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# A Decision-Support Framework for Predicting Construction Delay Disputes Using Multi-Factor Analysis and Relative Importance Index

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**ABSTRACT**

The primary issue addressed in this study is the occurrence of disputes within construction projects. These disputes typically arise from a range of underlying factors, including site conditions, project delays, acceleration requirements, coordination challenges, value engineering decisions, conflicting objectives, the inherent complexity of work, quality-related concerns, and variations in tender specifications. The research examines time-related delay disputes by drawing on extensive literature, which reflects variations across different time periods, project types, and geographical contexts. To identify and categorise these causes, personal interviews were conducted, leading to the formulation of a comprehensive list of 110 dispute factors, which were incorporated into a structured questionnaire. The questionnaire consisted of two sections: the first gathered demographic and professional information of experts, while the second presented a series of categorised questions. It was then distributed among construction professionals, including owners, consultants, engineers, and contractors. The participants possessed varying levels of experience, ranging from five years to over thirty years in Egyptian construction projects. For analytical purposes, the Relative Importance Index (RII) was applied to determine the top fifteen causes of time delay disputes in the Egyptian construction sector. Based on the questionnaire findings, a predictive framework was developed and designated as the Time Delay Dispute Prediction Model (TDDPM). The model utilises inputs such as project-specific information, the probability associated with each of the top fifteen identified causes, and different weighting approaches, which may be equal, manually assigned, or automatically determined. The model generates outputs in the form of predicted delay dispute percentages, classification grades, and a concise set of recommendations aimed at mitigating delay-related disputes. A case study was also conducted to validate the findings, where its conditions were compared against the identified root causes from the questionnaire. The comparison demonstrated a complete alignment between the case study and the identified factors. Furthermore, when the case study was analysed using the developed model, the results showed a strong correspondence between the model's output and the observed case conditions. The model achieved an estimated prediction accuracy of 83%, and additional recommendations were proposed to reduce the occurrence of time delay disputes.

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## 1. Introduction

The principal drivers of project delays are disputes within construction activities, which exert adverse impacts on both project schedule and cost performance. Such disputes can emerge across all stages of a construction project lifecycle and are typically multifaceted in origin, reflecting differing perspectives among stakeholders involved in the project. Common sources include schedule overruns, additional work requirements, variations in contractual scope, alterations in physical site conditions, unforeseen events or disasters, and ambiguities or errors within contractual provisions. Disputes between parties often lead to prolonged resolution periods, thereby extending project duration and increasing overall costs. Negotiation processes are generally undertaken to secure compensation in the form of time extensions, financial adjustments, or a combination of both, in order to restore the position of the affected party. Certain projects may be inherently more susceptible to disputes, a condition that can be associated with project characteristics, organisational structures, or contractual frameworks. Accordingly, it is essential to implement proactive measures aimed at early identification of potential dispute sources. This enables timely intervention and the adoption of appropriate preventive strategies, thereby reducing the probability of dispute occurrence and mitigating their impact on construction project performance.

### *1.1 Causes Of Dispute*

Construction disputes arise from an intricate interaction of environmental and behavioural determinants, broadly grouped into uncertainty, deficiencies in contractual arrangements, and adversarial behaviour among stakeholders. Due to the inherent technical complexity and extended duration of construction projects, it is not feasible to foresee all potential contingencies or define every requirement at the outset, which inevitably results in contractual omissions where agreements fail to address emerging circumstances. Uncertainty reflects the gap between the information required to perform tasks effectively, shaped by project complexity and time or cost constraints, and the information that is actually available through planning processes and interpretation [9]. This initial lack of clarity means that design specifications and drawings are subject to continuous revision, necessitating close coordination among participants to resolve issues before they escalate into formal disputes [27].

