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Modelo de implementación para obras de vivienda residencial en Cuba aplicando la filosofía de Construcción Lean.
Implementation model for residential housing works in Cuba applying the Lean Construction philosophy

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Resumen-- **Esta investigación explora la aplicación de Lean Construction como estrategia para mejorar la productividad en la industria de la construcción. Un estudio de caso de 52 viviendas en el barrio de Roble reveló que solo el 45% del tiempo de trabajo se dedica a tareas productivas, mientras que el 35% es contributivo y el 19,5% no contributivo. Las principales causas de ineficiencia incluyen una planificación deficiente, una comunicación ineficaz, la desorganización en las obras, el suministro inconsistente de materiales y problemas de transporte que afectan a la asistencia de los trabajadores. Se presenta un análisis detallado de las herramientas Lean clave y sus metodologías de implementación, identificando oportunidades específicas de mejora. En respuesta, se desarrolla un modelo experimental de implementación Lean para guiar a profesionales y empresas en la adopción de estas prácticas. Los hallazgos buscan promover una mayor integración de los principios de Lean Construction en todo el sector para abordar dichas ineficiencias y mejorar el desempeño general..**

Palabras clave— Lean Construction; Metodología; Productividad; Mejora continua; Vivienda residencial.

Abstract— **This study explores the application of Lean Construction as a strategy to enhance productivity in the construction industry. A case study of "52 homes in the Roble neighborhood" revealed that only 45% of working time is dedicated to productive tasks, while 35% is contributive and 19.5% non-contributive. The main causes of inefficiency include poor planning, ineffective communication, disorganized job sites, inconsistent material supply, and transportation issues impacting worker attendance. A detailed analysis of key Lean tools and their implementation methodologies is presented, identifying specific opportunities for improvement. In response, an experimental Lean implementation model is developed to guide professionals and companies in adopting these practices. The findings aim to promote broader integration of Lean Construction principles across the sector to address such inefficiencies and improve overall performance**

Index Terms— Lean Construction; Methodology; Productivity; Continual Improvement; Residential Housing.

I. INTRODUCTION

THE construction industry is a fundamental pillar of a nation's economy, making it essential to evaluate the management systems adopted by leading global construction firms known for their high performance (Porras et al., 2014) (Al Balkhy et al., 2021). One such system is the "Lean Construction" methodology management approach focused on enhancing productivity and minimizing waste through efficient tools and processes (Lean Construction Institute, 2023).

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Although its adoption in Latin America remains limited, countries like Chile, Brazil, Peru, and Colombia have begun to make significant strides in its implementation (Cacciuttolo et al., 2025). For example, in Brazil, a study analyzed the resilience of construction companies during the COVID-19 pandemic and found that companies with a higher degree of Lean Construction adoption demonstrated greater resilience in coping with pandemic-induced challenges (Dallasega et al., 2017). Similarly, in Chile, Lean practices have helped improve collaboration and streamline workflows, especially in the face of disrupted supply chains caused by the pandemic.

However, smaller enterprises across the region—including in Cuba—often hesitate to adopt Lean principles, perceiving them as costly, time-consuming, and of limited benefit to business growth (Ferrán, 2022). In Cuba's case, the construction sector has long faced critical challenges, including declining quality, project delays, and financial losses. These issues have been exacerbated by chronic shortages of essential materials such as cement, the repercussions of the COVID-19 pandemic, and ongoing economic and trade restrictions imposed by the U.S. government. This complex environment has hindered progress in a sector that is vital to national development.

Recent research also highlights how Lean Construction has adapted to the challenges of the post-COVID era. For instance, a study on the integration of Building Information Modeling (BIM) with Lean methods in China's disassembly and reuse projects showed that the combined approach led to improved labor efficiency, reduced construction periods, and minimized waste generation, even in the context of disrupted operations (Hei et al., 2024) (Li et al., 2024). In Peru, the pandemic underscored the need for effective planning, and Lean methodologies provided key benefits such as better identification of project constraints and enhanced communication (Erazo-Rondinel et al., 2023) (Fernández et al., 2023). These examples illustrate that even in developing economies, Lean Construction can contribute to overcoming challenges like material shortages, workforce disruptions, and planning inefficiencies.

Given this context, it is imperative to develop strategies aimed at boosting productivity and revitalizing the construction sector. This study moves beyond simply reducing labor costs, embracing Lean Construction as a comprehensive philosophy for process optimization. Through efficient resource management, waste reduction, and strategic planning, Lean not only reduces costs but also promotes sustainable, responsible construction practices. Ultimately, this research aims to provide a holistic and adaptable framework for implementing Lean in developing contexts—offering tools and methodologies aligned with the principle of continuous improvement.

