APPLICATION OF CONSTRUCTION 4.0 IN INTERNET OF THINGS AND LEAN CONSTRUCTION OF TOOLS IN THE QUALITY MANAGEMENT SYSTEM OF RESIDENTIAL BUILDING PROJECTS

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***Abstract*- The emergence of Building 4.0 has played an important role in the development of the construction projects through quality improvement. Internet of Things (IoT) and Lean thinking concepts are among the parameters that have had a huge impact on construction quality management in the era of industrial revolution. Lean construction is characterized by clear objectives for project deliverables that involve simultaneous planning of products and processes. The purpose of the study is to conduct a preliminary study on the application of Construction 4.0 in the quality management of construction works and the development of Lean-based quality management models: The survey design approach and random sampling were used in the research. To select study samples. Information on the quality aspect of the construction project was collected through a structured questionnaire on a Liker scale of 1-5, which was used to build the model. The resulting parameters were formed into a quality management model.**

The resulting factors were classified into three (3) quality categories, namely zero level error area, medium quality and high-quality area. Three (3) quality factors were recommended for quality management of housing construction projects.

***Keywords*: Internet of Things; lean; waste; quality; regression; factor.**

1. INTRODUCTION

A building is one of the construction products that are often patronized in the economy. He is responsible for providing shelter and living space to the masses. The importance of ensuring protection is extremely important, so quality must also be maintained during the production phase. The construction process of real estate production requires the quality of the procurement system, material handling, the design process and the post-commissioning phase. Recently, however, the focus has been on maintaining the quality of the construction process. Customers are gradually complaining more and more about the cost, time, and quality and performance requirements of construction products. Government and legislative organizations also create standards and laws that focus on meeting the basic requirements of building regulations that define cost, quality and time parameters. Developed countries around the world have designed their laws around construction site health and safety practices, while the difficulty in developing and underdeveloped countries has been compromise on the quality of the final construction process. In developing countries, a system is needed that allows zero errors to occur right from the beginning of the production process.

Quality management, on the other hand, eliminates waste and increases productivity at low costs. It is against this background that this research showed how the concept of Lean could be used to create a regression model to help create a quality model for the construction application to prevent poor quality management on construction sites. In connection with this research, the following objectives were formulated: (i) to determine the extent of the waste limit applicable to construction sites, (ii) the impact of Building 4.0 parameters on the quality management of construction projects, (iii) the impact for the Internet of Things (IoT) and industry 4.0 tools in the quality management process of construction projects and (iv) critical success factors of construction quality management using the Lean construction concept and the development of a Lean-based quality management framework for residential projects. Regarding the formulation of the problem of this research, which is limited to construction projects, quality management and control of construction works, risk is inherent in most of the construction portfolio, so proper planning is essential. One of the risk areas is construction quality management. Poor quality management on site always has a negative impact on the overall success of the project. Quality management must therefore be clearly defined from the point of view of all stakeholders, which largely determines the overall success of the project. In terms of risk management and its effects, previous studies highlighted the possible negative consequences of a project, such as cost overruns, poor design, and forecast delays.

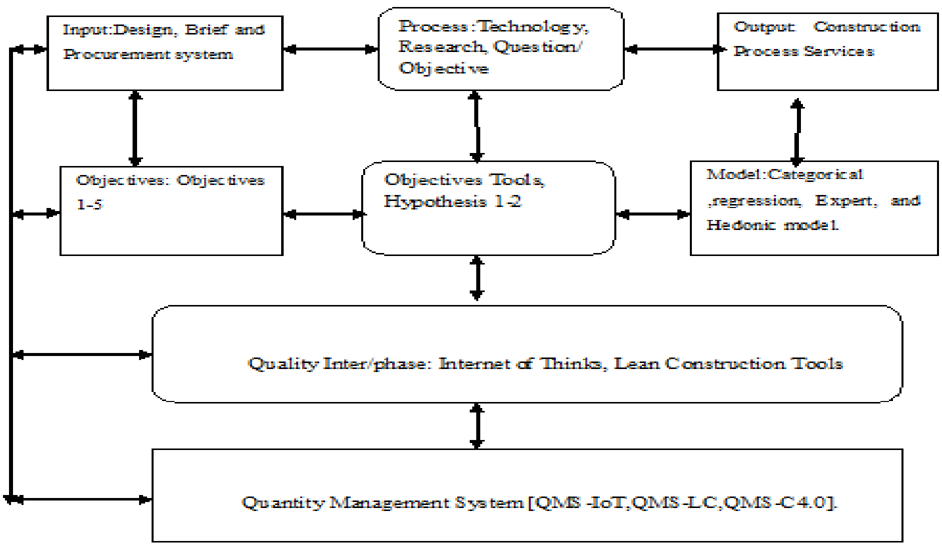
Building Information in 4D Building Modelling