These challenges are often intensified by contractual shortcomings, particularly when standard forms or heavily modified bespoke agreements transfer risks to parties that may lack the capacity to manage them effectively. Such alterations can introduce ambiguity, resulting in differing interpretations of risk allocation, further complicated by an evolving legal environment. When these structural factors intersect with human behaviour, stakeholders may engage in opportunistic actions, maintain unrealistic expectations, or deny responsibility to safeguard their own interests, especially in relation to common sources of conflict such as variations, design discrepancies, and coordination failures. To address these risks, contemporary contractual frameworks, including FIDIC, have implemented strict procedural requirements, particularly regarding timely notification. Although the loss of entitlement to an extension of time (EOT) due to delayed notice may appear stringent, it serves an important function by encouraging early disclosure of claims. This enables concurrent assessment of causation and impact, allowing project owners and managers to implement timely mitigation measures before delays become irreversible.

#### *1.1.1 Root Causes and Management of Construction Disputes*

Construction disputes typically result from the combined influence of environmental and behavioural factors. Given that construction projects are long-term in nature and characterised by significant uncertainty and technical intricacy, it is rarely possible to anticipate all eventualities during the initial contractual stage. As a result, gaps within contracts frequently arise. The primary sources of such disputes can be classified into three categories: uncertainty, contractual deficiencies, and human behavioural factors.

#### *1.1.2 Uncertainty*

Uncertainty represents the discrepancy between the information necessary to execute a task and the information that is actually available [9]. The extent of required information is shaped by the level of project complexity alongside defined performance constraints, typically time and cost, whereas the availability of information is contingent upon the thoroughness and quality of the planning process. As it is not feasible to finalise every aspect prior to project initiation, a high degree of uncertainty leads to continuous revisions in design drawings and technical specifications [27]. In the absence of proactive and coordinated problem-solving among project participants, these ongoing modifications are likely to intensify and eventually develop into formal disputes.

#### *1.1.3 Contractual Problems*

Standard form contracts are intended to define and distribute risks and responsibilities in a structured manner; however, their inflexibility can limit their suitability for long-duration projects that operate within dynamic and uncertain environments. In addition, the adoption of customised or extensively modified contractual arrangements often transfers risk to parties that may lack the capacity or resources to effectively manage it. These adjustments frequently create ambiguity, resulting in differing interpretations regarding the allocation of risks among stakeholders. The situation is further complicated by ongoing developments in the legal framework, which continuously influence and reshape the interpretation and enforcement of such contractual provisions.

#### *1.1.4 Behavioural Factors*

Since contractual documents cannot foresee every possible situation, the behaviour of involved parties during disruptions becomes a decisive factor in the emergence of disputes. Such disputes commonly arise from several behavioural tendencies: opportunism, where one party attempts to maximise its own benefit at the expense of another; conflicting perceptions, where stakeholders interpret the same event in different ways; unrealistic expectations, resulting from insufficient objectivity that hinders consensus; and liability avoidance, where responsibility is denied to reduce financial or legal exposure. These behavioural responses are often triggered by recurring project issues, including variations, coordination breakdowns, design inaccuracies, delays, and quality-related deficiencies.

#### *1.1.5 Regulatory Mechanisms: The FIDIC Approach*

To address these challenges, contemporary contractual frameworks such as FIDIC introduce stringent notice obligations as a condition precedent. Contractors are required to provide immediate notification of any events that may lead to project delays. Failure to comply with these notification requirements typically results in the loss of entitlement to claim an EOT or additional compensation, both under contractual provisions and, in many jurisdictions, under applicable legal frameworks. Although this requirement may appear stringent, it serves a critical function by ensuring that potential claims are identified at an early stage. This facilitates real-time investigation of causation and impact by the employer and enables timely implementation of mitigation measures to minimise delays. To further illustrate the interaction between these factors and their management, the subsequent table presents the associated triggers along with corresponding mitigation strategies, as detailed in Table 1.