A. Key Concepts

Lean production (lean manufacturing or waste-free production) is a business management approach that seeks to maximize production efficiency by eliminating waste and optimizing processes (Escuela Origen International Education, 2022). Lean Construction emerged when this way of working was adapted to the construction sector and is a methodology that offers multiple benefits in terms of competitiveness (Muñoz, 2019). Lean Construction is a philosophy that guides the actions of people involved in construction. It is important for companies in the construction sector to adopt the Lean system as a business strategy because, if they do not, they could be left out of the market in numerous projects that require increasingly efficient, sustainable, standardized, automated, and industrialized processes. Currently, concepts such as Building Information Modeling (BIM), Lean Construction, and Integrated Project Delivery (IPD) are being used together and perfectly adapt to the upcoming changes in the industry. The Lean approach in construction aims to optimize processes by reducing waste and promoting continuous improvement, but its implementation varies depending on the context. In our study, we have analyzed how this methodology can be adapted to the specific conditions of Havana, where factors such as limited material availability, economic constraints, and resource planning impact project efficiency. Instead of applying a generic model, we have identified strategies that address these particular challenges, ensuring that the proposed improvements are realistic and applicable within the local environment. As Juan Felipe Pons Achell mentions, experts are predicting that sometime between 2060 and 2070 there will be a change in the economic system driven by efficiency, excellence, and productivity, leading to greater automation and less dependence on labor. It is thought that by around 2030, a transition from the fourth to the fifth industrial revolution could begin, characterized by artificial intelligence, robotics, and neural networks. In this sense, the Lean Construction production system already fits perfectly into this new situation. The COVID-19 crisis has accelerated a process of change and evolution that was already underway, which will turn the construction industry into a modern, safer, more productive industry with higher quality and more satisfied customers (Bartolón, 2020).

On the other hand, in construction, three types of work can be found (Ramos, 2016):

- Productive Work (PW) refers to activities that directly contribute to production and generate value for the customer. Productive work refers to work that produces a unit of production, for example, in the activity of masonry execution, it would be the masonry itself or interior partition walls (Cusihuaman et al., 2014).
- On the other hand, Contributive Work (CW) is the support work necessary to carry out productive work but does not add value, such as transporting materials, cleaning the site, and measuring the progress of masonry work (Miranda et al., 2020).
- Finally, Non-Contributive Work (NCW) refers to any activity that does not generate value and is considered a waste of time and resources. These activities are not necessary for the production process and only add unnecessary costs, concerning aspects such as waiting times, travel and rework (Pheng et al., 2006). In contrast to approaches that seek to eliminate break times and workers' physiological needs, there are theories that recognize and respect the importance of breaks and health in the workplace, as highlighted in the literature on labor rights, where

it is emphasized that the physical and mental well-being of employees is essential for productivity and the creation of a fair and sustainable work environment (Canessa, 2009).

It is crucial to increase the amount of productive work, reduce the amount of contributive work, and eliminate non-contributive work to reduce losses. The key to achieving this is proper, efficient planning that carefully considers workflows (Ramos, 2016).

II. Methodology

The main objective of this research is to apply the Lean Construction management system to enhance efficiency in project management. Specifically, the study focuses on the execution of 52 housing units in the Roble neighborhood, Havana, Cuba, aiming to optimize project leadership, planning, and control.

To achieve this goal, an implementation model is proposed to minimize waste, reduce idle time, and maximize the efficient use of available resources. The application of Lean Construction seeks not only to improve productivity in project execution but also to ensure higher quality outcomes, aligning with international best practices in the construction industry.

This study will analyze key Lean Construction tools and methodologies, such as the Last Planner System (LPS), value stream management, and continuous improvement, to establish strategies that contribute to project efficiency. The proposed model is expected to have a positive impact on cost reduction, execution time, and stakeholder satisfaction in the construction process.

A. Lean Tools Used During the Research

1) General Activity Level (GAL)

The general activity level refers to the proportion of work of the three types of tasks (Productive Work, Contributive Work, or Non-Contributive Work) in relation to the total work of the project. To determine this level, it is necessary to conduct a random observation of the entire project and record each time a worker is seen performing a specific task and the type of task they are performing. It is also known as the "5-minute test" and must be carried out at random and varied times throughout the day (Ramos, 2016).

2) Last Planner System

The Last Planner System (LPS) is a methodology designed to plan and control production, aiming to achieve a continuous and reliable workflow. The system consists of five main parts (Cusihuaman et al., 2014) (Miranda et al., 2020). The LPS, with its five elements, is characterized by being a methodology with a well-defined process. Its implementation requires standards, routines, regular planning meetings, and specific tools. Additionally, it incorporates a continuous improvement approach through regular measurement of indicators, root cause analysis, and corrective actions for unexpected results. Its execution requires a solid organizational structure and time dedication. It also involves a mindset shift from traditional project management (Conexión Esan, 2019). The implementation of this system can be applied to all types of construction projects and is a key strategy to stay ahead of the market, be more competitive, and improve customer satisfaction (Gilacopa et al., 2020).

Within the LPS, six stages can be distinguished, which are fundamental for its proper functioning:

- Stage 1: Master Scheduling. Objective: Establish milestones and initial agreements (López et al.,2020).
- Stage 2: Phase Planning. Objective: Specify deliverables and dates for each team/sector involved in the project.
- Stage 3: Look Ahead Planning. Objective: Prepare the work by identifying constraints and achieving their release (Pons et al., 2019).
- Stage 4: Weekly Scheduling. Objective: Establish progress commitments for the period (Pons et al., 2019).
- Stage 5: Daily Scheduling (Daily Log). Objective: Show the activities to be carried out during the day (Pons et al., 2019).
- Stage 6: Learning. Objective: Identify the causes of any non-compliance and act to address them (Richert et al., 2022).