A project has dependent variables that must be tracked, called risk management, while the independent project variable is project success. For example, risk management was described in as something that the project managers of a project must link together with other project participants, relying on an implementation framework when necessary. However, communicating project quality management risks is important when communicating project risks. Different methods are often used, some of which are in the form of categorical regression models, stochastic and recent experience modelling frameworks, artificial intelligence, Lean applications and Internet of Things (IoT). For example, several types of frameworks have been used in the quality management of risks in the construction industry. In recent research, risk quantification was modelled with Structural Equation Modelling (SME), identifying risks related to quality management.

1.1 Development of Research Hypotheses:

A hypothesis is an assumption, a statement that is considered incomplete and requires further verification with the support of additional information, facts and data. A hypothesis is usually part of the objectives and serves as an additional basis for factual cross-examination to create a confirmatory basis for baseline survey questionnaires and data collection. In this study, the hypothesis was based on some previously set objectives to confirm the reliability of their content. Research gaps were found through the exploration of research-related concepts. The gaps identified include the extent of on-site waste, the impact of construction 4.0 tools, especially IoT, the impact of Construction 4.0 on quality management, factors affecting the success of construction quality management and the challenges of Lean thinking in construction.

Three hypotheses were proposed to confirm some of the objectives. The hypotheses are as follows: (i) Hypothesis 1 H1 (Objective 3): Opinions about the impact of Internet of Things (IoT) and industry are consistent. 4.0 tools for the quality management process; (ii) Hypothesis 2 H2 (objective 2): Due to the automation of the process, there is a positive consensus regarding the waste limit in construction sites; and (iii) Hypothesis 3 H3 (Objective 4) Respondents' opinions differ regarding the classification of factors influencing the success of a construction project. The integration of the structural components of the quality management system with other research areas is shown in the diagram in.



Integration of quality management system with the Internet of Things (IoT), Lean Construction (C 4.0) domains.

The gaps led to the development of significant research questions from which the hypothesis derives. Some of the questions are. How much loss can be measured locally to ensure quality control? What tools are needed in quality management? What are the successful enablers of Ravenous 4.0 in construction projects? What are the factors affecting the success of construction quality management? Is it possible to develop an implementation model for the quality framework Construction 4.0 together with the industry 4.0 and Lean Construction? From the objectives, a hypothesis was developed with the aim of further expanding the selected relevant objectives.

2. METHOLOGY

2.1 Construction 4.0 (C 4.0)

The industrial revolution was an important addition to modern society. Construction 4.0 (C 4.0) increase the productivity of the construction industry and is said to increase the global GDP of countries by 6% and the construction GDP by 8%.In global construction investment reached 11 trillion USD by 2019 and is projected to reach 14 trillion USD by 2025.Construction 4.0 was already launched in the 18th century (19th century). It arose from the Coal Age to the Iron Age, until the middle of the 18th century when mechanization took place. A summary of the industrial revolution process was illustrated in. Regarding the authors indicated that the Industrial Revolution began in 1800 with Construction 1.0, which was mainly focused on the development of steam plants and locomotive innovations. This continued until the beginning of the 20th century, when the Industrial Revolution was born 2.0 (I 2.0).Came at the beginning of the 20th century with advanced industrial automation with the help of artificial intelligence and robotics. The era of digitization began when manually operated devices and tools were replaced by sensor-based devices. Industry 4.0 encompasses the era of digitization of processes.

