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Analysing the Causes of Delays in Residential Construction Projects in Algeria: A Case Study Using DMAIC Methodology

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Abstract

Timely project completion is a key indicator of efficiency. However, the construction process is often influenced by numerous unpredictable variables and factors, making it rare for projects to be completed within the planned timeframe. This study investigates the key causes of delays in residential construction projects in Algeria, focusing on the construction of 228 housing units in Ali Mendjeli-Extension Ouest, Constantine. The study employs the D.M.A.I.C methodology to systematically analyze project delays. Structured interviews were conducted with key stakeholders to identify the most critical delay factors among 24 causes, categorized into seven major groups. The severity and frequency of these causes were assessed to develop effective mitigation strategies. The analysis identified three primary causes of project delays: low work rate, poor management and supervision, and adverse weather conditions. Based on these findings, a corrective/preventive action plan and a comprehensive Project Management Plan were proposed to enhance project efficiency and performance. The findings provide construction professionals, policymakers, and project managers with data-driven insights into the primary causes of project delays. and propose practical solutions to minimize them, ensuring the successful completion of future construction projects.
Keywords: Construction delays; Residential projects; Problem-solving; DMAIC; Project Management.

1. Introduction

The evolving dynamics of human needs, construction market trends, competition, and management requirements have made the construction industry more complex than ever before (Nikolić and Cerić, 2022). Modern construction projects encompass highly intricate activities, where effective risk management is crucial for ensuring success (Sanni-Anibire *et al*., 2022). Due to the inherent complexity and dynamic nature of these projects, various factors introduce significant uncertainties into the management of time, costs, and resources (Chan *et al*., 2004; Bosch *et al*., 2011).
Completing construction projects within the originally stipulated timeframe has become increasingly rare, particularly for large-scale and complex developments (Lepage, 2017). While some projects may be completed ahead of schedule, the majority experience delays due to various contributing factors (Sanni-Anibire *et al*., 2022). In certain cases, project stakeholders—such as architects and engineers—formally acknowledge these delays and adjust the completion date accordingly. However, in many instances, delays remain unresolved, leading to prolonged and costly disputes. These disputes often stem not only from disagreements over entitlement to additional time but also from the reluctance or inability of involved parties to fairly allocate responsibility for the extended project duration (Chapman *et al*., 2016 ; Kikwasi, 2012). While comparing the actual duration with the contractual timeline provides a straightforward assessment of total delay, determining accountability for specific delays remains a significant challenge.
Delays represent a major challenge in construction project management. They can be caused by numerous factors, including adverse weather conditions, logistical inefficiencies, inadequate planning, delays in material deliveries, and labor-related issues (Megha and Rajiv, 2013). These delays often result in significant consequences, such as increased costs, contractual penalties, and a loss of stakeholder confidence. As a result, traditional management approaches

designed for stable production environments are no longer sufficient. Construction projects now require adaptive and dynamic management methodologies, leading to the rise of project management as a specialized discipline.
In light of the growing population in the Nouvelle Ville Ali Mendjli in Constantine (Algeria), the timely completion of a large-scale 228-home residential project, as part of a broader 500-home program is of paramount importance. This project has been designed with the specific demographic characteristics of the region in mind, aiming to provide housing solutions tailored to different population segments. Managing such a complex project presents substantial challenges, necessitating a thorough analysis of potential obstacles and viable solutions.
This study focuses on a single large-scale residential project by identifying and addressing the primary obstacles encountered in the construction of 228 residential units, with particular emphasis on project delays. The overarching goal is to ensure the project's efficiency and performance concerning cost, schedule adherence, and quality. This leads to the central research question: What are the primary causes and effects of delays in residential construction projects in Algeria, and what proactive strategies can be implemented to mitigate them?. The primary objective of this research is to analyze the root causes of delays in residential construction projects, assess their impact on overall project performance, and develop practical recommendations and strategic solutions to effectively minimize these challenges.

