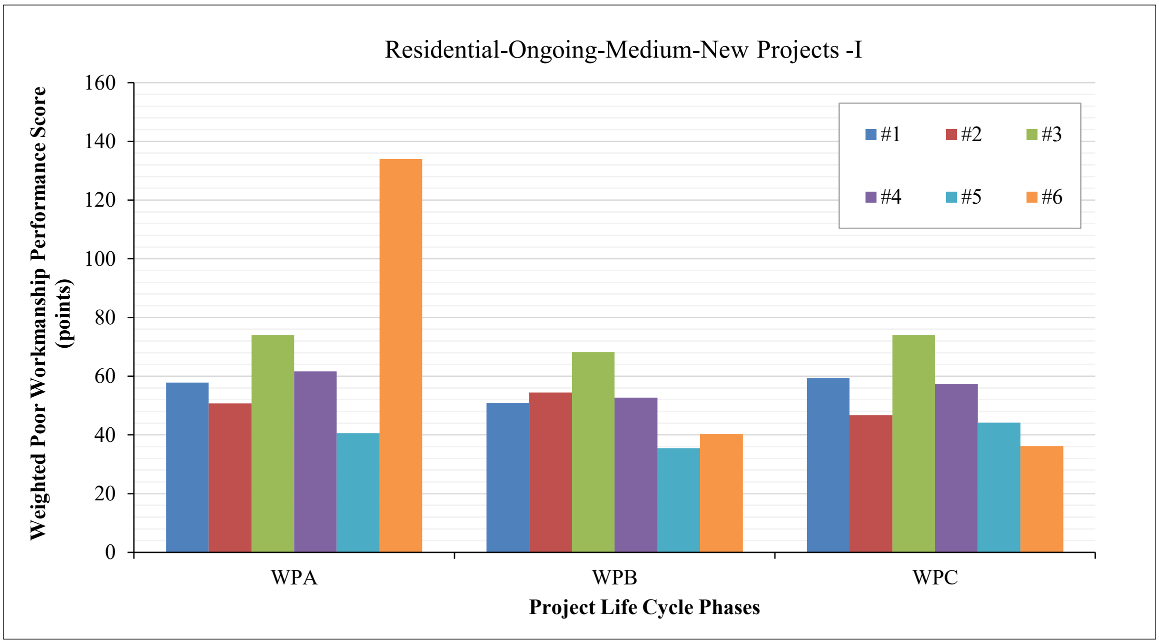

Figure 7. Residential Ongoing Medium New Projects–I

Further analysis (Figure 8) showed that projects #1, #2, and #3 achieved high workmanship performance scores relative to their critical success factors. This correlation reflects their lower scores for poor workmanship (Figure 7), emphasising the effectiveness of the integrated benchmarking framework utilised in the evaluation. Zunguzane et al.

[51] highlighted that poor workmanship significantly contributes to building failures and defects, attributing 90% of these issues to management and workmanship problems during the design and implementation stages. The average workmanship performance scores for these projects, particularly concerning defect occurrence, are below 50, revealing a relatively higher performance level across all phases of the project life cycle.