**Table 1**
Comparative Analysis of Construction Dispute Drivers

| Dispute Driver | Primary Triggers | Mitigation Strategy |
|---|---|---|
| Uncertainty | Incomplete designs, site conditions, scope creep. | Rigorous pre-planning and integrated project delivery (IPD) methods. |
| Contractual | Ambiguous bespoke terms, unfair risk shifting. | Use of unlamented standard forms (e.g., FIDIC, NEC) and clear legal review. |
| Behavioural | Lack of transparency, adversarial culture, unrealistic claims. | Partnering workshops, early warning systems, and transparent communication. |

### *1.2 Objectives of the Study*

In this paper, the focus is on construction delay disputes, specifically identifying the primary causes of time-related disputes, proposing strategies to minimise their occurrence, and developing a computer-based model to predict such delays. Construction disputes are often centred on project delays and the allocation of responsibility, which necessitates strong contractual provisions for the EOT. Although EOT mechanisms are intended to protect the employer's right to claim liquidated damages by redefining the project completion date, their application has historically been reactive. In many international projects, the assessment of a contractor's entitlement to an EOT has typically been postponed until the later stages of the contract, when delays become apparent. From the employer's perspective, this retrospective evaluation complicates the accurate determination of delay causation, as the passage of time reduces the availability of reliable evidence and increases the likelihood of disagreements regarding the contractor's contractual rights. One of the key objectives of this study is to develop a predictive model for time delay disputes that can assist decision-makers, including clients, contractors, and consultants, in estimating the likelihood of construction disputes and providing recommendations to mitigate or prevent them. The proposed model is constructed based on the most significant causes of time delay disputes identified within the Egyptian context, derived from questionnaire data. The model produces a concise output report, which includes the predicted probability of delay-related disputes and practical recommendations for reducing or avoiding such occurrences.

### *1.3 Research Problem*

The research methodology is structured into several stages, beginning with problem identification, followed by a literature review to examine previous studies on construction disputes and delay causes. This is followed by data collection to identify dispute types, their root causes, and resolution methods such as mediation, arbitration, and litigation. Subsequently, a detailed analysis is conducted to interpret the questionnaire results, both at the level of individual stakeholders and in aggregate. The next stage involves the design of the predictive model, referred to as the TDDPM, based on the questionnaire findings. The study also includes a case study and concludes with findings and recommendations. Finally, the research analyses a real arbitration case between the General Authority for the Implementation of Industrial and Mining Projects and the Arab Contractors Company, examining the causes of the dispute and the rulings issued by the arbitration authority. This structured approach ensures accurate data collection and rigorous analysis, thereby supporting reliable model development and validation.

## 2. Theoretical Analysis

### *2.1 Delay Disputes*

Construction dispute resolution has long been approached through multiple mechanisms, including negotiation, mediation, conciliation, dispute resolution boards, arbitration, and litigation [13]. Among these, mediation is often regarded as an effective approach, as it relies on the expertise of a neutral and knowledgeable third party with familiarity in construction processes. However, all dispute resolution methods exhibit inherent limitations, notably the absence of a preventive framework, insufficient systematic technical evaluation, and the complexity of managing disputes at scale. These limitations highlight the growing need for knowledge-based expert systems to support claims management and dispute resolution processes.

In a comprehensive study of construction delays in Hong Kong Chan and Kumaraswamy [6] identified 82 distinct delay factors, systematically classified into eight categories: project-related, client-related, design team-related, contractor-related, materials, labour, plant and equipment, and external influences. Their analysis revealed that the most critical delay drivers included poor site management and supervision, unforeseen geotechnical conditions, variations in work scope, slow decision-making processes, and client-initiated changes. Across both building and civil engineering projects, the most influential categories were associated with contractor performance, design team efficiency, labour availability, external conditions, and project-specific characteristics.