2. Background

Throughout their lifecycle, projects are subject to a variety of factors and constraints that influence the implementation of the various phases. These phases often encounter difficulties that can compromise the achievement of objectives and lead to blockages in various forms. According to Bramble and Callahan (2011), the term “delay” refers to the extension of part of a project beyond the originally planned deadline due to unforeseen circumstances. It is therefore an unanticipated extension of the original schedule.
An analysis of historical global industry data on major investment programs reveals that almost two-thirds of projects are over budget and over schedule. The failure rate highlights a variability in delivery time ranging from 30% to 120% for infrastructure projects, with an average 50% increase for construction projects, most of which record an overrun of between 30% and 120% (Autodesk, 2015). A meta-analysis by Sanni-Anibire et al (2022) identified 36 frequently studied causes of delay worldwide. The five main causes identified in construction projects were: poor site management and supervision, inaccurate or incomplete plans, slow decision-making, customer-initiated modifications, and shortage of skilled labor. Hoque et al. (2023) analyze the main causes of construction delays in Bangladesh and their impact on project quality. It identifies critical delay factors and proposes measures to improve project performance and ensure timely delivery of quality construction projects.

Vo et al. (2025) provide a comprehensive review of delay analysis techniques used to address concurrent delays in construction projects. It compares the strengths and limitations of different methods and discusses their applicability for improving delay evaluation and dispute resolution. Yang et al. (2022) present a model for selecting the most suitable delay analysis method in construction projects. The model considers project conditions and available data to improve the accuracy and reliability of delay assessment and support effective dispute resolution. In addition, Abdelalim et al. (2023) identify and evaluates the key criteria for selecting appropriate Delay Analysis Methods (DAM) in mega construction projects. It highlights the factors that influence method selection and provides guidance for achieving more accurate delay assessments and effective dispute resolution.

Concerning residential construction projects, Mahamid (2021), through a study carried out in the West Bank (Palestine), established a significant correlation between design quality and delays in these projects. The five main delay factors identified were: late payment, low labor productivity, lack of qualified personnel, frequent changes to orders and rework. In the Indian context, Megha and Rajiv (2013) identified 59 causes of delay grouped into nine broad categories, based on a literature review and interviews with experts. In addition, Singh et al. (2018) ranked the main causes of delay in projects in India according to contractors and consultants. These include on-site material shortages, unforeseen ground conditions, ineffective supply planning, site access difficulties, rework, weather conditions, insufficient modern equipment, lack of skilled labor and equipment breakdowns. Sikarwar and Shelake (2023) examine delay analysis in residential construction projects using an augmented approach. It aims to improve the accuracy of identifying delay causes and assessing their impact on project timelines through enhanced analytical techniques.

3. Research Approach And Context

3.1 Project Description

In the 500-apartment program at the ALI MENDJLI - EXTENSION OUEST site in UV14, wilaya of Constantine, our project consists of lot N°03, which houses 228 apartments (F3 with an average surface area of 68.05 m²) with play areas for children and parking lots.

Given the growing population of the new City, the realization of this project (see Table 1) is of crucial importance in meeting the diversified needs of the public. The project has been designed with the region's specific demographics in mind, aiming to provide housing solutions tailored to different segments of the population. It thus aims to offer residences specially designed for the elderly, large families and students, responding to the diversity of housing needs. This initiative is also part of a wider effort to contribute to urban development .

3.2 Data Collection And Data Analysis

Managing large-scale construction projects, such as the 228-unit residential development, presents numerous challenges that often lead to delays and cost overruns. This study aims to identify and address these challenges by applying a structured problem-solving approach. To achieve this, we adopted the DMAIC (Define, Measure, Analyze, Improve, Control) methodology, a Six Sigma-based framework recognized for its effectiveness in process improvement and decision-making. A combination of quantitative and qualitative tools was utilized to collect and analyze data, ensuring a comprehensive evaluation of project delays and their underlying causes.

