Nanayakkara, N.H.V.T.N., Perera, K.P.H. and Halwatura, R.U., 2025. Impact on project attributes due to constructability issues in large-scale condominium projects in Sri Lanka. In: Waidyasekara, K.G.A.S., Jayasena, H.S., Wimalaratne, P.L.I. and Tennakoon, G.A. (eds). *Proceedings of the 13th World Construction Symposium*, 15-16 August 2025, Sri Lanka. pp. 826-840. DOI: https://doi.org/10.31705/WCS.2025.62. Available from: https://ciobwcs.com/papers/

IMPACT OF CONSTRUCTABILITY ISSUES IN LARGE-SCALE CONDOMINIUM PROJECTS: A CASE STUDY FOR SRI LANKA

N.H.V.T.N. Nanayakkara[1], K.P.H. Perera[2] and R.U. Halwatura[3]

ABSTRACT

Sri Lanka's construction industry has experienced significant growth over the past decade, with an average growth rate of 8.5% from 2010 to 2020. Large-scale condominium projects have emerged as prominent projects in the real estate sector since they hold a dominant portion. Successful completion of these projects requires advanced construction techniques and strategic planning throughout the project, starting from pre-construction stages to project handover. The study adheres to a dual-level classification model for constructability issues in Sri Lankan condominium projects as common and project-specific issues. The evaluation of the impact of these issues on project evaluation criteria is vitally important for contractors to complete projects successfully. The study follows a sequential mixed-method approach consisting with a detailed questionnaire and were conducted among industry professionals to evaluate eight (8) constructability issues, including design complexity (DC), Mechanical, Electrical, and Plumbing work (MEP) integration issues, to check their effect on seven (7) project evaluation criteria. Through the collected consensus from the industry professionals, the constructability issues are evaluated and analysed using professional agreement rates, cross-tabulation, and using Kruskal-Wallis (KW) Test. The results generated through the KW tests, having lower $p<0.05$, show that DC, integration of MEP, and material handling are major constructability issues, while issues with $p>0.05$, including having long shear walls, work hour restrictions, are project-dependent constructability issues. This research contributes to the industry by providing actionable insights into mitigating constructability-related risks, ultimately facilitating the successful completion of large-scale condominium projects in Sri Lanka.

Keywords: *Constructability Issues; Cost Estimation; Project Attributes; Project Planning.*

1. INTRODUCTION

Construction is one of the major industries that underpin economic development across the world and is usually linked with infrastructure development, income generation, employment, and urbanization (Al-Fadhli, 2020). According to the Construction Industry

[1] Postgraduate student, Department of Civil Engineering, University of Moratuwa, Sri Lanka, thilankanalaka@gmail.com

[2] Senior Lecturer, Department of Civil Engineering, University of Moratuwa, Sri Lanka

[3] Senior Professor, Department of Civil Engineering, University of Moratuwa, Sri Lanka, rangika@uom.lk

Statistics 2025, it is among the major industries in the world, employing over 100 million people and contributing about 13% to the worldwide Gross Domestic Product (GDP). The industry's long-run impact on the economy is much bigger and also affects other industries that provide machinery, building materials, transport, and services (Langappuli, 2023). In the last decade, the construction industry has continued to grow phenomenally, with the global construction market surging from USD 9.5 trillion in 2014 to USD 12.9 trillion in 2022. Further, a growth of 35% is expected in the next eight years by 2030. (Al-Fadhli, 2020). Higher urbanization, improvement in construction technologies, and greater consideration for sustainability and resilience in the building industry have led to an upsurge in development in the construction industry (Contrada et al., 2019). The Sri Lankan construction industry is vital to the country's economic development. It had contributed 6.2% to the nation's GDP in 2020, with a Compound Annual Growth Rate (CAGR) of 15.1% (De Silva et al., 2023). The census report for 2021 by the Department of Census and Statistics, Sri Lanka, reports that the construction industry employed an estimated 1.03 million workers in 2020, or about 7.5% of total employment in Sri Lanka (De Silva et al., 2023). However, the Sri Lankan construction industry faced a severe downfall within the years of 2020 to 2023, due to the COVID-19 pandemic followed by the economic downturn. It resulted in project halts, labour shortages, and significant material price fluctuations. Large-scale projects, including condominiums, were either delayed or abandoned due to limited foreign funds and investment costs.