Construction 4.0 has led to the development of construction vehicles and attachments equipped with laser lights that enable greater power and performance. Region 4.0 began in 2013, while 5.0 began in 2020. In construction 5.0 includes 5D innovations that enable human-machine collaboration through robotics and intelligent production/manufacturing. However, according to construction 4.0 still has a promising future. For example, the good future prospects of construction 4.0 are the digitization of the value chain of material and construction management and intelligent production with sensor–based applications. Construction material and construction management and intelligent production with sensor based applications .Construction 4.0 and Internet of Things (IoT) application in quality management of the construction industry.

2.2 Construction 4.0 and Internet of Things (Iot) Application in Construction Quality Management

The construction industry around the world is known for providing real estate that in turn satisfies the needs of consumers. Products include large housing and housing. However, manufacturing construction products is labour intensive and requires a lot of effort. In this context, input refers to the contribution of construction project organizers whose efforts determine the quality of construction products. In light of the above, monitoring and control are essential for quality results and production in the construction industry. Therefore, quality must be comprehensive and cover the product life cycle. The building life cycle starts from the idea planning phase, which always means that high-quality design and implementation starts already from the idea planning phase. Before the advent of Construction 4.0, the analogy reality model was mainly used in the project decision support system and in construction monitoring and management. Among other things, the analogy model was known for its time-consuming and expensive functions and inflexibility in customizing functions. However, the appearance of Ravenous 4.0 offers an improved model.

For example, in the Construction 4.0 era, sensor-based 3D systems are used in the modelling of construction products. The introduction of computer-aided design (CAD) in the construction industry made it possible to ensure the quality of the design process. CAD allows designers to visualize the layout of a drawing or layout of a drawing. This allows for timely adjustments and manipulation. According to the calibrated application has reached the construction industry. In Ravenous 4.0, quantitative tools of quality management that capture function and form in construction are used in decision support systems and in the formulation and development of quality parameters. Processes there are many opportunities in the implementation of construction 4.0 in quality management.

2.3 Lean Construction (Lc): Application of Lean Construction Technique In The Construction Building

Although there have been difficulties in the adoption of LC in the construction building, several industries have experienced adoption progress through Lean implementation. Researchers have identified many benefits and advantages. One of the biggest advantages of lean construction in companies is the minimization of waste. Lean construction promotes the construction process by eliminating waste: reducing the usage time of equipment and workers, balancing the team, coordinating the flow of information, removing restrictions due to material limitations, reducing input dispersion and changes, e.g. as well as difficult settings and reducing interpersonal tensions. Also, according to, the most important benefit is increased customer satisfaction.

Customer-oriented construction companies that implement Lean construction are able to respond to customer needs, define value from a project perspective, respond to opportunities and changing needs with flexible resources and adaptive planning, and apply targeted cost and value analyses. Sanitation and coordination are important advantages because they often mask opportunities for improvement and sources of problems. According to when the workplace is clean, cracks, missing parts or equipment leaks are more visible, which increases workplace safety and minimizes the risk of accidents. In addition, Lean construction promotes equipment productivity, skilled operators, proper equipment utilization and high equipment performance.

Cleaning is a good starting point and a successful way to develop and reinforce important work habits, behaviours and skills for waste reduction, continuous product development and Lean building. According to the advantages of Lean construction that come from construction organizations and can be the main advantages of Lean construction techniques in the construction industry are: better safety, less waste, lower costs, increased. Productivity, shorter schedules, better reliability, higher standard of living, higher customer satisfaction, better predictability and improved design for easier construction According to lean construction professionals believe that lean construction helps organizations reduce their inventory, increase the use of multi-skilled workers, eliminate the management structure and concentrate the most resources.