Table 1. Project description

Program name and location		Etude de réalisation des 500 logements au niveau de site ALI MENDJLI – EXTENSION OUEST à UV14, wilaya de Constantine
Operation number		03.25.1.01.14.21.2.25001
Program inscription		500 public rental housing units (in separate lots) under the 2015-2020 five-year plan, scheduled for 2021
Program projects		**1st lot :** 140 appartments **2nd lot :** 228 appartments **3rd lot** : 132 appartments
Total surface	**Program**	33 500,00 m²
	Project	15 515,40 m²
Budget	**Program Overall:** 1 705 573 879,97 DA	
	Project Overall: 822 360 625,14 DA	
Time	20 months	
Procurement mode		Tender (invitation to tender)
Construction start date		23 May 2023
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Two primary data collection methods were employed in this study: Questionnaire and Direct Observation. A structured questionnaire was designed to gather insights from key project stakeholders. As defined by Fortin (1996), a questionnaire is a data collection tool that requires respondents to provide written answers to a set of predefined questions. Our questionnaire incorporated both closed- and open-ended questions, focusing on seven key areas relevant to project delays: Planning (6 questions), Materials (3 questions), Manpower (3 questions), Environment (2 questions), Management (5 questions), Legal (1 question) and External factors (1 question). Each question addressing the impact of delay factors was linked to a specific performance indicator, ensuring a structured assessment of project inefficiencies. The questionnaire was completed by 06 representatives of the project's stakeholders
In the other hand, the observational approach was conducted through two complementary methods: On-Site Observations where field visits were carried out every two weeks for three hours, allowing for direct observation of construction progress, worker conditions, and environmental factors such as weather; and Organizational Internship where to gain deeper insights into project workflows, we conducted an internship at OPGI's general management and the ALI MENDJLI unit. This allowed for a better understanding of administrative processes, project coordination, and decision-making mechanisms influencing project timelines.

Table 2. Classification on 5 likert scale the impact and frequency of delay causes.

Impact	1	2	3	4	5
	Very low	Low	Medium	High	Very high
Frequency	1	2	3	4	5
	Rarely	Occasionally	Sometimes	Frequently	Very frequently

The collected data was analyzed using Excel software and measured on a 5-point Likert scale (see Table 2 and 3). The Criticality Index was calculated to assess the severity and frequency of delay factors, using the formula: Criticality = Impact × Frequency

Table 3. Classification of the ciriticality levels.

Criticality	Levels
(1-2)	Very low
(3-4)	Low
(5-8)	Moderate
(9-12)	High
(13-20)	Very high
(21-25)	Critical

The identified issues were then classified according to Table 3, prioritizing them based on their criticality levels. This classification enabled the identification of the most pressing challenges, ensuring that corrective actions focused on the most critical problems requiring immediate attention. By leveraging the DMAIC framework, this analysis provided a data-driven basis for developing corrective and preventive action plans and strategic interventions to mitigate delays and improve project efficiency.

4. Results and Discussion

DMAIC is a powerful continuous improvement methodology and can bring significant improvements to an organization or project.

4.1 Defining the Problem

We defined the problem by identifying and categorizing delay factors into 24 causes grouped into seven major categories (see Table 4). The causes are identified from direct observations and interviews with project actors

Table 4. Cause-effect of delay problems.

Type	Problem	Causes	Effects
Planification	Delay in approval of contract specifications	Slow administrative validation process	Delay in starting the work
	Delay in starting the work on site	Delay in approval of contract specifications; Discovery of networks and rocks at the beginning of the work	Financial losses, delay
	Lack of health and safety plan	Negligence by the contractor; Non-compliance with health and safety regulations at work	Increased risk of work accidents (delay); Possibility of legal sanctions; Absence of workers
	Insufficient funding to support the project	Poor cost estimation; Budget overruns	Risk of suspension or stoppage of work; Impact on the quality and progress of the project; Delay in payments to subcontractors and suppliers
	Impropre initial planning	Inability of project management offices within the company; Failure to collect and analyze relevant data	Delays in completing on-site tasks; Conflicts between different work teams;Necessary realignment of the schedule
	Delayed review and approval of design documents	Inefficiency of validation processes	Delay in starting the corresponding work
	Manholes discovered at the start of earthworks, necessitating site relocation	Poor soil study	Need to rework the design and execution of the earthworks Delays in the overall project timeline
Materials	Difficulties in supplying materials (iron)	Shortage of raw materials; Logistic problems; Price fluctuations	Delays in construction tasks requiring iron; Supply chain interruptions
	Errors and discrepancies in design documents	Ineffective communication between designers and stakeholders; Lack of plan validation, Misinterpretation of requirements	Risk of delays and field modifications; Increased correction costs
	Delay in delivery of materials	Transport issues; Supplier delays; Stock shortages, customs issues	Interruptions in work, risk of delays in completion; Increased costs, impact on planning
Labor	Lack of workers and inability of the company to mobilize the necessary resources	Human resources management and recruitment issues Lack of hygiene and safety	Slowdown in work and delays in assigned tasks
	Poor subcontractor management	Lack of coordination and follow-up	Non-compliant or delayed work
	Delay in subcontractor work	Poor subcontractor management	Delay in project completion
	Low work rate	Poor site management; Lack of worker motivation; Difficult working conditions	Delay in project completion
Environment	Complexities related to land acquisition (private property) requiring prior relocation procedures	Legal and regulatory issues	Delays due to administrative or legal obstacles
	Problems associated with virgin site without networks	Unexpected site complexities; Non-developed site	Delays in work; Need for additional work
	Rocky terrain	Poor consideration of land characteristics during design	Excavation and foundation difficulties; Delays
Management	Non-compliance with the schedule by the contractor (poorly established planning)	MaPoor planning and organization	Cumulative delays
	Slow decision-making	Complex decision-making structure; Lack of effective communication; Lack of stakeholder accountability	Delay
	Poor site management, supervision, and planning	Lack of project management skills; Ineffective communication; Inadequate supervision: Inadequate planning; Absence of project management plan	Delays in work; cost overruns
	Exceeding quantities planned in the infrastructure construction phase (additional work)	Errors in resource estimation	Delays in completing the work, budget overrun
	Inadequate communication between the various parties involved in the project	Lack of coordination and collaboration	Misunderstandings, delays, and inefficiency
Legal	Disputes related to land ownership	Legal challenges over ownership	Delays due to ongoing legal proceedings
External Factors	Weather conditions causing delays in work progress	Unfavorable weather conditions	Work interruptions, delays in schedules