3) Constraint Analysis

A constraint can be defined as any activity or task that hinders or makes it impossible to carry out the next activity (Pons et al., 2019). Constraint Analysis is a project management tool used to anticipate possible obstacles that may arise in the execution of an activity (Rodríguez, 2023). The "Theory of Constraints" (TOC) is a methodology that addresses problems by identifying the most crucial obstacle preventing the achievement of goals and objectives in a project. From a practitioner's standpoint, by establishing a strong theoretical foundation for TOC, we assist managers deploying it to gain better understanding of TOC elements and ultimately avoid implementation failures (Naor et al., 2013). For example, if delays with suppliers are frequent, TOC would help identify the main constraint causing these delays, and through good management, it would be eliminated. According to this theory, each project has a main constraint, based on the concept of the weakest link in a critical chain. Resolving this constraint strengthens the project process and improves its flow (Proud, 2007).

4) Percent Plan Complete (PPC)

The "percent plan complete" refers to the ratio between the total number of scheduled tasks completed and the total number of scheduled tasks, expressed as a per-centage (Altertecnia) (Mejía et al., 2007) (Castillo, 2001). PPC is a tool used to evaluate the quality of the scheduling carried out. Only activities that have been fully completed are considered, with the aim of identifying the possible causes of those that were not completed 100%. This allows for corrective measures to be taken to continuously improve the process (Conexión Esan, 2019). Therefore, the formula used to calculate PPC would be the number of completed tasks divided by the total number of scheduled tasks, expressed as a percentage.

5) Big Room

The Big Room is a place where the project team meets; however, its purpose goes beyond just being a meeting place. To create an effective Big Room, it is essential that expected behaviors are clearly defined. Additionally, the team must develop the "Conditions of Satisfaction," which are a set of criteria that define the project's success and guide decision-

Fig. 1. Typical ground floor of buildings with the two apartments. Havana Architecture and Engineering Projects Company EPROB, 2023

making. It is also important to create an environment that fosters open and transparent discussion (Miranda et al., 2020) (Pérez, 2019) (Bravo, 2021). The Big Room goes beyond just being a meeting place, as when it is set up and implemented correctly, it creates the environment for the project team to do their best work for the project, resulting in the creation of maximum value for the clients (Orihuela et al., 2011). The number of figures and tables should be limited as much as possible, sending only those that are truly useful, clear, and representative. They should be numbered consecutively according to their citation in the text. All tables and figures must be cited within the main text of the article; otherwise, they will not be considered necessary.

6) Integration of Lean Methodologies into the Cuban Context.

The implementation of Lean tools in Cuba requires an adaptive analysis that considers both the strengths and limitations of the local environment. From a legal standpoint, the Cuban construction framework is highly centralized and regulated by state institutions. This can hinder the immediate adoption of agile methodologies such as the Last Planner System, which depend on operational autonomy and decentralized decision-making. However, the existence of policies aimed at improving efficiency and sustainability in public works presents an opportunity to progressively incorporate these practices, as long as they align with national technical standards and the guidelines of the Ministry of Construction (MICONS). On the technical side, one of the main challenges is the limited availability of construction technology and resources, which may pose obstacles for the full implementation of certain Lean tools, such as Constraint Analysis or Big Room, especially when these require specialized software or well-equipped collaborative spaces. Nevertheless, this constraint also offers an opportunity to develop creative, resource-sensitive solutions. For instance, collaborative planning meetings can take place in existing company spaces, and task tracking can be carried out using low-cost tools such as spreadsheets, physical boards, or simple mobile applications. From an economic perspective, applying Lean Construction in Cuba could significantly help mitigate the effects of material shortages, idle time due to logistical interruptions, and low on-site productivity. The focus on waste reduction and continuous improvement can translate into more rational use of available resources—an essential approach in a context where inputs must be carefully managed. For sustainable integration, however, it is necessary to train both technical and managerial teams in these methodologies, foster an organizational culture based on learning and collaboration, and establish incentives within state and cooperative construction structures that reward efficiency and process quality.

B. Project Characteristics

The project under analysis corresponds to a set of homes being built on a plot belonging to the "AZUMAT" Logistics Company (investment promoter), and the future owners of these apartments will be the workers of this entity. The plot is located at Máximo Gómez Street No.20, between C.20 and H. streets in the Roble neighborhood of the Guanabacoa Municipality, located east of Havana city. The project includes the construction of 52 homes, distributed in 13 typical buildings of 2 levels each and 4 homes per building, including the design of exterior areas and road renovation's methodological value proposition (Fig. 1).