2.4 Overview of the Implementation Of The Quality Management Framework

The audit was conducted in Construction 4.0 Internet of Things (IoT) and Lean and Process and Product Quality Management in residential construction. There are two types of quality control in construction works, namely the quality control of the construction process and the quality control of the manufactured product. In quality was considered a subjective concept. It is subjective according to parameters often dictated by consumer needs, customer needs and professional input in any quality standard. In the presentation of the ISO 9001 standard, quality management as a process includes component quality as a process to achieve quality in a construction project. This means focusing on the needs and demands of the consumer, leadership, involving people, adopting a systematic approach, continuous improvement, using facts to make decisions and building mutually beneficial relationships. The quality management system ensures compliance with quality regulations to meet customer requirements, continuous improvement of quality processes, and conformity of products and services with company goals and standards. Similarly, the quality management of a housing project as a product could be viewed from the perspective of the component that condenses into quality in the final product. This means that there are no defects in the final product. In point, the quality component as a product could be summarized as the required composition discussed about quality management, quality system, quality management team and achieved quality level. In summary, product quality could be measured based on the perceived quality of the final product, the quality of the management process, the set of interconnected systems and the requirements contained in the finished product in a model way.

2.5 Rationale for Proposed Quality Management Frameworks

In the field of construction, several types of research have been conducted on the quality management of construction projects. There are many frameworks based on stochastic and regression models. Some of these frameworks include total quality management (TQM), hedonic models, case models, lean models, expert models, and artificial intelligence models. A study by concluded that current regression-based models lack data handling and consistency. According to the data application of the TQM model and related framework is limited by its ability to predict variables, ability to update data, and data sparsely, among other factors.

However, there are reasons why new frameworks and models are needed, and this reason is that the previous model according to is built according to a step-by-step approach, while the framework proposed in this study is based on a systematic approach. However, their similarity is due to the following aspects: the tendency to consolidate into a single framework, the ability to add detailed goals, objectives and plan implementation, and the tendency to update the framework component cited in. However, this study did not use the three Construction 4.0 tools in the way they were used to develop a qualitative framework in the context of this study. In relation to this study, tools, ie Internet of Things and Lean thinking tools, were used to configure the reference structure. The choice of systems was unique due to the Lean concept and the positive characteristics of the Internet of Things. The complete model allows taking advantage of the good features of IoT in the automation base, while the Lean design parameters were used in the design of the quality anatomy of the finished model. Features include zero defects, effective quality communication, quality control and monitoring, and training and development.

3. MATERIALS AND METHODS

This section presents the methodology used in the study.

3.1 Study Design

A qualitative research method with targeted sampling methods was used, focusing on professionals and construction companies that practice industrial tools, IoT and Lean concept approach, as reflected in the questionnaire used to collect answers from respondents. . The survey was conducted using a structured questionnaire with a semantic rating scale.

3.2 Population Frame

A sample of 250 medium and large construction companies was used in this study.

3.3 Sample Size

The sample used in this study consists of professionals working in selected construction companies, a total of 150 construction specialists. The questionnaires were prepared according to a Likert scale with a scale of 1-5 and were distributed to 150 respondents. The sample size was determined using this ratio: $n = N/\ [1\ ((S-1))/N]$ (1)

Where n is the sample size, N is the population, and S is the margin of error.

The respondents are professionals such as builders, architects, engineers and contractors out of which Architect = 30, Builders = 30, Quantity Surveyors = 30, Engineers = 30 and Contractors = 30.

3.4 Sampling Techniques

Random sampling is often used to select the sample. Population framework using qualitative and quantitative research methods therefore 150 respondents who formed the research sample used in the study were selected through random sampling. Respondents were selected from different construction companies, and personal interviews were collected from construction company professionals.

3.5 Research Data

The secondary material for the study was collected by studying different literatures related to the subject and previous studies conducted in the research area. These include information from textbooks, scholarly journal articles, peer-reviewed research articles, academic papers, conference proceedings, and electronic sources. Respondents were asked to indicate their level of understanding by marking the relatively important column.

3.6 Data Analysis

The purpose of the analysis was to find out the validity of the collected data according to the justification of the research variables. Some of the methods used to analyze aggregate data include simple percentage, chi-square, Mann-Whitney U test, Spearman's rank test, and mean scores.