Prior to the economic downturn, condominium developments had the largest share in the real estate market under the construction industry, due to increased urbanization, higher demand for high-rise residential units, and foreign investments (Prathapasinghe, 2018). Between 2006 and 2017, a total of 895 certified completed properties and 15,483 condominium units were recorded in the market as of 2017 (Prathapasinghe, 2018), and it is estimated that another 200 projects under construction will add another 13,000 units. But with the effect of the downfall, according to the Urban Development Authority, only 18 new condominium projects were approved in 2022, compared to 47 in 2019. However, the sector is showing signs of recovery with an increase in approved condominium projects in urban centres like Colombo and Kandy (Central Bank of Sri Lanka, 2024). Thus, it is still important to understand the factors influencing the condominium projects within Sri Lanka. Large-scale construction projects, especially condominium developments, are pivotal in a country's development. But they are often plagued by constructability issues arising from poor integration between design and construction phases, inadequate planning, or site constraints that adversely impact project schedules, costs, and quality (Ahmed & Mahjoob, 2024). The primary aim of constructability is to enhance cost efficiency, improve the quality of the project, and serve as a bridge between the designer and the construction team (Contrada et al., 2019). Literature has consistently highlighted key constructability issues, such as excessive design complexity, inadequate integration of mechanical, electrical, and plumbing (MEP) services, site congestion, material logistics inefficiencies, and ineffective workforce and time management. Even though the significance of constructability issues has been increasingly recognized in global construction practices (Wong et al., 2006). Thus, there is a profound need to identify these constructability issues and generate proper mitigation measures to address those issues. These solutions are suggested to be long-term proactive planning rather than short-term practices for the temporal removal of the issue. Through proactive planning and a collaborative approach, completion of the project within the specified quality standards can be ensured (Wimalaratne et al., 2021). Constructability and related issues have been widely studied globally under many research projects. These projects can be categorized as qualitative, quantitative, and mixed-approach projects. Most of these constructability issues are country-dependent, with the construction practices in which the industries are involved (Trigunarsyah, 2004). In developed economies, such as the UK focuses on design rationalization in simplifying designs to reduce on-site complications. In countries like the USA, Australia, and Singapore emphasized the development of management systems and construction practices that allow for the integration of construction expertise at earlier stages in the project as per Cheetham & Lewis (2001), Trigunarsyah (2004). However, in Sri Lanka, few empirical studies have systematically classified or quantified these issues within the context of high-density urban projects like condominiums. Thus, there is a gap that should be addressed by conducting a comprehensive study to identify the constructability issues. In several previous studies, the term constructability had been examined, but a very limited amount of work is available focusing on a dual-level classification model for the available constructability issues in Sri Lankan condominium projects. The classification is conducted under two aspects as common constructability issues and project-oriented constructability issues. The study provides a novel diagnostic framework using cross-tabulation and the Kruskal-Wallis test to analyze the impact of constructability issues across different stakeholder demographics and project features and classify them under project-specific or common constructability issues.

2. METHODOLOGY

2.1 DATA COLLECTION AND SURVEYS

This study examines constructability issues in large-scale condominium construction projects in Colombo and nearby suburbs, Sri Lanka, aiming to identify and evaluate key challenges that impact project execution. A sequential mixed-methods approach was employed, combining expert interviews and surveys as research methods and semi-structured interviews and structured questionnaires as data collection techniques. A mixed-method approach is applied to increase the generalizability and interpretability based on statistical representation of the results, connecting them with the initial expert consensus (Malina et al., 2011). Initially, 12 constructability issues and 12 evaluation criteria were identified through a literature review of Wimalaratne et al. (2021), Wong et al. (2006), Yustisia (2014), and expert interviews. A Delphi study involving 12 experienced professionals helped refine the questionnaire by filtering the most significant constructability issues based on a 75% agreement rate (Garusinghe et al., 2023). Then, the initially identified constructability issues and evaluation criteria were refined to eight and seven, respectively. The final survey is distributed to fifty-two (52) construction professionals, including project managers, engineers, architects, and quantity surveyors. They were selected from the professionals who had engaged in the construction of condominium projects to have different levels of experience, designations, project locations, and project scales. And 5-point Likert Scale is used to measure their agreement levels on the impact of each constructability issue. The Likert Scale is a widely used psychometric tool in research to measure attitudes, perceptions, or opinions by individuals (Nyutu et al., 2020). The respondents rate their "level of agreement" to the particular statement using a structured scale from "Strongly Disagree" to "Strongly Agree" (Joshi et al., 2015). This structured methodology allowed for the systematic quantification of subjective perceptions, ensuring a comprehensive analysis of constructability issues in Sri Lankan condominium projects.

2.2 DATA ANALYSIS

The qualitative data that is collected from the respondents is given a quantitative value, where it is easy to generate a quantitative comparison of the generated results.

2.2.1 Percentage Agreement Rates

Percentage agreement rates are a statistical tool that is used to evaluate the level of respondents who have a certain level of agreement expressed to a statement. Within this study, the number of respondents who agreed or strongly agreed with the statement is considered under the agreed population for the statement, and using Equation 1, percentage agreement rates are found (Noor Aslinda et al., 2014).

$$Agreement\ rate = \frac{No.\ of\ Agreements\ (Strongly\ Agree\ count + Agree\ count)}{Total\ number\ of\ responses} \times 100\% \quad Equation\ (1)$$

This equation can be applied to find the agreement rates of 52 responses, and this method is particularly useful in identifying key factors affecting project execution by quantifying expert agreement on constructability issues.

2.2.2 Cross-Tabulations

Cross-tabulation, also known as contingency table analysis, is a statistical method used to examine the relationship between two or more categorical variables (White, 2003). Cross-tabulation in the Statistical Package for the Social Sciences (SPSS) is the method used in analysis. In the context of this study, cross-tabulation is conducted to analyse variations in perceptions of constructability issues. They are analysed based on different factors, such as designation, experience level, project duration, and project location. The cross tabulation is conducted on the basis of Equation 2 (Atkinson et al., 2021):

$$Percentage\ response = \frac{Frequency\ of\ a\ specific\ response\ in\ a\ group}{Total\ number\ of\ responses} \times 100\% \quad Equation\ (2)$$

Using the cross-tabulated percentage values, more significant constructability issues can be identified where all the respondents agreed, despite their designation, experience level, project duration, and location. Similarly, instances with different responses with the change of the considered parameters, designation, experience level, project duration, and location can also be found. Thus, a clear exposure to commonly found constructability issues and project-oriented constructability issues can be identified through cross-tabulations.