1) Considerations for Implementing the Lean Model in the Cuban Context

In the Cuban context, the construction sector is governed by a highly centralized legal and institutional structure, where strategic decisions, budgets, and procurement processes are predominantly managed by state entities. To ensure the successful implementation of Lean Construction in Cuba, it is crucial to fully understand the existing regulatory framework,

MEASUREMENT OF THE GENERAL LEVEL OF ACTIVITY ON SITE

Project: 52 Houses in Barrio Roble
Project Phases: Structure and Installations
Summary of 10 Days

Workday: 8 hours
Start: 8am
End: 5pm
Lunch break: 1 hour between 1pm–2pm

					TYPES CW					TYPES NCW							
No.	PW	CW	NCW	TOTAL	I	S	L	M	X	T	B	E	N	D	R	S	X
1	170	79	71	320	12	20	40	2	5	12	2	3	12	14	1	19	8
2	132	134	54	320	18	34	78	2	2	13	4	5	10	6	-	10	6
3	131	112	77	320	20	23	67	-	2	20	4	10	9	13	2	9	10
4	163	94	63	320	15	23	49	6	1	10	4	14	12	9	1	8	5
5	182	78	60	320	24	16	34	1	3	12	2	12	11	2	-	13	8
6	119	149	52	320	22	47	78	1	1	14	1	12	9	4	-	10	2
7	112	125	83	320	12	23	87	2	1	17	2	14	10	12	3	15	10
8	155	100	65	320	18	12	67	-	3	12	2	16	8	15	1	8	3
9	134	127	59	320	23	15	80	3	6	20	4	8	12	9	1	4	1
10	147	133	40	320	16	13	95	3	6	10	2	1	7	10	-	4	6
Total	1445	1131	624	3200	180	226	675	20	30	140	27	95	100	94	9	100	59
Total Hours Summary	361	283	156	800	45	57	169	5	7,5	35	6,8	23,75	25	24	2,3	25	14,8

PW								
CW	I: Instructions	S:Transport	L: Cleaning	M:Measurements	X: Others			
NCW	T: Late arrival to site	B: Physiological needs	E: Waiting	N: Idle time	D:Breaks	R: Rework	S: Left before end of shift	X: Others

Fig. 1. Data obtained during the 10 days of measurements on site.

which is governed by the Ministry of Construction (MICONS). The Cuban construction sector operates within a highly structured and centralized system, where strategic decisions and budgets are primarily controlled by state entities. Key policies such as the Plan de Inversiones en la Construcción and Programas de Ahorro de Recursos provide a foundation for enhancing construction efficiency through resource optimization and quality control. These policies emphasize reducing waste, improving project timelines, and increasing labor productivity, aligning well with Lean Construction principles. This implies that any attempt to introduce methodologies such as Lean Construction must be compatible with the guidelines established by the Ministry of Construction (MICONS) and other national regulations. Nevertheless, existing policies focused on improving construction efficiency—such as resource-saving programs and quality control protocols—present an opportunity to align Lean principles with institutional goals. Additionally, Cuba's existing construction practices, such as the Sistema de Planificación y Control de Obras (SPCO), already incorporate certain elements of resource management and project tracking, which could be enhanced with Lean tools. For example, the SPCO framework, which tracks material availability and labor allocation, could benefit from Lean methodologies like the Last Planner System to improve forecasting accuracy and team collaboration. In this regard, effective implementation could be supported by public policies that encourage innovation and modernization in construction processes.

From a technical standpoint, Lean tools require solid foundations in planning, communication, and real-time work tracking. Although access to advanced technologies in Cuba remains limited, the flexible nature of Lean allows for practical adaptations. For example, tools like the Last Planner System can be implemented using traditional means such as physical boards, printed schedules, and manual tracking forms—without the need for complex software. Moreover, it is important to recognize the ongoing challenges within the Cuban construction sector, including limited access to advanced technologies and the need for adaptive strategies. While modern software tools for Lean construction may be less accessible, practical adaptations using traditional methods (such as physical boards and printed schedules) can still provide significant improvements in communication, planning, and real-time tracking of project progress. Furthermore, Lean methodologies can strengthen the technical skills of construction personnel by introducing new practices in scheduling and control that promote critical thinking, team coordination, and shared accountability.

One of the greatest benefits of the Lean approach in the Cuban context lies in its potential to maximize the efficiency of material and human resources—critical elements in an environment marked by logistical and economic constraints. Reducing idle time, eliminating unnecessary tasks, and improving workflow can lead to significant cost savings without compromising the quality of the final product. In sum, the integration of Lean principles into the Cuban context must not only consider existing regulations and technical frameworks but also involve careful adaptation to local resources and capabilities. By aligning Lean practices with the policies and systems already in place, the potential for improved efficiency, reduced waste, and enhanced productivity becomes a feasible and valuable strategy. In addition, performance indicators such as Percent Plan Complete (PPC) can provide valuable feedback to identify inefficiencies, anticipate recurring issues, and support more informed decision-making for future projects.

Lastly, it is important to recognize that applying Lean methodologies is not only a matter of changing processes, but also of transforming mindsets. In Cuba, where workplace culture may be shaped by traditional organizational habits, transitioning toward a more participative, results-driven, and continuously improving model requires training and awareness-raising efforts. This involves educating managers, technicians, and workers in Lean principles, while also promoting values such as transparency, collaboration, and shared responsibility.

III. Discussion

A. *Evaluation of the General Activity Level on Site*

An evaluation of the General Activity Level was carried out on the site. For this, the entire site was surveyed (building 1, which is the only one currently being executed), and the activities being carried out were recorded at 15-minute intervals for each worker, including details of the three fundamental types of work: productive work (PW), contributive work (CW), and non-contributive work (NCW). The stage of the project at the time of the evaluation was the structural stage, so when evaluating the workers, all tasks are related to this stage.