4.2 Measure and analyze the problem

In this analysis phase, we adapted the cause-effect analysis tool and the Pareto chart to identify and indicate the major factors influencing delays. This section includes an analysis of the data collected between March 01 and June 01, 2024. Table 4 classify the problems in our project into and 07 categories and shown their causes and effects. However, As shown in Tables 5, 6 and 7, problems are ranked in descending order of criticality to identify the main contributors to the delay. We found that the delay-related problems with the highest criticality are: Low work rate; Poor site management, supervision and planning and Bad weather conditions with impact = 5 (very high), Frequency = 5 (Very frequent) and criticality = 25. There were other factors with negligible frequency, but their impact was very high and affected the overall project timeframe, such as the discovery of manholes at the start of work, with a delay of 3 months, and hard rocks on site (earthworks phase), as well as the absence of workers. The overall delay is equal to 5 and a half months.

Table 5. Critical and very high delay causes and their action plan.

Causes	Delay	Impact	Frequency	Criticality	Cumulative	% cumulative	Corrective actions	Preventive actions
Low work rate	15 days	5	5	25	25	10,46%	Identify the causes of slow work rates and propose corrective solutions to the company. Implement monitoring and control measures to ensure that the company improves its performance.	Require the company to develop and implement a site organization plan. Carry out regular site inspections to ensure that the organization plan is being respected.
Poor site management, supervision and planning	/	5	5	25	50	20,92%	Identify gaps in skills or experience within the corporate team. Offer training or workshops to the company team to improve their skills.	Elaboration d’un plan de management de projet détaillé (Voire le document de PMP). Effectuer des inspections régulières sur le chantier pour s'assurer que le plan de gestion est respecté.
Weather conditions causes delays in work progress	15 days	5	5	25	75	31,38%	Implement protective measures on site to minimize the impact of bad weather. Identify alternative solutions for continuing work during bad weather, if possible. Document delays caused by bad weather and claim compensation from contractors if necessary.	Include force majeure clauses in contracts with contractors. Develop a risk management plan to identify and mitigate weather-related risks. Monitor weather forecasts and adapt project schedules accordingly.
Lack of workers and inability of the company to mobilize the necessary resources	30 days	5	4	20	95	39,74%	Helping the company to recruit and train personnel.	Integrate human resources management Put in place monitoring and control mechanisms to ensure that the company meets its resource mobilization commitments.
Poor subcontractors management	15 days	4	5	20	115	48,11%	Monitor subcontractor performance and identify potential problems.	Establish rigorous selection criteria for subcontractors. Establish clear and precise contracts with subcontractors.

Table 6. High delay causes and their action plan.