2.2.3 Kruskal-Wallis Test

To further examine the relationships between professional background, project location, experience level, and project duration with the ratings assigned to the constructability issues, the Kruskal-Wallis Test (Kruskal & Wallis, 1952). This Kruskal-Wallis (KW) Test is a non-parametric test and is selected because it is well-suited for analysing data from multiple independent groups that do not follow a normal distribution. The KW Test allows for the identification of statistically significant differences in the responses across the different demographic groups (Lelwala et al., 2024). The formula to find the H statistic in the KW test is as follows in Equation 3:

$$H = \frac{12}{N(N+1)} \sum_{i=1}^{c} \frac{R_i^2}{n_i} - 3(N+1) \qquad Equation(3)$$

where, C represents the sample number, N is the total number of samples, and R_i is the sum of ranks in the i^{th} sample. A minimum of 5 samples is required to satisfy the chi-square distribution (Kruskal & Wallis, 1952). When sample sizes are large enough ($n > 5$ for all groups), the H-statistic approximates a Chi-squared (χ^2) distribution with C−1 degrees of freedom. The p-value is then calculated based on the H-index using SPSS software. A small p-value (typically ≤ 0.05) indicates that the observed data is unlikely under the null hypothesis, providing strong evidence to reject it. (Bonovas & Piovani, 2023). This indicates a significant difference between the consensus of the compared sub-classes. The null hypothesis represents a statement approved by most respondents. A large p-value (greater than 0.05) suggests that the observed data is likely under the null hypothesis, indicating insufficient evidence to reject it. (Marasini et al., 2016). The results indicate that constructability issues in large-scale condominium projects can be categorized into universally recognized challenges ($p > 0.05$) and critical issues that vary across different classifications ($p < 0.05$). While some issues are consistently acknowledged across all sub-groups, others show significant differences in perception, highlighting their varying impact based on project characteristics.

2.3 QUESTIONNAIRE REFINING

An initial frequency analysis is conducted to identify the most common constructability issues having high agreement rates of more than 75% (Garusinghe et al., 2023). Table 01 provides the selected and omitted constructability issues for the questionnaire development. Constructability issues: Insufficiency of Health and Safety, Poor Monitoring and Controlling of Work Progress, Requirement for controlling of material wastage and project attributes with Design Change, Project Procurement, Project Risk, Project Stakeholder and Scope of Work Statement were omitted with respect to expert consensus and following constructability issues and project attributes were selected. Common constructability issues identified for the evaluation are as follows.

1. Complex architectural design (CD)
2. Integration issues in structural & MEP drawings (IMEP)
3. Difficulty in material handling and storing due to over-utilized land area (SM)
4. Difficulty in placing/arranging Tower cranes, Hoists, booms & stationary pumps due to over-utilized land area (OL)
5. The project consists of lengthy shear walls (LS)
6. Difficulty in material feeding due to large bulk quantities (BM)
7. Manpower (Staff + workers) at peak exceeds 500 (MPR)
8. Time restrictions on working hours (WR)

And these issues were summarized to analysed under the following project attributes:

1. Impact on project cost (IPC)
2. Impact on project duration (IPD)
3. Problems that may appear during the maintenance stage (IPM)
4. Impact on maintaining resource requirement (IRR)
5. Impact on maintaining QAQC (IQAQC)
6. Impact on maintaining productivity (IMP)
7. Impact on maintaining construction teams' motivation (ICM)

This questionnaire is further refined using the consensus, applying the Delphi study, and the final questionnaire is formed as in Table 1.

Table 1: Final Questionnaire

Constructability issue and evaluation attributes	Acronym
1. Complexity of design (Complex architectural design)	
Impact on project duration	COMP1
Impact on project cost	COMP2
Impact on maintaining QAQC	COMP3
Impact on maintaining resource requirement	COMP4
Impact on maintaining construction teams' motivation	COMP5
Impact on loss of productivity	COMP6
Possibility of problems may appear during the maintenance stage	COMP7
2. Integration issues (Integration issues in structural and MEP drawings)	
Impact on project duration	INTISS1
Impact on project cost	INTISS2
Impact on maintaining QAQC	INTISS3
Impact on maintaining resource requirement	INTISS4
Impact on maintaining construction teams' motivation	INTISS5
Impact on loss of productivity	INTISS6
Possibility of problems may appear during the maintenance stage	INTISS7
3. Overutilized land area (Difficulty in material handling and storing)	
Impact on project duration	OULA1
Impact on project cost	OULA2
Impact on maintaining resource requirement	OULA3
Impact on maintaining construction teams' motivation	OULA4
Impact on loss of productivity	OULA5
4. Lack of space for placement of construction machinery	
Impact on project duration	PCOMA1
Impact on project cost	PCOMA2
Impact on maintaining resource requirement	PCOMA3
Impact on maintaining construction teams' motivation	PCOMA4
Impact on loss of productivity	PCOMA5
5. The project consists of lengthy shear walls with lengths exceeding 10m	
Impact on project duration	PROJCH1
Impact on project cost	PROJCH2
Impact on maintaining QAQC	PROJCH3
Impact on maintaining resource requirement	PROJCH4
Impact on maintaining construction teams' motivation	PROJCH5
Impact on loss of productivity	PROJCH6

Constructability issue and evaluation attributes	Acronym
6. Difficulty in material feeding due to large bulk quantities	
Impact on project duration	DIFMAFE1
Impact on project cost	DIFMAFE2
Impact on maintaining QAQC	DIFMAFE3
Impact on maintaining resource requirement	DIFMAFE4
Impact on maintaining construction teams' motivation	DIFMAFE5
Impact on loss of productivity	DIFMAFE6
7. Manpower (Manpower (Staff + workers) at peak exceed 500)	
Impact on project duration	MANPOW1
Impact on project cost	MANPOW2
Impact on maintaining QAQC	MANPOW3
Impact on maintaining resource requirement	MANPOW4
Impact on maintaining construction teams' motivation	MANPOW5
Impact on loss of productivity	MANPOW6
Possibility of problems may appear during the maintenance stage	MANPOW7
8. Time restriction	
Impact on project duration	TIMREST1
Impact on project cost	TIMREST2
Impact on maintaining resource requirement	TIMREST3
Impact on maintaining construction teams' motivation	TIMREST4
Impact on loss of productivity	TIMREST5