B. *Results of the General Activity Level Measurement*

The methodology involved measuring the performance of construction workers over 10 randomly selected days, focusing on identifying inefficiencies and comparing them with global benchmarks for construction productivity. Data was collected from 10 workers, with measurements taken at 15-minute intervals throughout an 8-hour workday (from 8:00 AM to 5:00 PM), including a one-hour lunch break from 1:00 PM to 2:00 PM, as shown in Fig. 2. This sampling method provided insights into the evolution of activities throughout the day, capturing both productive and non-productive work.

Although a broader observation period was conducted, ten random days were selected for detailed analysis. This decision is supported by the stability observed in work patterns throughout the entire monitoring period, indicating that the results from this sample are representative of the overall dataset. Therefore, the selection of these specific days does not compromise the validity of the study, as the key productivity indicators remained consistent across the broader timeframe.

The primary criteria used to measure productivity, efficiency, and waste reduction were:

1. Productive Work (PW): Time spent on tasks that directly contribute to the completion of the project, such as construction activities and technical tasks.

2. Contributory Work (CW): Time spent on tasks that support productive work, such as preparing materials, organizing the site, and other non-direct but necessary activities.

3. Non-Contributory Work (NCW): Time spent on activities that do not directly or indirectly contribute to the project, such as idle time, waiting for materials, or other unproductive activities.

The collected data was categorized into these three types of work and analyzed in Fig. 2 to identify areas for improvement. The data was then compared to international benchmarks for construction productivity, which generally indicate that productive work should account for 60% to 80% of the total workday. In this study, productive work (PW) accounted for 45.16% of total activities, which is below the lower end of the global benchmark range.

In comparison to global standards:

- International Benchmark: Productive work typically ranges between 60% and 80%, with best-performing projects often reaching the higher end of this spectrum.

- Study Findings: At 45.16%, the productive work observed in this study is significantly lower than the global benchmark, highlighting potential inefficiencies on the construction site.

This underperformance is primarily due to factors such as poor site organization, material shortages, inefficient planning, and delays caused by transportation or worker attendance issues. These inefficiencies contribute to a higher percentage of contributory work (CW) and non-contributory work (NCW), which, although necessary, do not directly add value to the project. The analysis of these findings points to key areas for improvement, particularly in resource management, scheduling, and site organization. By addressing these inefficiencies, it is possible to enhance overall productivity and align performance with global best practices (Ma et al., 2019).

C. Improvement Opportunities

Once the main causes of losses on the site have been identified, the following improvements are proposed to combat these losses, prioritized according to their estimated impact:

1) Implement BIM (Building Information Modeling) to improve design quality and avoid rework.

- Description: Improving design plans with more information and fewer errors is key to avoiding rework, which significantly reduces unnecessary man-hours. The use of BIM can optimize construction processes, reduce costs, and shorten execution times.

- Estimated Impact: High. Improving design quality and reducing errors can significantly reduce rework and associated costs.

2) Avoid improper material distribution and establish an inventory control and supply system.

- Description: Lack of timely material provision can cause significant time losses. Implementing an inventory control system, assigning a supply manager, and establishing clear procedures for material requests and delivery ensures materials are always available, preventing work stoppages and inefficient use of resources.

- Estimated Impact: High. Ensuring material availability improves daily productivity by reducing waiting times and non-productive work.

3) Implement a collective transportation system for workers.

- Description: Implementing a collective transportation system for workers will ensure they arrive and leave on time, preventing delays at the start and end of the workday. If it's not feasible for both shifts (morning and afternoon), it can be done for one shift and adjust the workday accordingly.

- Estimated Impact: Moderate-High. Improving worker punctuality enhances overall operational efficiency and reduces downtime at the start and end of shifts.

4) Establish daily work orders to assign tasks to each crew.

- Description: Creating daily work orders ensures that each crew has clear instructions, preventing downtime due to lack of direction or information on what tasks to perform.

- Estimated Impact: Moderate-High. Clear task assignments improve efficiency and reduces interruptions, optimizing workflow.

MILESTONE	INTERVIEWER	MONTH-MAY 2023				MONTH-JUNE 2023				MONTH-JULY 2023				MONTH-AUGUST 2023			
		Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4
Culmination Facilities	Construction Company																
Culmination Finishing	Construction Company																
Start of testing	Municipal Physical Planning Inspector																
End of project	Construction Company - Client																

Fig. 3. Proposal for a Master Plan by Milestones for the future execution of the remaining buildings.

5) Greater involvement of the site manager in supervising workers.

- Description: The site manager must be more involved in supervising workers continuously, eliminating idle times and reducing the need for experienced workers to spend excessive time instructing new colleagues.

- Estimated Impact: Moderate. Improved supervision reduces idle time and enhances daily work efficiency.

6) Optimize site layout to improve the flow of material and equipment transportation.

- Description: Optimizing the site layout can reduce time losses from transporting materials and equipment. A more efficient layout improves workflow and reduces time spent moving materials around the site.

- Estimated Impact: Moderate. Improved site layout contributes to a more efficient workflow by reducing time lost on unnecessary movement of materials.

7) Daily planning to ensure the availability of materials and equipment.

- Description: Planning the tasks, materials, and equipment needed one day in advance helps avoid delays caused by lack of preparation. This ensures that activities can proceed continuously without interruption.