Causes	Delay	Impact	Frequency	Criticality	Cumulative	% cumulative	Corrective actions	Preventive actions
Improper initial planning	/	4	3	12	127	53,13%	Critically analyze the initial schedule and identify errors and omissions. Draw up a new, realistic and detailed schedule, taking into account project constraints.	Use rigorous project planning methods, such as PERT or GANTT. Involve all project stakeholders in the planning process. Use efficient planning software such as MS-Project.
Delayed review and approval of design documents	4 months	4	3	12	139	58,15%	Implement a system for tracking design documents to ensure they are processed on time. Facilitate communication between designers and those involved in document validation.	Propose simplifications to validation processes, in collaboration with the stakeholders concerned.
Delay in delivery of materials	12 days	3	4	12	151	63,17%	Identify alternative suppliers in case of failure of current suppliers. Monitor orders and deliveries to identify potential problems.	Establish solid relationships with reliable suppliers. Negotiate penalty clauses for late deliveries.
Problems associated with virgin site without networks	3 months	4	3	12	163	68,20%	Adapt construction techniques to the characteristics of the terrain. Identify local sources of supply for building materials.	Carry out in-depth geotechnical studies before launching the project. Incorporate additional costs for site preparation into the project budget.
Non-compliance with the schedule by the contractor (poorly established planning)	/	4	3	12	175	73,22%	Identify the causes of the delay and propose corrective solutions to the company. Take alternative measures, such as allocating additional resources or adjusting the schedule, if necessary.	Integrate on-schedule clauses into contracts with the company. Set up a project schedule monitoring system.
Delay in starting the work on site	3 months	5	2	10	185	77,40%	Make up for delays by speeding up work, with an increase in the number of work teams	Carry out in-depth geotechnical studies before starting work. Include a "network discovery" clause in contracts with earthworks contractors.
Manholes discovered at the start of earthworks, necessitating site relocation	3 months	5	2	10	195	81,58%	Identify the exact location of manholes and determine their impact on the project. Evaluate possible options for relocating the site, such as relocating the buildings. Update the project schedule and budget to take account of the new constraints.	Carry out in-depth geotechnical studies before launching the project.
Inadequate communication between the various parties involved in the project	/	3	3	9	204	85,35%	Encourage open and transparent communication between all stakeholders. Hold regular meetings to discuss project progress and potential problems. Resolve any communication problems that arise promptly.	Set up a clear and precise communication plan for the project. Identify key stakeholders and define their communication roles and responsibilities. Establish effective communication channels, such as regular meetings, an instant messaging system or an online document sharing space.

Table 7. Moderate, Low, and Very low delay causes and their action plan.

Causes	Delay	Impact	Frequency	Criticality	Cumulative	% cumulative	Corrective actions	Preventive actions
Errors and discrepancies in design documents	6 days	2	4	8	212	88,70%	Require the company to perform rigorous quality controls on design documents before submitting them for validation. Implement a multi-stakeholder design document review process.	Improve design and quality control processes. Train designers in building design best practices.
Slow decision-making	/	3	2	6	218	91,21%	Assign Decision-Making responsibilities clearly	Establish clear Decision-Making Frameworks with structured processes, clear steps, roles, and timelines. foster open and efficient communication among stakeholders to avoid bottlenecks.
Delays in project launch	2 years	4	1	4	222	92,88%		
Lack of health and safety plan	/	2	2	4	226	94,56%	Require the company to draw up and submit a health and safety plan before work begins. Conduct regular site audits to ensure compliance with the health and safety plan.	Raise awareness of the importance of worker health and safety. Train workers in the use of protective equipment.
Delay in approval of contract specifications	4 months	3	1	3	229	95,81%	Set up regular meetings or digital collaboration tools to track contract status in real time.	Implement strict timelines for contract review and approval, with automatic reminders for stakeholders.
Insufficient funding to support the project	1 months	3	1	3	232	97,07%	Negotiate discounts with suppliers and subcontractors. Re-evaluate project budget according to actual needs.	Carry out a thorough financial analysis, taking all potential costs into account. Explore different financing options, including crowdfunding or sponsorship.
No site installation plan	/	2	1	2	234	97,90%	Validate the site installation plan before granting authorization to start work.	Include site installation plan requirements in calls for tenders and contracts.
Difficulties in sourcing materials (scrap metal)	10 days	2	1	2	236	98,74%	Find alternative Suppliers Quickly	Develop multiple supplier relationships
Complexities related to land acquisition (private property), requiring prior relocation procedures	/	2	1	2	238	99,58%	Identify and address key roadblocks	Early Engagement of landowners, local communities, and government authorities early in the process to address concerns proactively.
Exceeding quantities planned in the infrastructure construction phase (additional work)	20 days	1	1	1	239	100%	Identify the Root Cause of Overruns Re-Evaluate Budget and Funding Sources	Conduct detailed project planning and feasibility studies to ensure accurate quantity take-offs and cost estimates before project execution

Pareto analysis

Pareto analysis is based on the principle of Pareto's Law, which aims to examine data that can be divided into categories, with the aim of identifying the categories on which improvement efforts should be concentrated. A Pareto chart is a graphical tool for breaking down a major problem into its component parts, and showing which are the most important (Ivančić, 2014). Some Pareto charts also include a "cumulative percentage" line. Raw data is transformed into "percentage of total" and a parallel vertical axis is drawn on the right-hand side of the chart .