The relative mean index (RMI) and the relative importance and agreement index of mean item scores were calculated using the equation below, which was used by Likert on a 1-5 Likert scale.

Relative agreement index (RAI) $=5SA+4A+3N+2SD+1D= [5(SA+ A+ N+ SD+ D -1]$

Where SA means strongly agree, a means same, N means neutral, SD means strongly disagree, D means disagree, RII the relative importance index and RAI the relative agreement index.

Relative Importance Index (RII) $= 5SI+4I+ 3N+2SNI+1I[5(SI+I+N+SNI+ NI)]$

Where SI means very important, I means important, N means neutral, SNI means strongly un important, and RII means relative importance index.

3.7 Factor Rotation And Extraction For Model Development

This study developed a quality management model using the intersecting parameters of three (3) concepts, viz. Lean concept, Construction 4.0 and Internet of Things (IoT). The raw survey data was extracted from three (3) concepts and used in a model developed using SPSS statistical analysis software. Factors were subjected to factor rotation to reduce coefficients from 24 to twelve representing other factors using Direct Obilim and Varimax with Kaiser Normalization, while factors with small coefficients were suppressed and only factors with eigenvalues between 0.97 were extracted and 1.0. The resulting coefficients were used to generate a component model. Based on the scores of each independent variable, ie.

Lean construction parameters based, Internet of Things (IoT) and Industry 4.0 quality management parameters, the parameters included in the model were investigated. The eigenvalues of the parameters were used to classify the factors into high, medium and low quality factors. An attribute value of 1.0 was accepted as the highest absolute reliability score, and therefore the closer to 1.0, the more reliable. Accordingly, values between 0.9 and 1.0 were classified as the highest quality reliability score, values between 0.7 and 0.8 were classified as moderately reliable or average, and values between 0.5 and 0.6 were classified as poor quality values.

4. RESULTS AND RECORDS

4.1 The Score Biographical Information of the Respondents

The biographical information of the respondents is presented in .The status companies used in this study includes real estate companies, contracting organizations, project clients and consulting companies. Respondents were selected from the categories of companies listed in

Biography of the Respondents:

PARAMETERS	CATEGORY	FREQUENCY	PERCENTAGE
Have You Tried C4.0	Yes No Neutral	85 25 1	78.21 18.80 0.99
Age Group	21-30y 31-40y 40-50y	55 25 10	58.41 27.70 10.50
Years Of Experience	≥15 y 11-15y 5-10y ≥5 y	40 25 10 7	44.55 26.62 17.77 6.93
Investment In The Company	Project Manager [Builders] Design Specialist [Architect] Site Coordinator[Civil Engineer] Quantity Surveyor	30 25 10 10	30.00 23.90 9.6 9.6
Company Status	Developer Contractor Client Consultant	30 25 10 10	29.75 23.90 9.6 9.6

Table 1: Field Research by Author, 2023 C4.0–Application 4.0 Test of Normality of Variables

4.2 The Impact of Construction 4.0 in Quality Management of Residential Building Projects

The importance of Building 4.0 has greatly contributed to the productivity changes and delivery efficiencies experienced in the construction industry worldwide through the adoption of intelligent manufacturing and the development of digital initiatives for quality management. Intelligent manufacturing has made it possible to reduce risks thanks to the automation of the construction process. In quality management, manual quality assurance in the construction process has been replaced by automation systems.

For example, support and decision-making systems based on artificial intelligence are widely used and the results are enormous. In the planning phase, decision support systems have helped maintain planning automation, which eliminates waste and ensures high-quality decision making. Some such systems are Autodesk, Revit, Orion and Primavera. These systems helped ensure the quality of processes and products.