Similarly, Ogunlana et al. [24] examined delay causes in 12 high-rise construction projects in Bangkok, Thailand, spanning residential, commercial, healthcare, and educational buildings. Their investigation identified 26 delay factors grouped into six categories: owners, designers, construction managers or inspectors, contractors, resources and suppliers, and other influences. Their findings demonstrated that material shortages were the most significant factor, affecting 91.7% of the studied projects. In the Lebanese construction industry, Mezher and Tawil [21] conducted a stakeholder-based analysis of delay causes from the perspectives of employers, contractors, and consultants. The study revealed notable differences in priorities: employers were primarily concerned with financial implications, contractors emphasised contractual relationships, and consultants highlighted deficiencies in project management. Despite variations across stakeholders, delays were universally recognised as critical, costly, and high-risk issues, given their impact on both project performance and financial viability. These delays often evolve into disputes due to misaligned stakeholder interests.

Hiyassat et al. [17] investigated public construction projects in Jordan, covering residential, medical, communication, administrative, and educational sectors. Using statistical techniques such as regression analysis, correlation coefficients, and hypothesis testing at a 99% confidence level, the study compared planned and actual project durations. The findings indicated significant deviations, with approximately 81.5% of projects experiencing delays. The most prominent causes included variations, design changes, specification discrepancies, and financial or administrative issues, while delays were largely independent of project type, sector, or contract size. Elinwa and Joshua [14] analysed time overruns in Nigerian construction projects, reporting that 80% to 90% of projects experienced delays. Their analysis employed severity indices, ranking delay factors across respondent groups and applying statistical tests such as Spearman's correlation and distribution analysis to evaluate agreement. The study identified differing levels of responsibility for delays, with clients, contractors, and others contributing 62%, 32%, and 6%, respectively.

Mohamed [22] developed an expert system, the Diagnosing Egyptian System (DES), designed to identify potential delay causes during both pre-construction and construction phases. The system also provides recommendations for corrective actions, assisting both employers and contractors in mitigating delays and preventing future occurrences, thereby reducing their impact on project completion timelines. El-Gohary [10] examined high-investment construction projects in Egypt between 1990 and 2001, focusing on delay frequency, causes, and responsibility allocation. The findings showed that 79% of projects experienced delays, with durations often comparable to the original planned schedule. Major causes included design variations, engineering deficiencies, financial constraints, procurement issues, and planning shortcomings, with results indicating that delay characteristics were largely independent of project type and contractual parameters.

Hanna [16] explored construction claims and dispute resolution methods, analysing their lifecycle and the roles of key stakeholders, including employers, engineers, and contractors. The study, based on a survey of 40 Egyptian construction projects, highlighted the negative impact of unresolved claims on project execution and proposed preventive measures to minimise dispute-related disruptions. Chaphalkar [7] developed an expert system for evaluating engineering-related delay claims, focusing on factors such as design development, shop drawing processes, and stakeholder-driven changes. The system utilised various FIDIC contract forms and was designed to support both engineers and non-technical arbitrators in assessing claims, enhancing decision-making in claim evaluation. El Sayed [12] introduced a computer-based tool capable of conducting delay analysis in construction projects. By integrating data from Primavera software, the system applied a generalised equation to evaluate overall project delays, accommodating complex logical relationships between activities. The tool demonstrated effectiveness in analysing large-scale projects with extensive activity networks.

El-Sayegh [11] identified 43 key factors contributing to delays in the UAE construction industry, categorised into eight groups: contractor, consultant/designer, owner, financial, planning and scheduling, contractual relationships, government regulations, and unforeseen conditions. Construction disputes arise from multiple factors, including contractual deficiencies, defective works, variations, additional work, delays, and insufficient documentation. In the context of this study, emphasis is placed on time delay disputes, encompassing their definition, classification, and underlying causes. A delay is defined as the extension of project duration beyond the agreed contractual completion date, commonly referred to as schedule slippage. This deviation has significant financial implications: employers face losses due to delayed revenue streams and ongoing operational costs, while contractors incur increased overheads, exposure to price fluctuations, and additional labour expenses. Although timely completion remains a key performance indicator, the complexity of construction projects makes them vulnerable to numerous unpredictable factors, including stakeholder inefficiencies, resource limitations, environmental influences, and contractual interdependencies. Consequently, achieving project completion without delays is rare. Understanding the causes of delays, along with their timing and impact, is essential for resolving disputes through structured and scientific approaches, ultimately reducing the need for litigation. Increasing awareness among project participants regarding the high cost and risk of delay-related disputes further emphasises the importance of effective delay management strategies.