A detailed analysis of the problems encountered on this project (see Figure 1) reveals that, according to Pareto's 80/20 law (Pyzdek, 2021), a minority of causes generates the majority of delays. The main contributors, accounting for around 80% of the negative impacts, were low work rates, 10.46% poor work management, supervision and planning, 20.92% bad weather, 31.38% lack of workers and the company's inability to mobilize the necessary resources, 39.74% poor management of subcontractors, 48.11% the initial schedule. poorly established, 53.13 % delay in review and approval of design documents, 58.15 % delay in delivery of materials 63.17 % problem associated with the site 68.20 % failure by the company to adhere to the schedule 73.22 % delay in starting work 77.22 %.

Furthermore, to resolve the majority of delays, it's crucial to focus on improving these priority factors. Applying this approach can effectively reduce delays and optimize project performance.

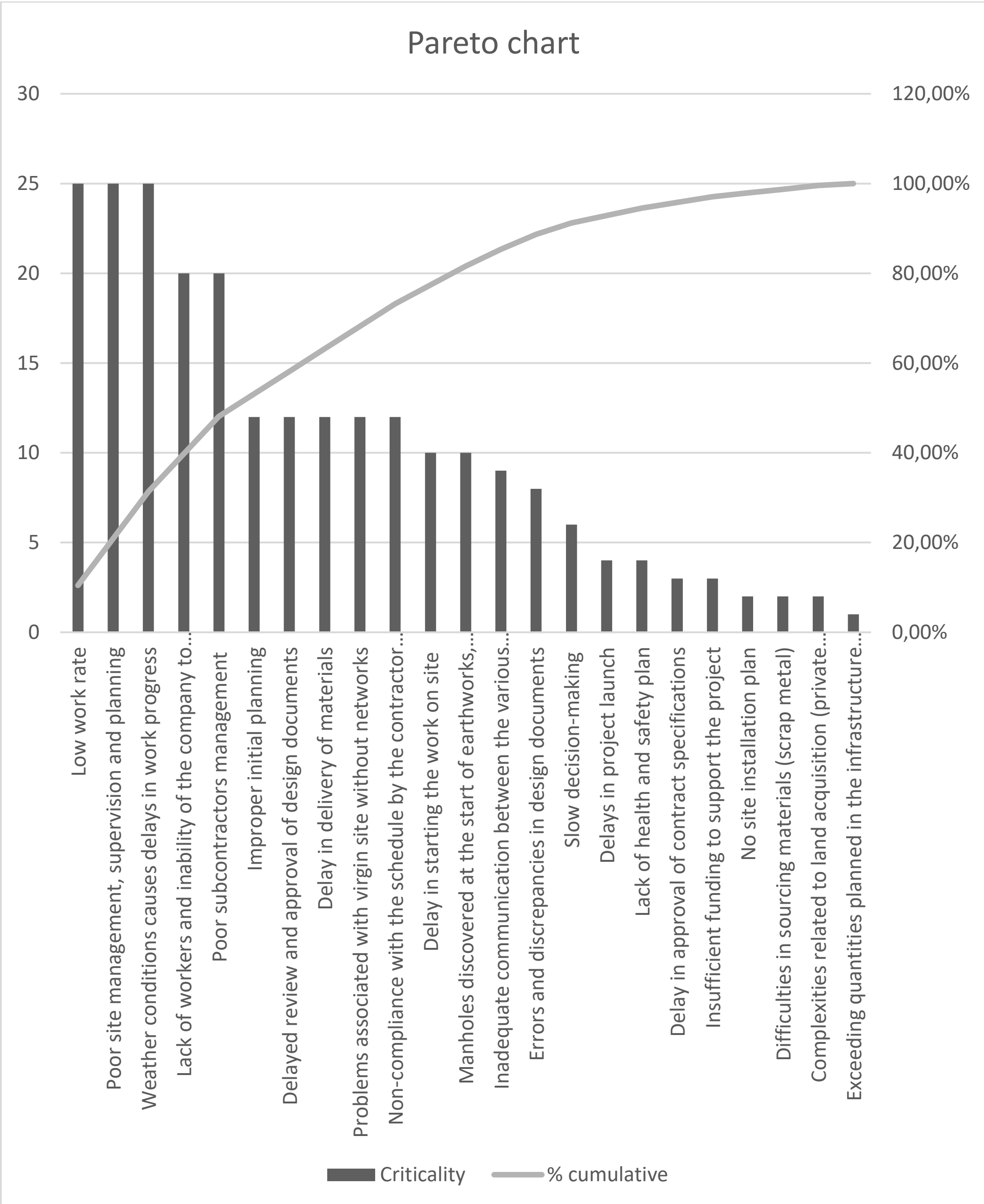

Figure 1. Pareto Chart.

4.3 Innovate (or Improve)

The improvement phase of the D.M.A.I.C. method aims to develop effective solutions to the problems identified in the analysis phase. Table 5 proposes specific improvements for each problem identified in the 228 housing project, using the DMAIC method as a guide. These proposals aim to address the underlying problems, optimize existing processes, and strengthen the overall management of the project to achieve its objectives on time and with available resources. Solving these problems requires a multi-dimensional approach, combining preventive, corrective and continuous improvement

actions. By applying these solutions, the project will be able to overcome the challenges encountered and progress efficiently towards completion, while ensuring worker safety, on-time delivery and quality of results. This problem-solving approach is part of a global approach aimed at optimizing project management and guaranteeing the success of the 228 housing project.