The Impact of Construction 4.0 on Quality Management:

Construction 4.0 Impact In Parameters	MEAN	RAI	RANK

Intelligent Manufacturing	4.475	0.897	1th
Development Of A Digitization Initiative For Quality Management	4.475	0.897	1th
Additive Manufacturing	4.465	0.895	3th
Artificial Intelligence In Quality Management	4.330	0.888	4th
Mobile Computer System For Quality Management	4.385	0.875	5th
Social Media And Multimedia System	4.350	0.850	6th
Innovative Robotics In Quality Assurance	4.300	0.830	7th
Automation Of Quality Management Of Construction Systems	4.000	0.830	7th
Big Data Application	3.990	0.800	9th
Cloud Service And Applications	3.875	0.799	10th
Virtual Reality And Augmentation	3.825	0.785	11th
High Quality 3D Printing In Documentation	3.775	0.775	12th
Expert System And Neural Network	3.750	0.750	13th

Table 2: Author's Field Study, 2023 RAI- Index of Relative Agreements.

The role of 4.0 in the construction sector was also mentioned in other statements, such as publications that mentioned the challenges of C 4.0 quality issues, investigated risk management and the solution for construction quality management was emphasized. In addition, as shown in Table 3, Building 4.0 has had a positive impact on the construction sector, and issues related to Building 4.0 include the areas of impact of Building 4.0 in the construction sector, according to the review publication.

4.3 Detailed Objectives for Project Quality Costs

The priority areas of quality control are first the setting of quality objectives, before the allocation of resources for their implementation, and then the creation of resources to realize the specifics of the objective. In addition, at all stages of quality management, project cost comparison, objective performance and, above all, expenses should be minimized. For this purpose, the parameters of the quality cost objectives are given in.

The results show that among the variables, the most important factors were the allocation of reserve funds for the purchase of tools and equipment, as well as the improvement of construction processes and thus the reduction of project costs. Audited and then benchmarked project costs due to maintenance of machinery and facilities (RII = 0.84). Minimizing costs to maximize profits was rated the lowest among respondents (RII = 0.82).

Parameters of Quality Cost Objectives

Parameters	**Mean**	**RII**	**Rank**
Enables Random Tools And Random Internal And External Bugs	4.295	0.850	1st
Improving Construction Processes That Reduce Project Costs	4.575	0.840	2nd
Comparative Analysis Of Project Costs Due To Maintenance Of Machines And Facilities	4.350	0.835	3rd
Minimizing Costs To Maximize Profits	4.200	0.825	4th

Table 3: Author field research 2023 RII - relative importance index.

4.4 Parameters of Communication, Authority and Responsibility

The survey data presented in show some parameters measuring communication, empowerment and responsibility. The results show that promoting effective communication of work quality standards to maintenance workers (RII = 0.886), followed by delegation of responsibility (RII = 0.867) and regular management of quality meetings received the greatest support from the professionals interviewed. Solving maintenance problems (RII = 0.850).

Parameters	Mean	RII	Rank
Developing An Effective Communication Strategy To Improve The Quality Of Work And The Quality And Level Of Work	4.470	0.886	1st
Delegation Of Responsibility Is Essential	4.375	0.867	2nd
Regular Quality And Maintenance Management Meetings On Websites	4.300	0.850	3rd
A Policy Implementation Committee Should Be Formed	4.275	0.843	4th
Creating A Command Line Is Essential	4.230	0.834	5th
Identify Value From The Customer's Perspective	4.250	0.840	6th
Cost Comparison Of Machinery And Equipment Maintenance Projects	3.975	0.780	7th

Table 4: Author Field Research 2023 RII - Relative Importance Index

As the last factor, the respondents mentioned the planning of mapping the future value flow of materials (RII = 0.780). Effective communication of quality issues is an essential part of quality monitoring and benchmarking in the construction industry. Decisions related to quality must be communicated to all members of the project team.

4.5 A Quality System Management Framework for A House Building Project

The results show that demonstrating organizational characteristics, Lean knowledge training and constructive communication, each with a corresponding relative importance index value (RII = 0.86), received the highest rating from respondents, while definition evaluation matrices received the lowest rating (RII = 0.80), by respondents of professionals in the field of construction. The study also describes important elements that could be implemented in the design phase, including integration of waste practices, identification of waste types, waste analysis, and questionnaire and work sample evaluation, SWOT analysis for Lean supply, Lean transformation plan and current status documentation a hole.