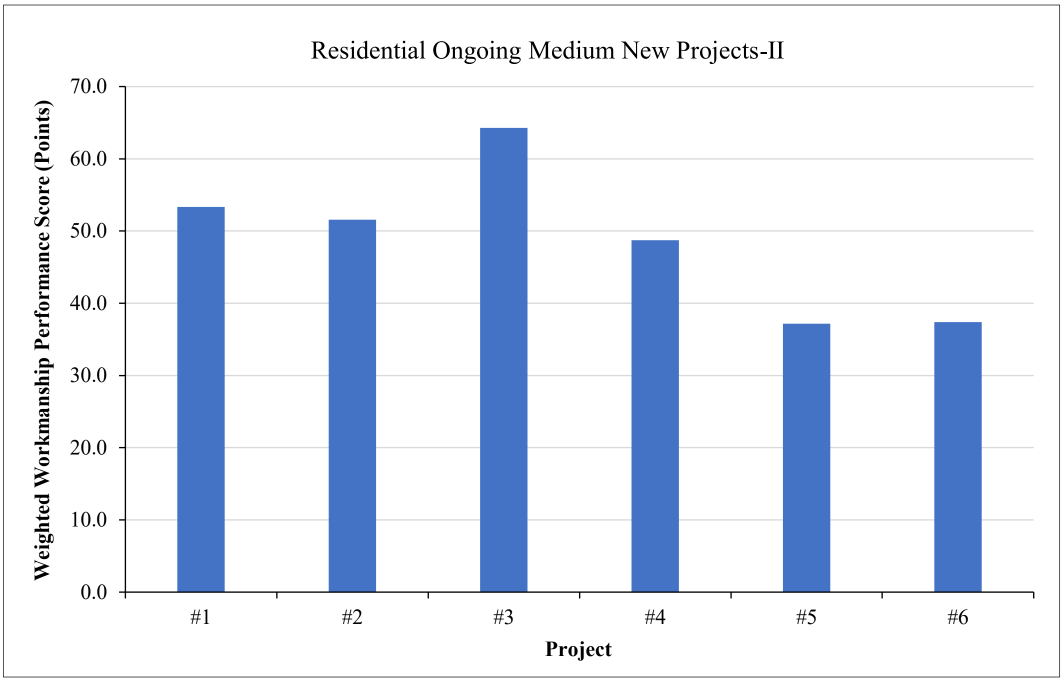

Figure 8. **Residential Ongoing Medium New Projects–II**

5-3- Residential Ongoing Large Building Projects

The analysis of workmanship performance in ongoing residential building projects reveals several key insights across different life cycle phases. Average weighted scores for workmanship performance remain below 45 (Figure 9), with a notable decline from the planning and design phase (WPA) to the construction phase (WPB) and further to the operation and phase-out phase (WPC). The scores indicate that the incidence of defects is highest during the planning and design phase, which recorded an average score of 41.86. In contrast, the construction phase scored 38.69, and the operation and phase-out phase scored 37.09. Despite WPA's lower score, it reflects a relatively high level of workmanship compared to the other phases, with WPA, WPB, and WPC scoring 70.2, 75.6, and 78.8 points, respectively.

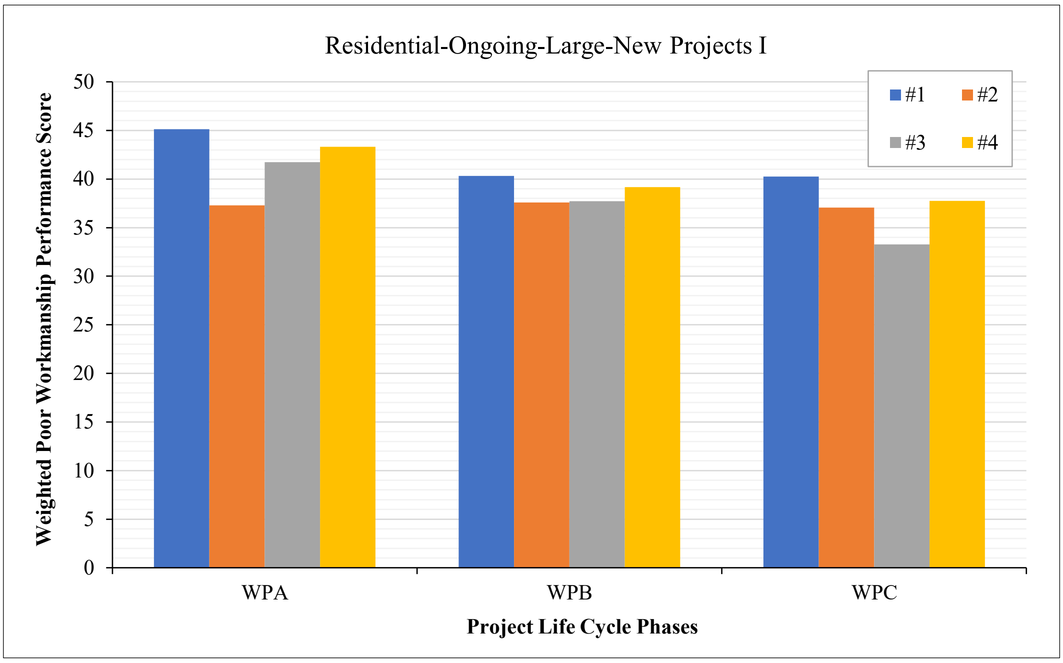

Figure 9. **Residential Ongoing Large New Projects–I**

An integrated benchmarking framework assessing large residential projects shows that workmanship performance consistently remains below 50 (Figure 10), indicating a widespread issue with defects and poor workmanship across all phases.