### *2.2 Project Delays' Classification (PDC)*

Project delays can be categorised based on their origin, timing, and entitlement to compensation. The following sections outline the different types of delays within each of these classifications.

#### *2.2.1 Delays Classified by their Origin*

Abudayyeh and Andersen [1] stated that project delays may arise from multiple sources. Certain delays are attributable to the employer, resulting in owner-caused delays (OCD), while others stem from the contractor, leading to contractor-caused delays (CCD). In addition, some delays are not exclusively attributable to either party, giving rise to third-party caused delays (TPCD).

#### *2.2.2 Delays Classified by their Timing*

The temporal occurrence of delays plays a vital role in determining their compensability. These delays can be grouped into four distinct categories based on their timing:

#### *2.2.3 Independent Delays*

Stumpf [29] noted that independent delays occur in isolation and are not triggered by any preceding delay. The impact of such delays on overall project duration can typically be quantified. In certain cases, an independent delay may initiate a chain of subsequent delays.

#### *2.2.4 Serial Delays*

Stumpf [29] defined serial delays as delays that occur as a direct consequence of a prior, unrelated delay affecting preceding activities. For instance, a labour strike involving sheet metal workers may postpone the installation of HVAC systems due to an earlier design hold on ductwork. Similarly, adverse winter conditions may delay installation work that was already postponed by earlier disruptions. In serial delays, the sequence and timing relative to preceding delays are the primary considerations. Unlike independent delays, serial delays form a sequence of consecutive, non-overlapping delays along a specific network path, and their cumulative impact is generally easier to determine.

#### *2.2.5 Concurrent Delays (CD)*

Stumpf [29] described concurrent delays as the occurrence of two or more delay events simultaneously, where each event independently has the potential to delay the project schedule. If either event had not occurred, the project would still have experienced delay due to the other. Concurrent delays may arise on parallel critical paths, such as when an employer delays approval of structural steel shop drawings while the contractor simultaneously experiences a subcontractor default. The following principles apply to concurrent delays:

1. Concurrent delays are considered valid only when both delays occur within overlapping timeframes and lie on parallel critical paths.
2. A delay on the critical path is not concurrent with a delay off the critical path during an overlapping period.
3. Delays outside the critical path may become concurrent only if they exceed the available float in their respective paths.

In dispute resolution contexts, responsibility for concurrent delays is typically not apportioned between parties unless a reasonable basis for allocation is established by the adjudicating authority. In most cases, each party bears its own associated costs.

#### *2.2.6 Pacing Delay*

Trauner [31] defined pacing delay as the deliberate slowing down of project activities by one party in response to a delay caused by the other party, with the intention of aligning progress with the revised project completion schedule.

### *2.3 Delays Classified by their Compensability*

Abudayyeh and Andersen [1] classified delays according to their compensability as follows:

#### *2.3.1 Excusable Delays (ED)*

EDs refer to delays for which the contractor is not held solely responsible. In such cases, the employer grants a time extension equivalent to the delay’s impact, allowing the contractor to complete the work without penalty. These delays are further divided into two subcategories:

#### *2.3.2 Excusable Compensable Delays (ECD)*

ECDs are excusable delays that fall within the responsibility of the employer or its representatives, including the construction manager, architect, engineer, or another contractor engaged by the employer. These delays may result from actions taken by the employer under the contract or from events for which the employer has assumed responsibility. Typical examples include variation orders, differing site conditions, suspension of work for the employer's convenience, and delays in reviewing submittals. Such delays may justify both an extension of time and the contractor's entitlement to compensation for additional costs, including extended site overheads and unabsorbed head office overheads.