Faced with multiple difficulties, such as project delays, planning problems, resource constraints and legal obstacles, it is imperative to adopt a proactive and innovative approach to ensure the success of the project as a whole. With this in mind, we present a comprehensive *Project Management Plan* (see Figure 2), integrated into our DMAIC approach, to ensure optimal management and effective problem solving. This Project Management Plan is designed to respond holistically to complex project challenges, focusing on strategic planning, effective resource coordination, transparent communication, risk and change management, and appropriate project closure. By integrating these elements into our innovation approach, we aim to transform obstacles into opportunities, and lead the project to success and the achievement of its initial objectives.

REPUBLIQUE ALGERIENNE DEMOCRATIQUE ET POPULAIRE

MINISTERE DE L'HABITAT, DE L'URBANISME ET DE LA VILLE

ENTREPRISE HYPROMAX

228 LOGEMENTS DANS LE PROGRAMME DES 500 LOGEMENTS A CONSTANTINE

réalisation des 500 logements au niveau de site ALI MENDJLI – EXTENSION OUEST à UV14., wilaya de Constantine

PLAN DE MANAGEMENT DE PROJET

Maitre d'Ouvrage :	Maitre d'Ouvrage délégué :
	OPGI CONSTANTINE

Entreprise

HYPROMAX

Réalisation de projet des 228 Logements dans le programme des 500 logements de site ALI MENDJLI – EXTENSION OUEST à UV14., wilaya de Constantine	Maitre d'ouvrage :		Maitre d'ouvrage délégué :	OPGI
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Figure 2. Cover page of the simulated Project Management Plan.

4.4 Control the action plan

The final stage of the DMAIC methodology focuses on monitoring and sustaining the implemented action plan using relevant performance indicators. The primary objective is to ensure that the improvements achieved remain effective over time, preventing any deterioration in project performance. The control phase in DMAIC establishes a structured monitoring system, allowing for continuous assessment of the implemented measures. If the expected outcomes are not achieved, this phase provides the flexibility to adjust and refine the improvements as needed. At this stage, operational teams are responsible for overseeing and tracking project progress, ensuring adherence to corrective actions and maintaining efficiency.

Table 8 represents the control plan, which serves as a structured framework for facilitating monitoring efforts, ensuring consistency, and enabling timely interventions when necessary.

Table 8. Control Plan.