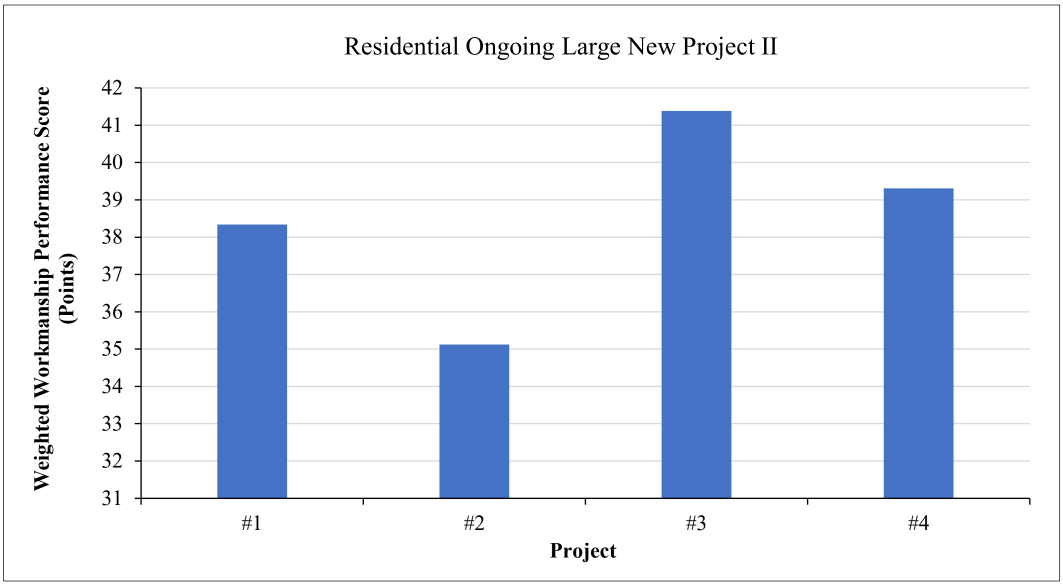

Figure 10. Residential Ongoing Large New Projects–II

Notably, residential building projects with poor workmanship recorded performance scores above the critical 50-point benchmark, suggesting fewer defective activities within the samples (Table 2). This trend points to a commendable adherence to regulations and standards in regions like Trinidad and Tobago, yet paradoxically reveals a lower overall project success rate related to systemic workmanship performance when evaluated against critical success factors throughout the project life cycle. Moreover, the examination encompassed organisational workmanship performance, revealing that scores fell below the 50-point benchmark in various stages (Table 4). This suggests that organisational and management practices within the regional residential built environment may need improvement despite compliance with building codes and standards.

Table 4. Residential Project Workmanship Performance Summary

	Poor WP (Workmanship Performance)			Success WP
Projects	**WPA**	**WPB**	**WPC**	**(WPA, WPB, WPC)**
Sample #1	Higher, 65pts	Higher, 66pts	Higher 61pts	Lower, 47.4pts
Sample #2	Higher, 70pts	Higher, 78pts	Higher 68pts	Lower, 39.4pts
Sample #3	Lower, 42pts	Higher, 60pts	Higher 58pts	Lower, 48.7pts
Sample #4	Higher, 70pts	Higher, 78pts	Higher 68pts	Lower, 39.4pts
Sample #5	Higher, 68pts	Higher, 73pts	Higher 73pts	Lower, 39.0pts
Sample #6	Higher, 63pts	Higher, 67pts	Higher 66 pts	Lower, 43.2pts
Sample #7	Higher, 65pts	Higher, 69pts	Higher 62pts	Lower, 43.2pts
Sample #8	Higher, 58pts	Higher, 60pts	Higher 65pts	Lower, 46.1pts
Sample #9	Higher, 64pts	Higher, 69pts	Higher 68pts	Lower, 40.4pts
Sample #10	Higher, 64pts	Higher, 66pts	Higher 68pts	Lower, 43.6pts
Sample #11	Higher, 66pts	Higher, 72pts	Higher 73pts	Lower, 39.8pts
Based on Workmanship Performance Scale (50 pts)				

5-4- Residential Building Project WP Analysis

The workmanship performance analysis of ongoing residential building projects, encompassing small, medium, and large scales (Figure 11), was based on critical failure factors and the overall project workmanship performance scale (Table 3). The workmanship performance analysis of 12 assessed residential projects demonstrated a cumulative weighted score of 150 (Figure 11), corresponding to 95 points on the workmanship performance scale. Medium-sized projects particularly stood out, exhibiting higher workmanship performance and lower defect incidence compared to both small and large projects, with scores ranging from 150 to 280, translating to 85 to 95 points on the scale.