### *2.3.3 Excusable Non-Compensable Delay (ENCD)*

ENCDs are excusable delays that are not attributable to either party, or may involve both parties in cases of concurrent delay. In such situations, both the employer and the contractor incur impacts, but neither is solely responsible. As a result, only a time extension is typically granted, with no entitlement to financial compensation for either party. These delays generally arise from events beyond the control of the contracting parties, such as labour strikes, force majeure events, or unforeseen extreme weather conditions. Each party usually bears its own associated costs, while the contractor is granted a time extension to avoid exposure to liquidated damages.

### *2.3.4 Non-Excusable Delays (NED)*

NEDs refer to delays for which the contractor bears full responsibility and is therefore not entitled to compensation. This category includes CCD, where the contractor is solely responsible for the disruption. Engineering activities commence prior to construction during the design and tender preparation stages and continue through construction, testing, and commissioning phases as illustrated in Fig (1).

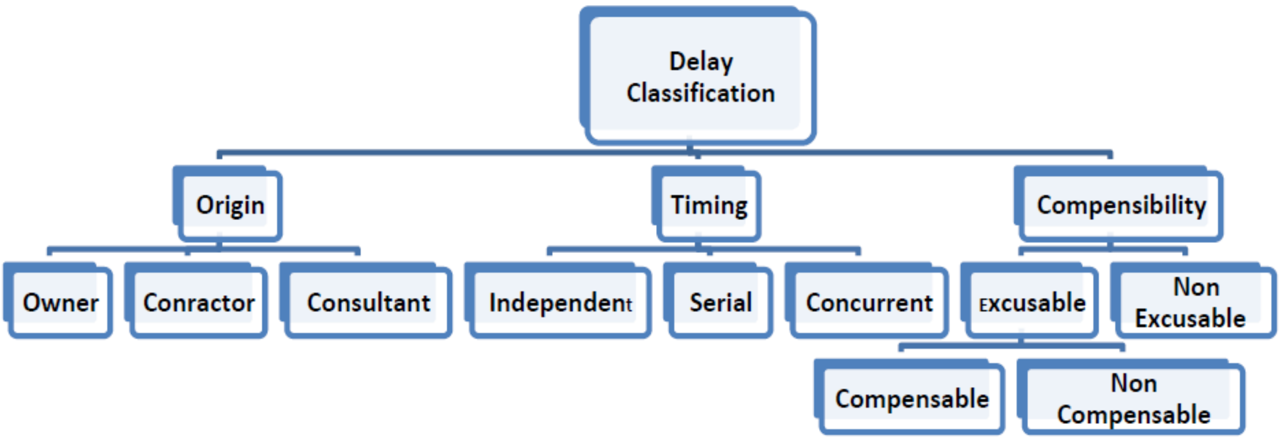


**Fig.1:** Construction Delay Classifications

This scenario is typically observed in employer-designed projects, such as design–bid–build systems, where the employer's consultants are responsible for design and oversight. In contrast, in design–build arrangements, the contractor assumes responsibility for design, while the employer's representatives review and supervise the process. Engineering-related delay claims are recognised as a major source of disputes in the construction sector, underscoring the importance of identifying their causes to minimise their negative impact on project performance.

### *2.4 Delay Analysis Techniques*

Based on the study by Mohan and Al-Gahtani [23], the United States construction sector employs a wide spectrum of forensic delay analysis methods to measure schedule overruns and allocate responsibility. These approaches span from basic techniques, such as global impact and as-planned versus as-built comparisons, to more advanced prospective and retrospective models, including impacted as-planned, as-built, and time impact analyses. In addition, the industry makes use of "but-for" (collapsed as-built) logic, isolated delay classifications, and detailed temporal assessments such as window snapshot and window but-for techniques, all of which are integrated with total float considerations to enable a rigorous determination of how individual events affect the project's critical path.

#### *2.4.1 Global Impact Technique*

The global impact approach is a basic form of delay assessment that determines the influence of disruption events through a simplified three-stage process: identifying the start and finish of each delay, representing these on a bar chart, and summing their durations to estimate total project delay. Although simple to apply, this method is generally considered weak in forensic analysis due to significant analytical shortcomings. It often produces exaggerated delay values that exceed the actual project overrun, thereby overstating potential compensation. Moreover, it fails to consider concurrent delays, does not differentiate between delay types, and ignores critical path logic. As a result, it inaccurately assumes that all delay events have equal impact on project completion, regardless of sequencing or float availability.