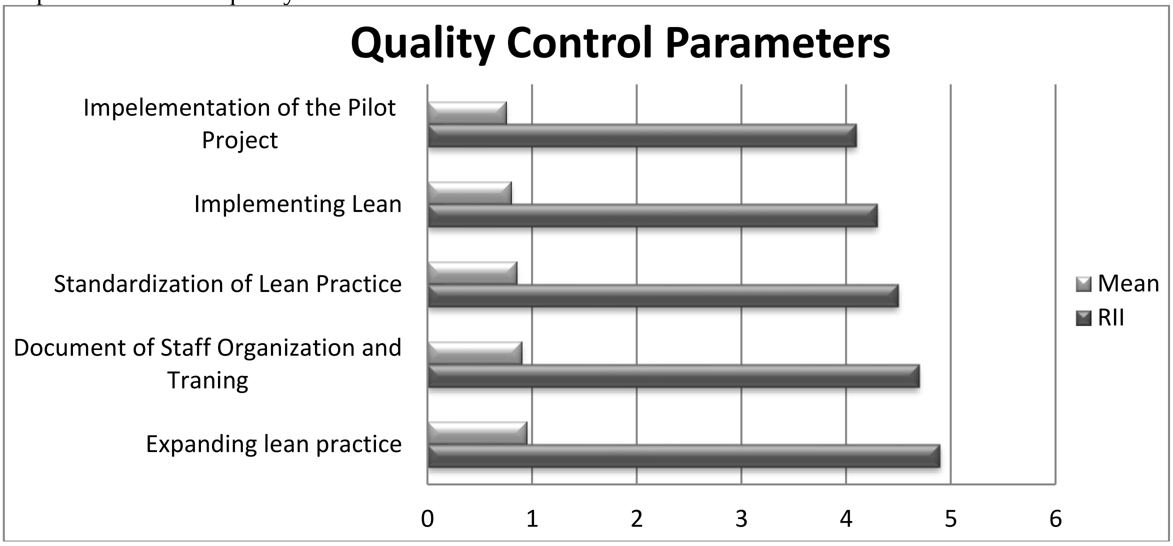
A chi-square test with a p-value of 0.05 was performed. The null hypothesis is usually rejected if the asymptotic significance is less than a p-value of 0.05, and the null hypothesis should be accepted if the asymptotic significance is greater than a p-value of 0.05. There should also be effective communication, review of waste practices and creation of assessment matrices to ensure quality.

Quality Monitoring and Control in the Management of the Construction Process

Conceptual Phase	Mean	RII	Rank
Introduction Of The Characteristics Of The Organization	4.425	0.877	1st
Thin Knowledge Training	4.380	0.868	2nd
Create Communication	4.320	0.860	3rd
Check For Potential Waste And Sustainable Practices	4.320	0.860	3th
Define Rating Matrices	3.975	0.800	5th

Table 5: Author's Field Research In 2023

According to there is no significant difference in the answers of the respondents for the five factors of presenting organizational characteristics, training in Lean knowledge, building communication and investigating possible wastes and Lean practices. The value should be recognized from the customer's perspective and the benchmarking of project costs due to machinery and facility maintenance that was supported. In relation to analysis in quality monitoring and control, knowledge of Lean technology in waste disposal is important to ensure quality.



Lean thinking quality control parameters. Legend: RII—Relative Important Index.

The respondents' assessments of the stage of implementation of the reference framework developed for the paradigm of housing construction projects. From the research data, it appears that the extension of Lean practice received the highest rating (RII = 0.88), followed by employees who organize, train and standardize Lean practice, each with a corresponding index of relative importance (RII = 0.86) while implementation. Pilot project Received the lowest rating from respondents (RII = 0.81).