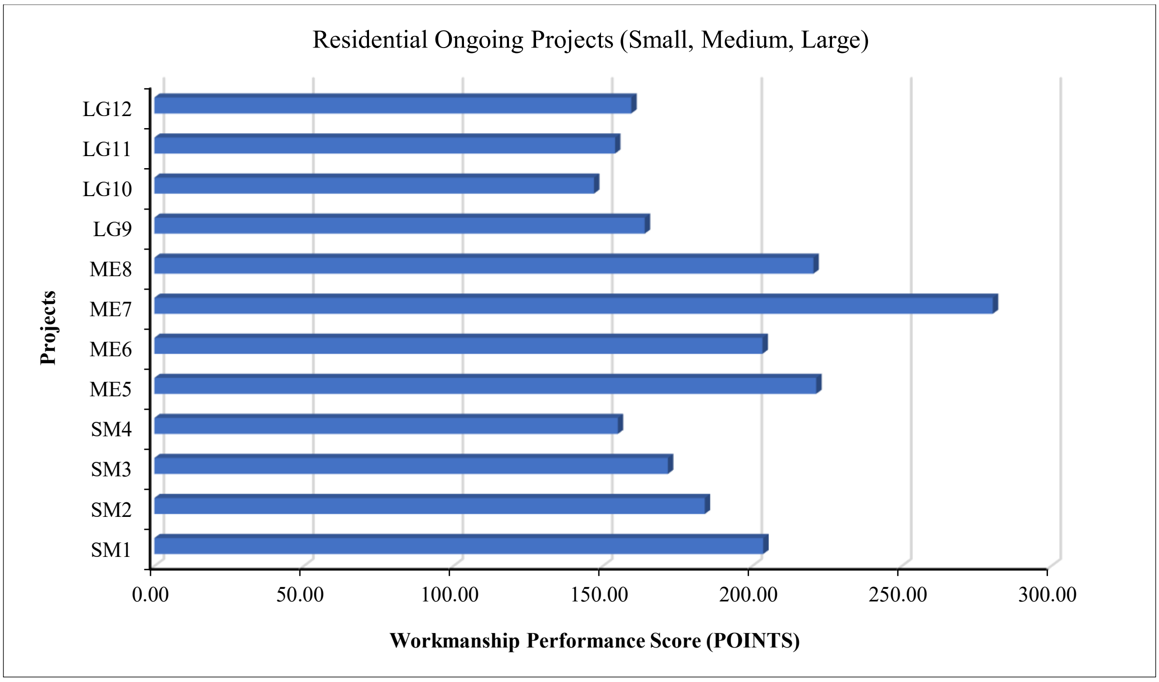

Figure 11. Residential Ongoing Projects

The average workmanship performance appears to be high, suggesting low levels of defects across all 12 projects. This indicates that the benchmarking framework can be effectively applied to various ongoing residential projects, irrespective of their size and capacity. Despite this seemingly positive outcome, a closer examination of critical success factors reveals that the workmanship performance scores are relatively low, ranging from 39 to 48.8 points (Table 4). This disparity highlights that, while regulation compliance and minimal defect occurrence are achieved, the overall project completion success rate is low, suggesting systemic issues in workmanship across the board.

Further investigation into new and renovated projects shows that new constructions (Figures 12 and 13) have weighted workmanship performance scores between 150 and 280, with a corresponding workmanship scale score of 85 to 95 points. Renovated projects demonstrate even higher performance, scoring 96 to 98 points on the workmanship scale with a lower defect occurrence.