- Estimated Impact: Moderate. Ensuring the prior availability of materials and equipment optimizes time usage and avoids interruptions due to resource shortages.

D. Implementation of the Lean System

In this section, several suggestions will be presented through standardized implementation models designed to improve production efficiency in the execution of housing projects in Cuba.

1) Creation of the Master Plan by Milestones as General Project Planning. First part of the "Last Planner System".

The person responsible for planning and scheduling the project likely used Project software to carry out the general planning of the project using the Gantt Chart. However, it has been observed that this planning tends to deviate from the initial approach from the very beginning. As a result, two options arise: the first option involves making regular adjustments to the general planning of the project as tasks develop. The second option is to use the original planning only as a reference guide, without making modifications as the project progresses (Pheng et al., 2006). The first alternative involves a great deal of dedication and consumes a lot of time, as it generally results in delays and fails to fully achieve its original objective as an advanced guide for the work. On the other hand, in Cuba, the second option is usually the most frequent.

LIST OF RESTRICTIONS									
	CONSTRUCTION SITE: 52 HOUSING UNITS IN THE ROBLE NEIGHBORHOOD				DATE CONTROL:				
ID	DESCRIPTION OF THE CONSTRAINT/PROBLEM	IMPACT / ACTIVITY AFFECTED	ACTION	Priority	RESPONSIBLE FOR RELEASING IT				
					COMPANY	PERSON	COMMITMENT DATE	ACTUAL RELEASE DATE	OPEN / CLOSED
#1									
#2									
#3									
#4									
#5									

● When the restriction is of High Priority
● When the restriction is of Medium Priority
● When the restriction is Low Priority

Fig. 4. Look Ahead proposal for the future execution of the remaining buildings.

To carry out this milestone-based scheduling, it should be noted that the main milestone to be marked will be the building delivery deadline or project completion, as well as other important milestones such as the delivery of the plot, the start date of the project, among others.

Therefore, if a "template" model were to be created that could be used for the execution of the rest of the buildings in the project, it would be as follows (Fig. 3).

In this way, the main milestones of the entire project can be placed in the cells of the first column, the main intervening agent of each milestone in the second column, and finally, their expected completion date.

2) Intermediate Planning "Look Ahead". What "can" be done.

From the master planning, "Look Ahead Planning" emerges, an intermediate planning that covers a period of 3 to 8 weeks. In this specific project, it is proposed to implement a period of 4 weeks with 1 month in advance. This prior period provides a solid understanding of the available resources, including labor, materials, and equipment. Short-term planning ensures high compliance, allowing for the completion of most or all activities scheduled for that period. This ensures compliance with both partial and total project deadlines. The key lies in analyzing the constraints of each activity during this intermediate planning. It is established as a rule to transfer tasks from the master plan only if all constraints of those tasks are released or at least have a committed date for their release. Constraints include crucial elements such as resources, machinery, labor, and time. This approach ensures the necessary reliability in the planning system.

Therefore, a "Look Ahead" model to implement at any stage of this project would be as follows (Table 3). It is proposed that unreleased activities be placed in the red as they require special attention, precisely because they are not yet confirmed and need to be managed carefully. In these activities, it is also recommended to place the person responsible for the constraint(s). The efficiency of "Look Ahead Planning" will be measured through the compliance percentages of the weekly plans.

3) Management of Activity Constraints.

After identifying the activities in the "Look Ahead" plan, it is essential to analyze the associated constraints. The main objective is to examine the necessary conditions to successfully carry out each activity, identifying possible limitations. This process requires an effective strategy to address the constraints in a timely manner and ensure the execution of activities according to the established planning. In this regard, the following model is proposed (Fig. 4). This format will provide detailed control of the constraints of each activity.

- Weekly Scheduling. What "will be done".

In weekly planning, planners take responsibility for advancing the project, committing to specific goals derived from the monthly "Look Ahead" plan. This increases reliability

WEEKLY SCHEDULING														
ID.	ACTIVITY	DATES		UNIT	PERSON IN CHARGE	TARGET		COMPLETED Yes/No	WEEK	DAY OF THE WEEK				
		START	END			COMMITTED	ACHIEVED			M	T	W	T	F
1														
2														
3														
4														
SUMMARY : Total Accomplished / Total Proposed Activities = %														

Fig. 5. Proposed Weekly Programming Model for the entire work.

Daily Scheduling

CONSTRUCTION SITE: 52 HOUSING UNITS IN THE ROBLE NEIGHBORHOOD

Work Order No.
Aimed at: Foreman
Date of drafting: month/day/year
Work order for day: month/day/year (normally this date will be 1 or 2 business days after the date of writing).

Activity	Number of workers	Number of work crews	Total number of workers	Scheduled hours	Actual hours	Expected fulfillment of the task expressed in %.	Causes of non-compliance with schedule	Causes of non-compliance with the expected % of the task

Fig. 6. Proposal for a daily work order for the project.

by committing to safer activities. The main premise for transferring an activity to the weekly plan is to resolve all its constraints. It makes no sense to plan tasks with unresolved constraints. There is an "alert zone" where some constraints can be resolved before starting that planned week, but if the probability of this happening is low, it is excluded from the weekly planning and analyzed in the list of constraints. Planning is done 1-2 days before the week, with data such as units, responsible person, and goal. The committed-goal column represents the expected compliance. Gantt charts can be used if necessary for a better understanding of the planning. This is the data to be completed before the week.