3. FINDINGS

3.1 PERCENTAGE AGREEMENT RATES

The agreement rate analysis highlights complex architectural design (CD) and MEP integration (IMEP) issues as the most critical constructability challenges, particularly impacting project duration (89% PA for CD, 88% PA for IMEP) and cost overruns (90% PA for CD, 92% PA for IMEP). These issues introduce construction difficulties, coordination challenges, rework, and delays. In terms of quality assurance and quality control (QAQC), CD and IMEP recorded 71% and 78% PA, respectively, due to their role in increasing defects and compliance risks. Resource constraints were another key concern, with 93% PA for manpower requirements (MPR), 85% PA for space management (SM), and 80% PA for bulk material feeding (BM), indicating frequent disruptions in workflow and logistics. Work-hour restrictions (84% PA) and site congestion (89% PA on IPD, 87% PA on IPC) further hinder productivity (93% PA). The primary causes of productivity losses were IMEP and CD, leading to frequent rework and extended timelines. Additionally, long-term maintenance issues were strongly linked to CD (87% PA) and IMEP (82% PA), proving that constructability challenges extend beyond construction into the operational phase of buildings. Effective workforce management, supply chain optimization, and better design coordination are crucial for mitigating these challenges.

3.2 CROSS-TABULATION OF EVENTS

By cross-tabulation of the rate of agreement or disagreement, the variation of perceptions on selected constructability issues depending on different criteria like designation, experience level, project duration, and project location can be assessed.

3.2.1 For Designation

Considering COMP1, 30 out of the 52 respondents strongly agreed with the statement. The responses marked "Strongly agree" are most prevalent in the category Project Engineer/Civil Engineer, with 12 out of 26 respondents, or approximately 46%, strongly agreeing to the assessment of COMP1. Response distribution showed consistency for most components, with roles such as Project Engineer/Civil Engineer and senior management roles like Chairman/CEO/GM/DGM/AGM rating favourably. For instance, from COMP2, 20 of 52 participants agreed to this component, while another 27 strongly agreed. In the meantime, other designations, such as Project Manager/Construction Manager, are more indifferent or diversified in opinion directions. Focusing on components dealing with project challenges and manpower management obtained more mixed responses across all roles, suggesting these are areas that might require further detailing or improvement. This would mean that such components as PROJCH1 and MANPOW6, which had responses that were more neutral or diverse, indicate possible areas where roles feel less aligned or satisfied with the current approach. For instance, PROJCH1 received 14 out of 46 respondents who chose either "Neutral" or "Disagree," indicating a high percentage of mixed feelings. In general, the data shows that the components are mostly well-received, especially by higher-level management and technical staff; there are, however, some noticeable areas where neutrality indicates room for improvement. For instance, in the case of COMP4 and COMP5, about 20% to 30% responded neutrally. Thus, the wide disparities in response for senior management against technical staff is experienced considering several constructability issues such as effect of CD in IRR and IMP, effect of SL in IQAQC, IRR, ICM and IMP.

3.2.2 For Experience

Under the classification of experience, COMP1 had a very high 30 out of 52 respondents (58%) strongly agreeing, with the "05-10 years" experience category having the highest level of agreement at 73%. This shows that the more experienced the professional, the stronger the recognition of the effect of particular constructability issues. Considering COMP2, about project feasibility, most of the "More than 5 years" of experience supported this, while 54% of the "05-10 years" respondents strongly agreed with it. By contrast, in the less experienced group, less than 5 years, responses were mostly divided, such as in the area of COMP6, related to effect of CD on IMP, with 10 out of 22 and between 05 – 10 years, 12 out of 26 respondents being neutral or disagreeing from this group. This means that junior professionals do not always have the same view or level of confidence in assessing available constructability issues, whereas with years of experience, respondents' level of agreement to statements regarding risk assessment and other critical factors such as project feasibility also increase. This trend is carried forward in COMP4, considering the effect of CD on IRR where "More than 20 years" experience recorded the highest level of agreement, showing a growing confidence in such assessments as experience in the field develops. Whereas PROJCH1, checking LS on IPC, and MANPOW6, checking MPR on IMP, yielded mixed responses for the experience of less than 10 years. Response tendencies were similar for relatively less experienced groups. In MANPOW6, 10 out of 22 participants with less than 05-year experience and 6 out of 26 participants having 05-to-10-year experience strongly disagree, disagree or stay neutral as the response. Senior professionals, particularly those with more than 20 years of experience, strongly agreed on the importance of managing project timelines and applying management techniques, as seen in TIMREST and IMEP attributes, while less experienced professionals showed disagreements or neutrality. This indicates that with increased experience, professionals become more confident and consistent in managing project timelines, feasibility, and risk management.

3.2.3 For Project Duration

Project duration data in the PDURN variable provides valuable information on how project length influences professionals' perceptions of various project characteristics. In the case of all the types of projects that last less than two years, 02 to 03 years, 03 to 04 years or more than 5 years, the dominant responses were mostly "strongly agree" or “agree” concerning how CD effects IPC (COMP2) (46 out of 52) and IRR (COMP4) (38 out of 52). This could, therefore, indicate that those dealing with the smaller projects might more readily witness first-hand how immediate architectural design would add complexity and increased project cost due to a necessarily accelerated rate of execution, consuming greater amounts of resources as a major constructability issue. As such, for projects less than 2 years, the response is more evenly distributed across categories, especially about the impact of CD on the ICM (COMP7), WR on all evaluation attributes, IPC, IPD, IQAQC, IRR, IMP, and ICM. But for projects with a lifetime of more than 05 years, the agreement rate is very high, approving the constructability issue arising due to WR. The effect of MPR on all aspects also plays a similar response pattern, highlighting the increase of the constructability issues with the longer project duration.