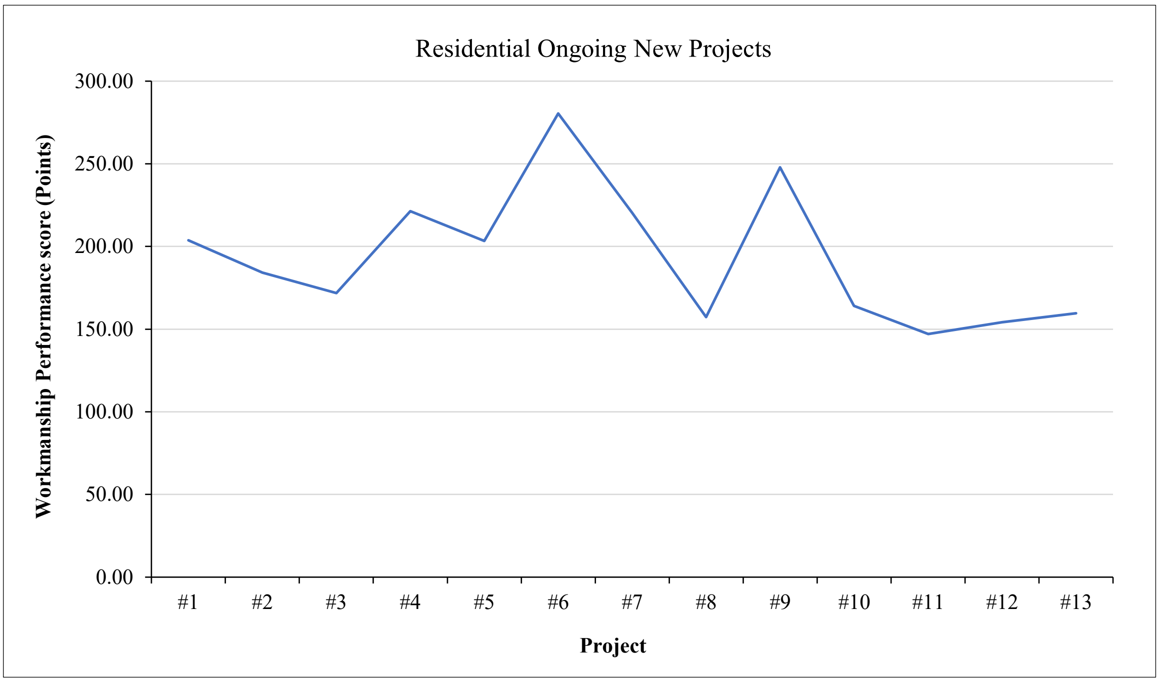

Figure 12. Residential Ongoing New Projects

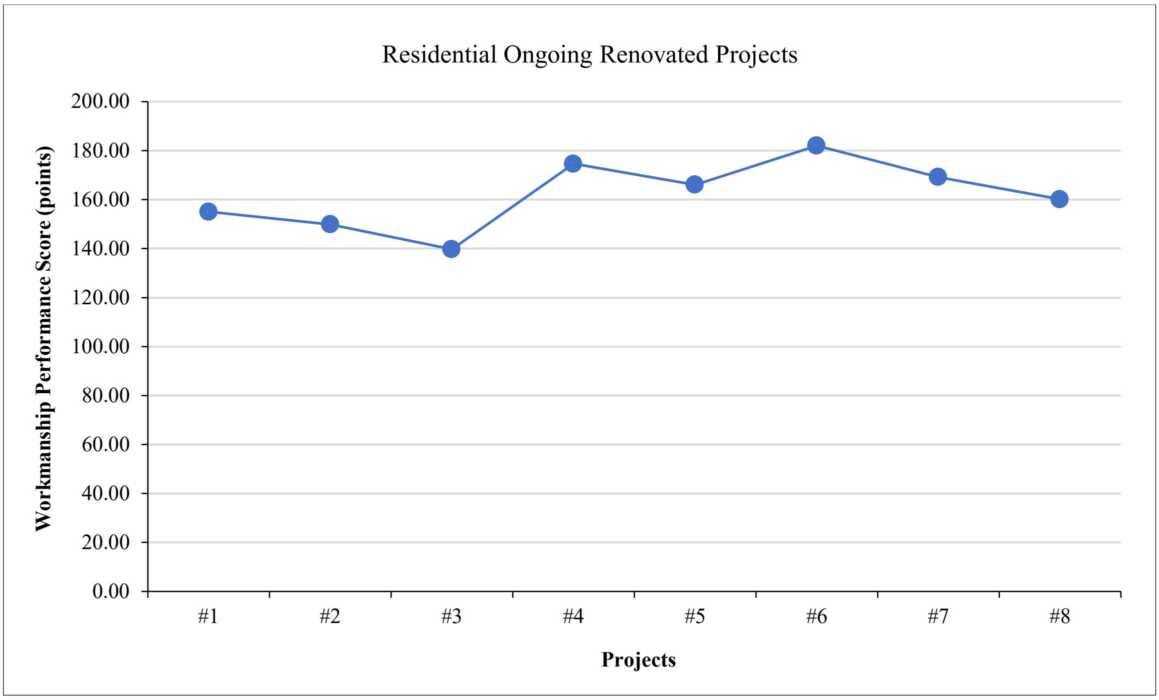

Figure 13. **Residential Ongoing Renovated Projects**

The analysis of workmanship performance in completed residential building projects, categorised by size (Figure 14), highlights significant findings regarding defect occurrence. Across 27 projects, the average cumulative weighted workmanship score fell between 150 and 250, translating to 95 points on the workmanship performance scale. Medium-sized projects (M1-M9) particularly stood out, with scores ranging from 200 to 280 and workmanship scale points between 90 and 95, indicating a lower rate of defects compared to small and large projects.

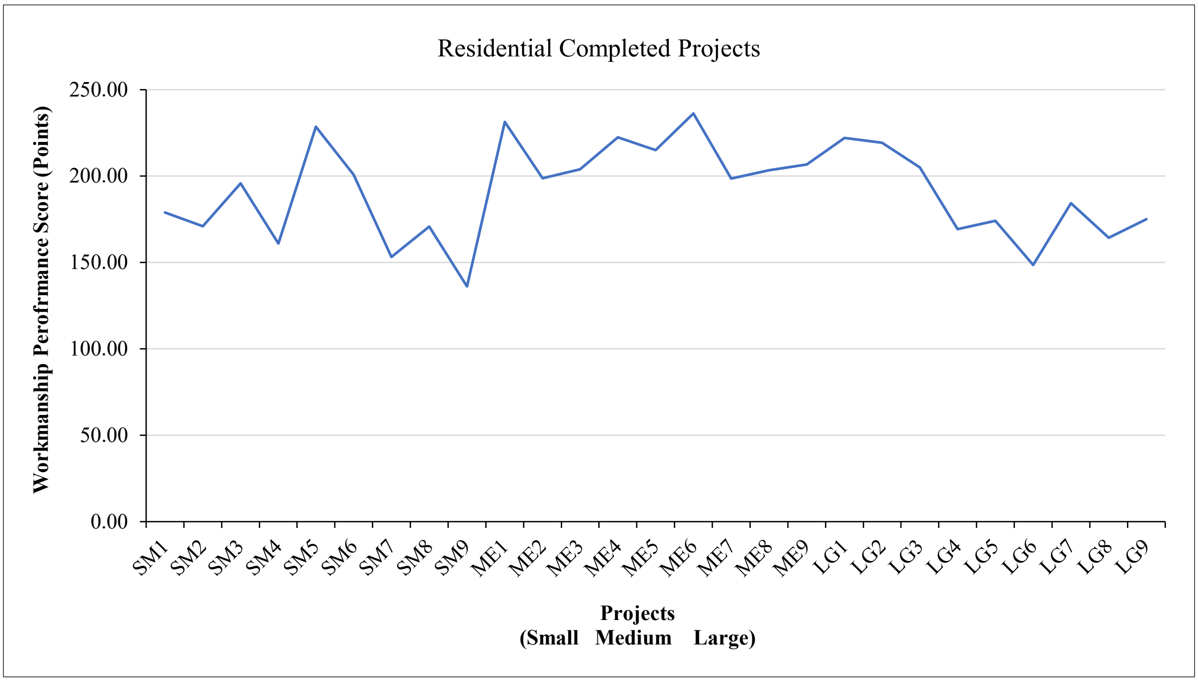

Figure 14. **Residential Completed Projects**

The workmanship performance appears to be high, indicating that the occurrence of defects is low across the 27 projects. In comparison to ongoing residential projects, the completed residential projects achieved similar performance levels but recorded higher weighted workmanship performance scores, ranging from 150 to 280, with workmanship scale points between 85 and 95, suggesting that the benchmarking framework could effectively apply to various residential project types, capacities, and scales.

While the overall workmanship performance suggests a high standard and low defect occurrence, the success assessment based on critical success factors revealed lower scores, ranging from 39 to 48.8 points (Table 4). This discrepancy indicates that, despite good performance in defect rates (Figures 15 and 16), systemic aspects of workmanship are lacking across all projects assessed. Key areas for improvement include organisational management, commitment from top management, quality culture, process planning, strategic quality management, employee empowerment, training and education, supply chain management, customer satisfaction, information and communication technology, and continuous improvement.