At the end of the week, compliance is evaluated through a binary analysis. For example, if the tasks of layout and installation of sanitary downspouts are fully completed, while laying electrical wires and installing pipes reach 90% of the planned, there would be 2 completed activities and 2 incompletes, resulting in 50% of the plan being fulfilled. In the last row, the Percent Plan Complete (PPC) for the week is summarized. This indicator is calculated weekly and compared with the proposed PPC to study the causes of non-compliance in weeks where the proposed PPC was not reached (Fig. 5.).

4) Daily Scheduling through Work Orders

Work orders represent a formal way to convey the information generated during weekly planning to the personnel on the worksite. To improve productivity, it is essential that the information provided by the site professionals reaches the field concisely and clearly. Work orders must meet certain minimum parameters to be timely and effective.

- First, it is necessary to list the tasks to be carried out during the day so that the site manager is aware of them.
- It is important to provide information on the number of workers needed to complete each task mentioned in the list.
- The schedules in which each task should be completed must be established.
- It is necessary to include the expected completion percentage for each task throughout the day.
- The reasons for non-compliance should also be mentioned, both in terms of schedules and the expected

52 HOUSING UNITS IN THE ROBLE NEIGHBORHOOD		ACTION PLAN FOR CONTINUOUS IMPROVEMENT. PDCA: PLAN-DO-CHECK-ACT					ACTION PLAN Number: 1	
		STAGE OF THE PROJECT: FINISHES. EXTERIOR CARPENTRY						
Nº	Date	PROBLEM	CAUSE	ACTION	WHO?	DATE OF IMPLEMENTATION	DID IT WORK ? YES/NO	STANDARDIZATION
1	07/04/2023	The workers could not were unable to place the windows in the bathrooms.	Shortage of suppliers that manufacture this type of carpentry in the the country	Ask the client to to modify the design of the windows	Construction Manager Client	07/06/2023	If yes: standardize the measure If no: apply another action	An agreement was reached with the client that every time there is a carpentry or furniture model that does not have suppliers that manufacture it, the modification of the design will be requested.

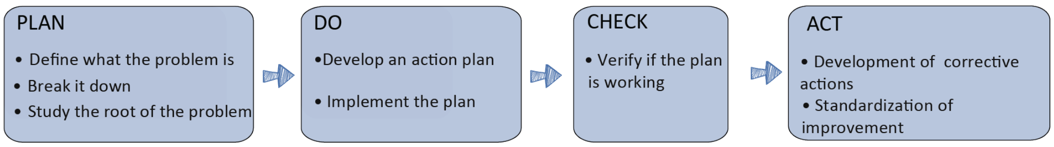

Fig. 7. Proposed template for Continuous Improvement in the work.

progress percentage for the day.

Typically, the date of drafting this document is 1 or 2 working days before the day for which it is drafted. Below is the proposed format for a work order (Fig. 6). Once the day has ended, the column for the actual schedule (i.e., the time each activity took) should be filled in, as well as the reasons for non-compliance with the scheduled time if it occurred, and the reasons for non-compliance with the percentage of the task to be completed during the day if it occurred.

- Feedback

Once planning has been completed at various levels, from Master Planning to Daily Planning, the latter through work orders, it is crucial to collect the information contained in these documents. Daily work orders contain data on the work performed and the use of labor in each task or item. From the weekly schedules, the reasons why the proposed plans were not met can be obtained. The feedback process is fundamental to evaluating the results of the information analysis. We can obtain productivity measurements, such as work performed, productive time (PT), contributive time (CT), and non-contributive time (NCT). Additionally, it provides the opportunity to optimize our work teams and improve overall productivity.

- Application of Continuous Improvement

It is proposed to follow up on actions through improvement cycles such as the Deming cycle or PDCA (Plan-Do-Check-Act) lines. It is important to note that for this cycle to close, corrective actions must be taken to help improve the performance of the planning system and work in general. The planning system will not work if actions are not taken to improve failures. In the PDCA cycle, the necessary measures will be taken to prevent detected problems from recurring.

To this end, it is proposed that after completing each stage or important milestone of the project, the following form be completed to monitor continuous improvement (Fig. 7). The cells of the table have been filled in red to improve understanding. As an example, the existing problem with the exterior carpentry of the bathrooms has been taken. In the project stage, the stage to which all the problems to be analyzed correspond should be written. In the date, the date the problem was detected should be placed. Then write what the problem is, its cause, and the proposed action. Next, the person involved in the action and its implementation date should be placed. Once implemented, the result is evaluated; if the result is favorable, the successful action is standardized; if not, another action is applied. As can be seen below the table, it explains how the 4 criteria of the Deming cycle (Plan, Do, Check, Act) are applied through this procedure. This model can be used at any stage of the project and for the continuous improvement of any activity. With this system, after any meeting, the team can identify the root causes of problems, learn from mistakes, and incorporate new solutions and improvements to those mistakes. This is a system that acquires knowledge and continuously improves with each cycle.

- Application of Visual Management and Creation of the "Big Room"

It is recommended to study the possibility of creating a collaborative workroom known in the Lean environment as the "Big Room," characterized mainly by visual management. The visual information should include key indicators related to the progress of the project.