Stage	Activity	Responsible	Frequency	Documentation
Before Starting the Work				
Review of Plans and Specifications	Ensure compliance with technical plans and specifications.	Quality Manager	Once before starting	Plans Review Report
Verification of Permits and Authorizations	Ensure that all necessary permits are obtained	Quality Manager	Once before starting	Permits and Authorizations
Inspection Planning	Develop a schedule for inspections	Quality Manager	Once before starting	Inspection Schedule
During the Work				
Material Control	*Material Receipt*: Verify delivery slips and conformity certificates.	Quality Inspectors	At each delivery	Delivery Slips, Conformity Certificates
	Laboratory Tests: Conduct material quality tests before use.	*Quality Inspectors*	As needed	Laboratory Test Reports
Structural Work Control	*Excavation*: Verify levels and soil compaction.	Quality Inspectors	Daily	Rapports
	Foundations: Check dimensions and concrete quality	Quality Inspectors	Daily	Inspection Reports
	Structures: Inspect reinforcements and formwork	Quality Inspectors	Daily	Inspection Reports
Finishing Work Control	*Walls and Partitions*: Check alignment, flatness, and thickness	Quality Inspectors	Daily	Inspection Reports
	Electrical and Plumbing Installations: Ensure compliance with plans and safety standards	Quality Inspectors	Daily	Inspection Reports
	Interior and Exterior Finishes: Assess the quality of coatings, paint, and other finishes	Quality Inspectors	Daily	Inspection Reports
After the Work				
Provisional Acceptance	Final inspection of works and verification of resolved issues	Quality Manager	Once at the end of the work	Provisional Acceptance Report
Final Acceptance	Verify corrections during the warranty period.	Quality Manager	Once after the warranty period	Final Acceptance Report
Documentation and Traceability				
Inspection Reports	Drafted after each inspection	Quality Inspectors	After each inspection	Inspection Reports
Non-Conformities	control on detected issues and corrective measures	Quality Manager	Continuous	Non-Conformity Register
As-Built Documentation	Compile all control documents, test reports, and material certifications	Quality Manager	At the end of the work	As-Built Documentation
Communication Archives	Record all internal and external project quality-related communications	Quality Manager	Continuous	*Communication Archives*
Internal and External Audits				
Internal Audits	Verify compliance with internal procedures	Quality Manager	As per audit plan	Internal Audit Reports
External Audits	Verify compliance with standards and regulations by independent bodies	Certification Bodies	As per audit plan	External Audits Reports
Corrective Actions				
Non-Conformity Identification	Detect deviations from specifications and standards	Quality Inspectors	Continuous	Non-Conformity Reports
Analyse des Causes	Investigate to determine causes of non-conformities	Quality Manager	As needed	Cause Analysis Reports
Corrective Action Plan	Develop and implement measures to correct non-conformities and prevent recurrence	Quality Manager	As needed	Corrective Action Plan
Training and Awareness				
Staff Training	Conduct training programs for staff on control procedures and quality standards	Quality Manager	As needed	Training Records
Quality Awareness	Run awareness campaigns to promote a quality culture on-site	Quality Manager	Continuous	Awareness Materials

5. Conclusion

Effective project management involves a combination of techniques for identifying, planning, and overseeing a project. However, modern advancements have increasingly emphasized the managerial aspect, aiming to maximize value and drive projects toward successful completion. This study aimed to identify and assess the causes of delays in residential construction projects in Algeria. While the literature extensively covers delay-related risks, research specific to the Algerian construction industry remains limited. Our objective was to bridge this gap by analyzing the root causes of delays and developing appropriate mitigation strategies to improve project timelines. To achieve this, we adopted a qualitative, case-study-based approach utilizing the DMAIC methodology (Define, Measure, Analyze, Improve, and Control) as a structured framework for problem-solving. The research was conducted through structured questionnaire and interviews with project stakeholders and observational approach. We identified 23 key delay factors, categorized into seven major groups. The study further assessed the frequency and severity of these causes. Our findings reveal that the most critical delay factors are: Low work rate; Poor management, supervision, and work planning; weather conditions. By highlighting these critical factors, this research provides valuable insights for stakeholders, offering a foundation for developing targeted corrective action plans. Implementing these strategies can enhance efficiency, reduce delays, and ultimately contribute to the successful completion of future residential construction projects in Algeria. However, this study focuses on a single large-scale residential project in Ali Mendjeli, Constantine, limiting the generalizability of the findings. Future research could expand the scope by examining multiple projects across different regions in Algeria.

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Conflicts of Interest

The authors report no conflicts of interest

Data Availability Statement

All data generated or analysed during this study are included in this published article and its supplementary files.

CRediT Author Statement

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