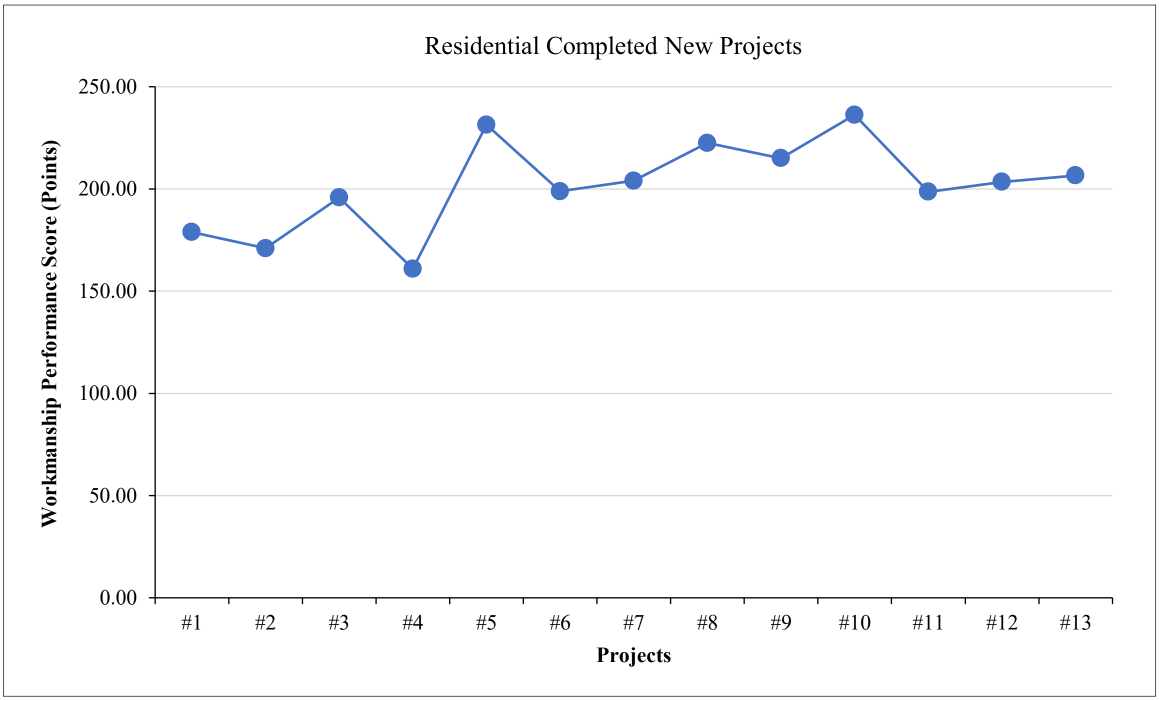

Figure 15. Residential Completed New Projects

Figure 16. Residential Completed Renovated Projects

Analysis of the workmanship performance of completed residential projects, both new and renovated (Figures 15 and 16), indicated weighted scores ranging from 150 to 240. Both categories received workmanship scores between 85 and 95 points, suggesting that higher workmanship performance correlates with lower incidence of defects in these projects.

6- Discussion

The overall workmanship performance in various construction projects has been assessed as low despite high scores in specific workmanship metrics related to defect occurrences and adherence to standards. This inadequacy is largely attributed to ineffective workmanship management [10], which is crucial for ensuring quality, cost-efficiency, and timely delivery in the construction industry. In many developing regions like Trinidad and Tobago, which are currently in intermediary phases of development, residential building defects—particularly in roofs, walls, and other structural elements are prevalent [52]. These defects, linked to poor workmanship, can lead to severe accidents, injuries, or even fatalities [52-54].

The study indicated that workmanship performance scores ranged from 39 to 48.8 points (Table 4) despite demonstrating high individual workmanship metrics. Systemic issues were identified as major contributors to these low scores, including inadequate supervision, insufficient training, poor communication, and a lack of strategic management practices. Ultimately, human errors, primarily arising from these systemic deficiencies, account for a substantial percentage of construction defects [10, 42] making effective management practices vital to improving overall workmanship quality in the construction sector.