3.2.4 For Project Location

Based on the data provided for the urban and suburban locations, or PROLN, several patterns can be observed from the responses to several questions regarding project characteristics. Considering COMP2, or how the CD affects a project, among the urban professionals, 20 out of 39 agree or strongly agree that the CD in a project affects its IPC, IPD, and IRR. In contrast, suburban professionals show a more neutral distribution. The urban location does, therefore, exhibit a higher degree of consensus and perhaps suggests that diversity in an urban setting is more striking and should be better handled under constructability issues than in suburban settings. For COMP3, on the effect of CD on ICM, both urban and suburban, respondents are more divided. When it comes to the CD effect on IRR, 28 respondents out of 39 agree with the effect, while in suburban conditions, 5 out of 13 reject the effect on IRR. This may mean that urban projects should deal with more structured and experienced teams, probably because of a greater resource pool and better project management frameworks, while suburban areas experience challenges in this respect. When analysing INTISS attributes based on MEP integration issues, which deal with the effectiveness of specific project interventions, it can be seen that urban professionals have higher magnitudes of agreement, while suburban professionals hold more neutral or disagreement views. It follows logically that urban locations may enjoy better tools, technologies, or training programs that make interventions more effective, and suburban areas may have more obstacles in adapting such interventions.

3.3 KRUSKAL-WALLIS TEST (KW TEST)

3.3.1 KW Test for Designation

The designation of a respondent directly affects the level of experience, exposure, and understanding the person possesses towards the construction project. Thus, depending on the destination, the type of response varies. Factors that received $p < 0.05$, mainly highlights, statistically significant variations with designation. As in Figure 1, effect of CD on ICM (p – 0.03), SM on ICM (p – 0.04), OL on ICM (p – 0.00), OL on IMP (p – 0.01), BM on ICM having (p – 0.00) and WR on IMP (p – 0.04) are construction issues that are shows statistical variations with designation of the respondent. Factors having received $p > 0.05$ are statistically non-significant factors across respondent designation. With the consistency of the respondents, these factors can be justified as fundamental construction issues which are widely recorded. The effect of IMEP on all seven considered evaluation attributes, including IPC and IPD, shows p-values ranging from 0.29 to 0.91, highlighting their common availability. Out of the bulk, the effect of IMEP on IPM is considerably accepted by professionals. The impact of CD on project duration, project cost, QAQC, and resource requirement has also commonly been identified. The effect of MPR on IPC and IPD is highlighted with common PA, driving to high p-values of 0.87 and 0.90, showing their common occurrence. Working time restrictions also show comparatively high p-values of 0.05, highlighting similar responses from professionals. Thus, the analysis displayed both statistically significant and non-significant construction issues. The effect of construction issues related to material handling, work-hour limitations, and space management and their effects on team motivation, productivity, and durations seems to be unknown or neglected. These factors also should be addressed with proper construction planning.

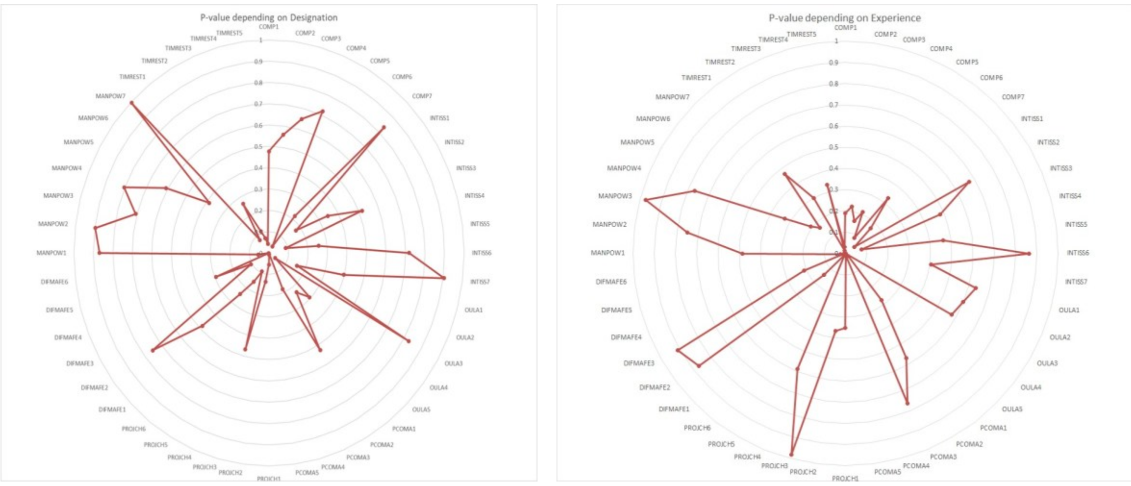

Figure 1: p-values for analysis under designation, level of experience, project duration, project cost and project location

3.3.2 KW Test for Experience

Professional experience directly influences the ability of a respondent to assess constructability issues based on their exposure and practical understanding. As in Figure 1, Material handling's effect on ICM (p = 0.00) and IMP (p = 0.02) show critical differences in how experience levels affect site logistics concerns. Similarly, OL on ICM (p = 0.01) and its effect on productivity (p = 0.00) highlight that these site constraints are more pronounced among experienced professionals with the agreement rate. The fact that