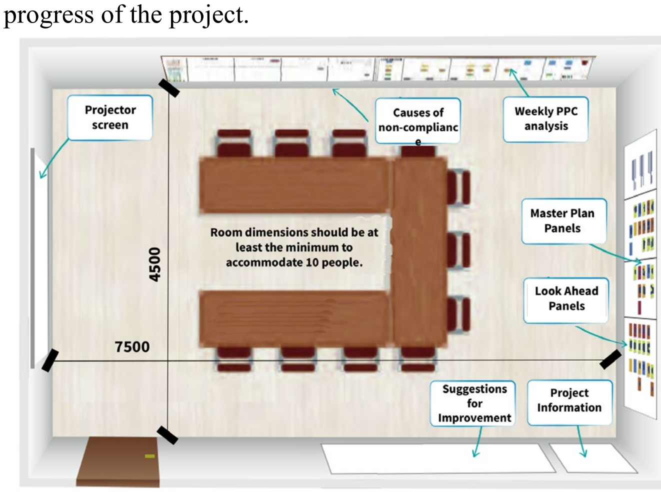

Fig. 8. Design proposal for the “Big Room”.

This information should include the following points:

1. Performance indicators for both PPC (Percent Plan Complete) and PPP (Percent Proposed Plan).

2. Causes of non-compliance with the PPP plan. It is important to find out and correct the reasons why the expected objectives are not met.

3. Feedback improvement system. The "Big Room" should have a mechanism to allow team members and stakeholders to make improvement suggestions on the previously designed continuous improvement scheme.

4. Medium and long-term planning panels (Place the panels of the Master Schedule and the Look Ahead made).

5. Any other relevant project information (See proposed distribution in Fig. 8).

6. In the case of Look Ahead, the weekly PPCs, and the causes of non-compliance with these, the new ones can be hung over the old ones so that, if necessary, they are there for re-view.

IV. Conclusions

The construction sector in Cuba has faced long-standing challenges related to quality deficiencies, project delays, and productivity issues. These inefficiencies, combined with external economic and logistical factors, have created a complex scenario that demands immediate action. In this context, the application of Lean Construction principles presents a viable solution to enhance efficiency and optimize resource utilization.

The case study of "52 homes in the Roble neighborhood" revealed that only 45% of the time is dedicated to productive work, while 35% is contributive work, and 19.5% is non-contributive work. The primary factors contributing to these inefficiencies include deficient planning, poor communication, inadequate site organization, irregular material supply, and transportation issues affecting worker attendance. However, most of these issues can be addressed through effective management strategies.

By implementing Lean Construction methodologies, this research demonstrates that significant improvements can be achieved in productivity and efficiency. The proposed planning and control tools are not only applicable to the Roble neighborhood project but can serve as a model for housing construction across Cuba. If implemented correctly, Lean Construction methodologies could result in the following key outcomes:

- Increased Productivity: Streamlining workflow and eliminating inefficiencies can increase the percentage of time allocated to productive work. Reducing non-productive time can result in a 15-20% increase in overall productivity.
- Reduction in Contributive and Non-Contributive Work: Enhanced planning, organization, and site management can significantly reduce unnecessary and non-contributive tasks. For example, eliminating miscommunication and improving material management could lower non-contributive work by 20-30%.
- Improved Communication and Coordination: Strengthened collaboration among managers, engineers, and workers can reduce delays and prevent mismanagement. Enhanced coordination could reduce project delays caused by poor communication by up to 25%, allowing for smoother operations and timely project completion.
- Cost and Time Optimization: By reducing inefficiencies and improving resource utilization, Lean Construction can optimize both costs and timelines. The estimated reduction in project delays and resource wastage could result in 10-15% cost savings, making the project more financially sustainable.
- Quality and Safety Improvements: Integrating Lean tools with technological advancements, such as BIM (Building Information Modeling), can enhance the quality of construction and safety standards. Using BIM could reduce design errors by up to 40%, leading to higher quality outputs with fewer corrections and rework (Pérez, 2019).

Future directions could focus on the integration of digital technologies such as BIM (Building Information Modeling) and automation in Lean management to improve project planning and control. It would also be relevant to analyses the economic and social impact of implementing Lean Construction in social housing projects, assessing its potential to reduce costs and increase accessibility.

In conclusion, although the transition to Lean Construction requires a cultural change and the commitment of all project participants, the potential benefits outweigh the challenges. While the implementation of Lean Construction in Cuba faces structural, technical, and economic challenges, its adaptable nature offers a valuable opportunity to enhance efficiency, optimize resources, and modernize project management practices—provided that these methodologies are tailored to the country's unique legal and operational framework. The findings of this research suggest that, with responsible use of the proposed tools, together with effective contract management and innovation in construction techniques, the Cuban construction industry can significantly improve productivity, reduce costs and enhance the quality of housing projects.

The Cuban construction sector has faced enduring challenges such as quality deficiencies, project delays, and productivity issues, exacerbated by external economic and logistical constraints. These inefficiencies present a complex scenario that demands immediate intervention. In this context, the application of Lean Construction principles offers a promising solution to enhance operational efficiency and optimize resource use.

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