6-1- Finding Implications

While regulations and workmanship standards effectively evaluate many failure factors, critical success factors (Figure 3) have not received adequate attention, resulting in subpar workmanship throughout the project lifecycle. This imbalance can lead to project failures and even building collapses, emphasising the need to recognise the equal importance of both factors in assessing overall project performance. To address these challenges, there is an urgent call for a comprehensive workmanship standard that encompasses both systemic (success factors) and structural (failure factors) aspects. Such a standard could greatly reduce the risks associated with failures and collapses in building projects.

6-2- Framework Potentials

Most critical success factors relate to technical sustainability, underscoring the necessity for a holistic framework that integrates success and failure factors across technical, economic, environmental, and social sustainability domains. An integrated framework for workmanship benchmarking is proposed, particularly for developing countries, to effectively evaluate project performance on both individual and organisational levels throughout the lifecycle, while regulating both systemic and structural components.

- The integrated benchmarking framework could help contractors make informed decisions on construction workmanship performance.
- Potential defects and safety hazards could be identified at an early stage of the construction project to implement necessary measures to minimize financial loss and failure.
- This integrated approach combined the methodological framework and principles from TQM, SMS, EMS, Value Based Management System, and Six Sigma techniques to develop a benchmarking system to aid the development of workmanship standards in developing countries, the Caribbean region, and Trinidad and Tobago.
- The benchmarking system developed in this study could be applied at the tendering stage for project evaluation and award.
- This integrated benchmarking framework provides a comprehensive analysis approach for construction workmanship performance assessment at both organization and project levels. It also provides a vital tool for building and construction professionals.
- The study successfully developed and ranked a set of critical success and failure factors for workmanship performance assessment.

7- Conclusion

This study introduced an integrated workmanship benchmarking framework designed to assess and measure the workmanship performance of building projects at any stage of their life cycle. The findings indicated that low workmanship performance is primarily due to systemic issues across all assessed projects, contributing to high rates of building failures and poor quality. The framework developed is thorough and capable of evaluating various types of buildings by examining both critical failure and success factors, as well as the project's structure and the organisations involved. Ultimately, this framework serves as a valuable tool for assessing workmanship performance throughout the entire life cycle of construction projects.

7-1- Specific Framework Implementation Strategies

An integrated computerised platform can facilitate implementing a benchmarking framework for workmanship in the construction industry. This initiative aims to offer a straightforward and easily adaptable system for evaluating performance. Alongside this framework, various training programs, including seminars, workshops, and certifications, can be introduced to bring together lower-level workforce members, management, and industry stakeholders. The framework can be effectively presented as a ranking system or checklist, streamlining its use for companies to assess their projects and internal processes. Through case studies of residential and commercial projects in Trinidad and Tobago and the Caribbean, the integrated benchmarking framework was validated, focusing on critical factors influencing workmanship performance. The findings highlight the widespread issues of poor workmanship, building failures, and collapses within the sector. Consequently, the study suggests that the developed framework could evolve into a Workmanship Performance Standard, a regulatory code, and application software. These tools would guide construction management in developing countries, helping to ensure quality workmanship and compliance with industry standards. Furthermore, the research acknowledges the potential impact of external factors, like economic limitations and regulatory policies, on the framework's success, which is currently being considered in the validation phase of the study.

7-2- Recommendations

- To effectively track and monitor all aspects of a project, it's important to incorporate mechanisms that can trace any changes back to their origin.
- The framework does not sufficiently address costs, so integrating this element is essential.
- The criteria emphasised in the framework lean more towards management rather than operational details; this aspect can certainly be improved.
- The project design options are not clearly outlined within the framework, yet the criteria provided can be utilised to assess the performance of different designs.
- Establishing a feedback mechanism would be beneficial, as it would enable targeted corrective actions in specific areas, improving processes without the need to dismantle the entire system in search of issues.

8- Declarations

8-1- Author Contributions

Conceptualization, R.S. and J.I.; methodology, R.S.; software, J.I.; validation, A.M., F.O., and K.S.B.; formal analysis, J.I.; investigation, R.S.; resources, R.S.; data curation, A.C.; writing—original draft preparation, R.S.; writing—review and editing, A.M. and F.O.; visualization, L.L.; supervision, A.M. and F.O.; project administration, R.S.; funding acquisition, R.S. All authors have read and agreed to the published version of the manuscript.

8-2- Data Availability Statement

The data presented in this study are available in the article.

8-3- Funding

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8-5- Institutional Review Board Statement

Not applicable.

8-6- Informed Consent Statement

Not applicable.

8-7- Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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