5. DISCUSSION

The global construction building is known for providing real estate that in turn satisfies consumer needs. Products include large housing and housing. However, manufacturing construction products is labour intensive and requires a lot of effort. In this context, input refers to the input of construction project operators whose efforts determine the quality of construction products. In light of the above, monitoring and control are essential for quality results and production in the construction industry. Therefore, quality must be comprehensive and cover the product life cycle. The life cycle of construction starts from the idea concept phase which always means that high quality design and implementation already starts from the idea planning. Before the advent of Construction 4.0, the analog reality model was mainly used in the planning of decision support systems and in the monitoring and management of construction. The analog model was at a disadvantage due to, among other things, its time-consuming and expensive characteristics and its inflexibility in customizing functions.

Therefore, there are many opportunities in the implementation of C 4.0 in construction quality management. In the authors noted that high-tech applications enable easy use of high-quality equipment in the construction industry. AI-based applications with 4D and 5D capabilities have been extremely helpful in quality control and assurance in the construction process, maintenance and post-occupancy of facilities. 2D and 3D printing applications have made huge contributions to automated printing applications. This has reduced the lead time for documenting quality documents in the construction building.

However, the arrival of build version 4.0 brought better model production. For example, in the Construction 4.0 era, sensor-based 3D systems are used in the modelling of construction products. The introduction of computer-aided design (CAD) in the construction industry made it possible to ensure the quality of the design process. CAD allows designers to visualize the layout of a drawing or how the drawing will look. This allows for timely adjustments and manipulation. According to calibrated applications has attracted interest in the construction industry. In Construction 4.0, decision support systems use quality management and quantitative tools that capture function and form in the design and development of quality parameters. In addition, in the era of construction 4.0, virtual reality and augmented reality applications help visualize how to quantify the quality impact in the construction process.

In addition, quality issues are extremely important in the construction industry and the creation of construction products. Today, quality control parameters are incorporated into most simultaneous applications in the manufacturing and distribution of construction products. Modern construction quality management systems have expert and intelligence-based quality management applications as presented in. Some of the identified applications, as referenced in the text, help digitize construction process quality management, additive manufacturing, intelligent manufacturing, construction process automation and robotics applications. This study developed a quality management reference framework for quality management applications in residential construction projects. Related reference frames were used in the quality management of construction works. Some of the comparable frameworks developed in this study include hedonic models, artificial intelligence (AI) models, total quality management (TQM), case-based models and lean thinking models.

6. CONCLUSIONS

Quality management eliminates waste and increases productivity at low cost. In this background, this research showed how the Lean concept could be used to create a regression model to help create a quality model for construction applications to prevent poor quality management on the construction site. In connection with this study, the following objectives were formulated for the study:

the influence of Building 4.0 parameters on the quality management of construction projects, the influence of the Internet of Things (IoT) and construction 4.0 tools in the quality management process. Critical success factors of a construction project, construction quality management with the concept of Lean construction and development of a Lean-based quality management framework for residential projects. The results of the study revealed challenges related to the integration of technological sectors such as Lean Construction 4.0 into the framework, including reducing flexibility to new conditions during the process of project implementation. Management becomes more and more expensive and the fact that the application of Lean principles offers little or no room for changes in the construction process, e.g. also, the developed model has practical applications in input process and product quality control, as described in this study.

The parameters of the developed model can be used to control the quality process so that quality decisions can be made in projects. Finally, the limitation of the study is the applicability to the construction life cycle process, which includes the entry stage, the process phase, and the modelling of the final construction product. The model could also be applied to industrial production processes and manufacturing that require input and output to be processed into product form. Lean tools must be communicated to stakeholders to be implemented.

According to the results of this study, the following factors must be considered in the initial phase of the project: Integration of waste and error reduction practices, identification of waste types, waste analysis, survey and evaluation of work samples, SWOT analysis for Lean. , Lean transformation plan of the provision and documentation of the current space gap. Similarly, the implementation of the Lean framework in the quality process of residential buildings requires the following measures: expansion of Lean practice, organization and training of personnel, standardization of Lean practice, documentation of Lean implementation and implementation of a pilot project. In addition, quality issues are extremely important in the construction industry and the production of construction products.

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