LS affects the ICM, as stated, and IMP further pinpoints structural complexities to affect perceptions across different experience levels. Meanwhile, some aspects such as effect of BM on ICM and IMP, were also with a low p value of 0.01 and 0.03, and work hour restrictions under IMP and IRR also were identified as statistically significant differences and imply that more experienced professionals seem to understand inefficiencies related to the mentioned above constraints better compared to low experienced from the agreements rates. Meanwhile, factors with $p > 0.05$ indicate a consistent perception across experience levels, implying that these issues are widely acknowledged as fundamental challenges in the industry. For example, integration issues in structural & MEP drawings (IMEP) show p-values ranging from 0.05 to 0.86, reinforcing their common occurrence. In the same vein, the impact of CD on project duration, cost, QAQC, and resource requirement maintains its consistent recognition across experience levels with higher p values from 0.08 to 0.33. This analysis identifies the significant and generally accepted construction issues and points out that, though certain factors are perceived more intensely by the experienced group of professionals compared to the rest as per the statistical variations, such as material handling, site logistics, and work scheduling. These construction issues, and generally encountered issues, require structured mitigation strategies to enhance the timely completion of the projects.

3.3.3 KW Test for Initial Project Value

The test results highlight the significant influence of financial scale on constructability in condominium projects. Complex architectural design shows variations in responses, with IPC at $p = 0.029$ and IPM at $p = 0.034$, indicating challenges in construction efficiency and resource management. Coordination issues among design disciplines are evident in larger projects, as IMEP p-values range from 0.000 to 0.007 for IPD, IPC, IQAQC, and IRR. Material handling constraints in high-value projects, particularly in over-utilized areas, are emphasized with $p = 0.039$, stressing the importance of spatial planning. Logistical challenges in urban development's require precise coordination of storage, staging, and delivery schedules. Structural demands increase with project size, affecting construction duration and cost, as shown by LS influencing IPD, IPC, IQAQC, and ICM, with p-values between 0.000 and 0.046. Work-hour restrictions, with $p = 0.019$ for IPD and $p = 0.043$ for IPC, are more prevalent in larger projects due to regulatory, environmental, and contractual factors. However, some constructability issues remain consistent across different project values, as indicated by non-significant p-values: CD on IPD ($p = 0.236$), IQAQC ($p = 0.748$), and IRR ($p = 0.184$), as well as IMEP on ICM ($p = 0.396$) and IMP ($p = 0.135$). Material handling issues (p-values 0.188-0.340 for IPD, IRR, IMP, and ICM) and MPR for IMP and ICM ($p > 0.130$) suggest that these challenges persist regardless of project scale, identifying them as inherent constructability concerns in the industry.

3.3.4 KW Test for Project Duration

The statistical analysis emphasizes the impact of project duration on constructability issues in condominium projects, highlighting how these factors change as the length of the project increases. The relationship between CD and ICM shows a significant p-value of 0.001, indicating that longer projects with complex designs are more likely to face difficulties in maintaining team motivation. Additionally, the influence of CD on IPC ($p = 0.004$) and IPD ($p = 0.028$) suggests that prolonged projects lead to increased cost and time pressures due to added complexities in design. The effect of IMEP on IMPD (p =

0.000) further emphasizes the growing challenges in design coordination as project duration extends, stressing the importance of careful planning and resource allocation for longer projects. The analysis also shows that project length influences BM on IRR, with a p-value of 0.003, indicating that managing the supply chain becomes increasingly difficult in longer projects. These projects require more accurate procurement and logistics planning to avoid delays and material shortages. However, factors such as the effect of SM on IPD ($p = 0.954$) and IQAQC ($p = 0.873$), as well as MPR on IQAQC ($p = 0.142$) and ICM ($p = 0.692$), demonstrate non-significant variations across project durations. This suggests that material handling and workforce management remain consistent concerns, regardless of the project duration. These persistent issues are inherent in construction, requiring ongoing management and standard solutions.

3.3.5 KW Test for Project Location

These analyses of project location impact on many of the above-mentioned constructability issues, showing significant statistical differences due to variations in professional responses. Thus, the factor of project location is a significant influence in shaping the perception of the different construction challenges. Factors with $p < 0.05$ show a statistically significant difference, while the biggest influence can be observed in CD and MPR. The impact of CD on IPC, IQAQC, and IMP consisted of statistically significant variations concerning project location at p-values of 0.03, 0.04, and 0.01, respectively, as in Figure 1, perhaps indicating the effect of the geographical context of a project. Further, the construction issue of CD to ICM also reflects location-specific issues that could affect morale, with $p = 0.03$. The analysis shows that project location also has a high degree of impact on MPR, IPD ($p = 0.00$), IPC ($p = 0.03$), and IQAQC ($p = 0.01$), which indicates that regional fluctuations in skilled labor, regulations, and the distribution of manpower are quite different. Similarly, WR also displays extreme statistical variations, though WR effect on IPD shows no significant variation at $p = 0.64$, highlighting fundamental availability of construction issue. The effect of WR on IQAQC ($p = 0.02$), IRR ($p = 0.00$), and IMP ($p = 0.00$) were significant, indicating regional boundaries setting uneven constraints on the hours of work that have a severe impact on productivity and the project timeline. Issues of integration in structural and MEP drawings, IPD ($p = 0.86$), and IPC ($p = 0.32$) did not show significant variations, suggesting that such constructability issues are similarly perceived despite the location of the project. Similarly, SM difficulties on IPD ($p = 0.76$) and OL effect on IPD ($p = 0.37$) also did not show significant variation, suggesting these issues are fundamental to construction regardless of location.

4. DISCUSSION

The findings from the agreement rate analysis, cross-tabulation, and Kruskal-Wallis tests align closely with the broader literature on constructability challenges in large-scale construction projects. Key issues such as design complexity (CD), MEP integration (IMEP), and site logistics emerged as dominant contributors to project inefficiencies, mirroring the global trends reported by Wong et al. (2006) and Capone et al. (2014). The agreement rates exceeding 85% for IMEP and CD across multiple evaluation criteria validate their critical influence, particularly on project duration, cost, and quality control. These results corroborate prior research indicating that complex designs and insufficient coordination among design disciplines often lead to rework and delays (Trigunarsyah, 2004; Cheetham & Lewis, 2001).

The strong correlations between workforce management issues, such as MPR and WR, and reduced productivity and motivation are also in line with earlier findings by Yustisia (2014) and Ahmed & Mahjoob (2024), who noted that labour inefficiencies are magnified in high-density urban projects. The cross-tabulation further highlights how professional background and experience influence perceptions, with more experienced respondents displaying a stronger consensus on the criticality of constructability issues. This trend underscores the value of institutional knowledge and aligns with Fischer and Tatum's (1997) emphasis on experiential learning in constructability planning.

Moreover, the Kruskal-Wallis test outcomes reveal statistically significant differences in perceptions based on project designation, value, duration, and location. For example, urban professionals reported more agreement with the impact of design complexity than their suburban counterparts, likely due to greater design variations and space constraints in dense cities. Meanwhile, project value emerged as a strong predictor for MEP integration and material handling challenges, confirming that scale amplifies coordination complexity, a concept widely supported in the literature (Contrada et al., 2019). Interestingly, some issues, such as IMEP and material handling, consistently showed p-values > 0.05 across all classification parameters, reinforcing their status as universally recognized constructability problems. This distinction between universal and project-specific issues is rarely explored in existing literature but provides a valuable framework for prioritizing interventions. In the Sri Lankan post-pandemic context, this differentiation is particularly relevant. The COVID-19 crisis introduced unanticipated constraints, such as workforce shortages and disrupted supply chains, which further exposed weaknesses in constructability planning (Jayakody et al., 2022). The resurgence of the industry in 2024 and 2025, while encouraging, demands a more resilient approach to managing both fundamental and situational constructability risks.

5. CONCLUSION

The study followed a mixed-method approach to conduct a dual-level comprehensive analysis to identify common constructability issues and project-oriented constructability issues. To facilitate a quantitative approach, statistical tools like the Kruskal-Wallis test and cross-tabulation analysis were utilized. The Kruskal-Wallis test and cross-tabulation analysis confirm that project duration, designation, experience, project value, and location significantly influence perceptions of constructability issues. Project duration affects team motivation, productivity, and cost, especially for complex designs (89% agreement). Designation impacts material handling (81%) and logistics (85%), while experience level influences workforce management (93%) and material feeding (76%). High-value projects face greater MEP integration (92%) and logistical issues (79%), and location affects time restrictions (96%) and manpower management (75%). Despite these variations, MEP integration, material handling, and workforce management remain universal issues with p-values > 0.05, indicating no significant difference across projects. Addressing these requires continuous improvements in planning, coordination, and resource management, while project-specific challenges need tailored mitigation strategies for improved constructability. Additionally, issues such as lengthy shear walls (50% agreement on project duration) and certain machine placement difficulties (54% agreement on productivity loss) were found to be less prominent and highly dependent on project-specific conditions. These challenges, while not widespread, require localized solutions based on project scale, design complexity, and site constraints rather than industry-wide reforms. The fundamental issues are persistent across the industry, requiring constant attention and standard strategies to resolve them. The study encountered several limitations, as the study is only restricted to condominium projects in the urban or suburban areas of the country, not focus on a rural context. Further, the questionnaire relied on expert consensus, thus, there can be bias based on respondents' organization roles or personal experience levels. But tailored strategies may be required to deal with the project-specific challenges, while fundamental issues will need to be managed through continuous improvements in planning, coordination, and resource allocation. Future research can be established by analysing across varying building types, investigating the effectiveness of specific mitigation measures and integrating novel techniques to solve constructability issues.

6. REFERENCES

Ahmed, O. A., & Mahjoob, A. M. R. (2024). The factors that affect constructability in Iraq. *Organization, Technology and Management in Construction: An International Journal*, *16*(1), 27–37. https://doi.org/10.2478/otmcj-2024-0002

Al-Fadhli, S. K. I. (2020). Value engineering and constructability assessment relating infrastructure projects. *IOP conference series: Materials Science and Engineering*, *737*(1), 012040. https://doi.org/10.1088/1757-899X/737/1/012040

Aslinda, A. S. N., Norhayati, Z., Jusoh, A., Arif, M. S. M., Bahari, A. Z., Zaidin, N., & Saman, M. Z. M. (2014). The development of green innovation measurement based on inter rater agreement approach: A preliminary study. *Advanced Materials Research*, *903*, 347–352. https://doi.org/10.4028/www.scientific.net/AMR.903.347.

Atkinson, A. L., Allen, R. J., & Waterman, A. H. (2021). Exploring the understanding and experience of working memory in teaching professionals: A large-sample questionnaire study. *Teaching and Teacher Education*, *103*, 103343. https://doi.org/10.1016/j.tate.2021.103343

Bonovas, S., & Piovani, D. (2023). On p-values and statistical significance. *Journal of Clinical Medicine*, *12*(3), 900. https://doi.org/10.3390/jcm12030900

Capone, P., Getuli, V. and Giusti, T., 2014. Constructability and safety performance-based design: A design and assessment tool for the building process. *In: 31st International Symposium on Automation and Robotics in Construction and Mining, ISARC 2014 - Proceedings*. University of Technology Sydney, 313-320.

Central Bank of Sri Lanka. (2024). Condominium market survey: Fourth quarter 2024. *Real Estate Market Analysis*. https://www.cbsl.gov.lk

Cheetham, D. W., & Lewis, J. (2001). Productivity, buildability and constructability: Is work study the missing link? In A. Akintoye (Ed.), *Proceedings of the 17th Annual ARCOM Conference* (pp. 271–280). Association of Researchers in Construction Management.

Contrada, F., Kindinis, A., Caron, J.-F., & Gobin, C. (2019). An early-design stage assessment method based on constructability for building performance evaluation. *IOP conference series: Materials science and engineering*, *609*(7), 072070. https://doi.org/10.1088/1757-899X/609/7/072070

De Silva, S. S., Wijekoon, W. M. C. L. K. & Kalugala, C (2023). Impact of economic crisis on employees of contractors' organisations in the Sri Lankan construction industry. *11th World Construction Symposium 2023*, 557–568. https://doi.org/10.31705/WCS.2023.46.

Fischer, M., & Tatum, C. B. (1997). Characteristics of design-relevant constructability knowledge. *Journal of construction engineering and management*, *123*(3), 253-260. https://doi.org/10.1061/(ASCE) 0733-9364(1997) 123:3(253)

Garusinghe, G. D. A. U., Perera, B. A. K. S., & Weerapperuma, U. S. (2023). Integrating circular economy principles in modular construction to enhance sustainability. *Sustainability*, *15*(15), 11730. https://doi.org/10.3390/su151511730.

Jayakody, S., Zimar, A. M. Z., & Ranaweera, R. A. L. M. (2018). Potential use of recycled construction and demolition waste aggregates for non- structural concrete applications. *Journal of the National Science Foundation of Sri Lanka*, *46*(2), 205-216. https://doi.org/10.4038/jnsfsr.v46i2.8421

Joshi, A., Kale, S., Chandel, S., & Pal, D. (2015). Likert scale: Explored and explained. *British Journal of Applied Science & Technology*, *7*(4), 396–403. https://doi.org/10.9734/BJAST/2015/14975

Kruskal, W. H., & Wallis, W. A. (1952). Use of ranks in one-criterion variance analysis. *Journal of the American Statistical Association*, *47*(260), 583–621. https://doi.org/10.1080/01621459.1952.10483441.

Langappuli, B. L., Ilangakoon, A., Pahalage, V., & Balasooriya. (2023). Framework to manage the impacts on the contractor's budget for construction projects due to the economic crisis in Sri Lanka. *Journal of Design and Built Environment*, *23*(3), 98–117. https://ejournal.um.edu.my/index.php/jdbe.

Lelwala, E. I., Seamasinghe, W. M., & Gunarathna, K. M. L. M. (2024). Nonparametric approach to detecting seasonality in time series: Application of the Kruskal-Wallis (KW) test on tourist arrivals to Sri Lanka. *South Asian Journal of Business Insights*, *4*(1), 3–19. https://doi.org/10.4038/sajbi.v4i1.61

Malina, M. A., Nørreklit, H. S. O., & Selto, F. H. (2011). Lessons learned: Advantages and disadvantages of mixed method research. *Qualitative Research in Accounting & Management*, *8*(1), 59–71. https://doi.org/10.1108/11766091111124702.

Marasini, D., Quatto, P., & Ripamonti, E. (2016). The use of p-values in applied research: Interpretation and new trends. *Statistica*,*76*, 315-325. https://doi.org/10.6092/ISSN.1973-2201/6439

Nyutu, E., Cobern, W. W., & Pleasants, B. A. S. (2020). Correlational study of student perceptions of their undergraduate laboratory environment with respect to gender and major. *International Journal of Education in Mathematics, Science and Technology*, *9*(1), 83–102. https://doi.org/10.46328/ijemst.1182.

Prathapasinghe, D., Perera, M. P. R. I., & Ariyawansa, R. G. (2018). Evolution of condominium market in Sri Lanka: A review and prediction. *2nd International Conference on Real Estate Management and Valuation 2018,* 92–99.

Trigunarsyah, B. (2004). A review of current practice in constructability improvement: Case studies on construction projects in Indonesia. *Construction Management and Economics*, *22*(6), 567–580. https://doi.org/10.1080/0144619042000202870

White, D. R. (2003). A student's guide to statistics for analysis of cross tabulations. *2004 World Cultures*, *14*(2), 179–193. https://escholarship.org/uc/item/8xn2s349

Wimalaratne, P. L. I., Kulathunga, U., & Gajendran, T. (2021). Comparison between the terms constructability and buildability: A systematic literature review. *Proceedings of the 9th World Construction Symposium 2021 on Reshaping Construction: Strategic, Structural and Cultural Transformations towards the "Next Normal",* 196–207. https://doi.org/10.31705/WCS.2021.17

Wong, F. W. H., Lam, P. T. I., Chan, E. H. W., & Wong, F. K. W. (2006). Factors affecting buildability of building designs. *Canadian Journal of Civil Engineering*, *33*(7), 795–806. https://doi.org/10.1139/l06-022.

Yustisia, H. (2014). The evaluation of constructability towards construction safety (Case study: Kelok-9 bridge project, West Sumatera). *Procedia Engineering*, *95*, 552–559. https://doi.org/10.1016/j.proeng.2014.12.216