#### *2.4.2 As-Planned Technique*

The impacted as-planned method, often described as a "what-if" scenario, uses the original baseline schedule as a fixed reference point to estimate the impact of hypothetical delay events. By inserting owner-related disruptions into the baseline, the technique estimates the resulting extension in project duration, which may support claims for compensable damages. Similarly, contractor-related delays can be analysed to evaluate potential liquidated damages. Although it can be implemented in a single step by introducing all delays simultaneously, this method has notable limitations in forensic contexts. It tends to overlook concurrent delays and opposing party impacts, while relying on a theoretical schedule rather than actual site progress. It also disregards change orders, real sequencing, and evolving critical paths, making it less reliable for determining concurrency and liability in complex disputes.

#### *2.4.3 Impacted As-Planned Technique*

The incremental impacted as-planned approach refines the standard method by introducing delay events sequentially in chronological order. This allows the analyst to track how each delay influences the schedule step by step. By examining the difference between successive updates, the specific impact of each delay can be identified. In this framework, delays attributed to the owner that affect the critical path form the basis for contractor compensation, while contractor-caused delays contribute to claims against the contractor. Despite this structured process, the method is criticised because it assumes a fixed critical path and does not reflect how project criticality evolves over time. Additionally, it excludes real-time progress data, making it more of a theoretical model than a reflection of actual project conditions, which may lead to inaccurate results.

#### *2.4.4 As-Built Technique*

The as-built versus as-planned method, also known as the net impact approach, is a retrospective analysis that compares actual completion dates with those originally planned. It evaluates differences between planned float and actual delays across activities. When a complete as-built schedule is unavailable, an adjusted version is used by modifying the baseline and incorporating delays as new activities. While this approach is straightforward, it is often considered insufficient in forensic analysis because it does not capture the evolving nature of the critical path during project execution. It focuses on the final outcome rather than the progression of events, making it difficult to assess concurrency or establish a clear cause-and-effect relationship between specific delays and their impacts.

#### *2.4.5 Time Impact Technique Analysis*

The time impact method, commonly used by organisations such as the U.S. Army Corps of Engineers, provides a detailed analysis by examining the effect of delays at specific points during the project timeline. Instead of analysing fixed periods, it focuses on the schedule immediately before and after a delay event to determine its effect. The process involves updating the baseline schedule with actual progress up to the point of delay, then inserting the delay as a fragment of the schedule to observe its impact on completion. This allows analysts to isolate the effect of a specific disruption by comparing outcomes before and after its introduction. However, this method has limitations in handling concurrent delays, as it may treat overlapping events separately, which complicates fair allocation of responsibility.

#### *2.4.6 But-For Or Collapsing Technique*

The but-for (collapsed as-built) approach is widely regarded as one of the most reliable forensic delay analysis methods and is frequently accepted in legal contexts. It involves analysing the schedule from both the contractor's and employer's perspectives to determine respective entitlements. From the employer's perspective, contractor-caused delays are removed from the as-built schedule to estimate a hypothetical earlier completion date, with the difference representing recoverable liquidated damages. From the contractor's perspective, employer-caused delays are removed to determine when the project would have finished without those disruptions, supporting claims for extensions and compensation.

#### *2.4.7 Isolated Delay Type (IDT)*

The IDT approach divides the project duration into separate time intervals and categorises delays based on contractual classification. It evaluates delays as non-excusable, excusable non-compensable, or excusable compensable, from both parties' perspectives within each time segment. While it requires periodic updates to the baseline schedule, it has limitations. It may combine multiple delays within a single period, which can obscure their individual effects. It also fails to reflect real-world changes in the critical path and does not effectively capture external influences such as weather, making its representation of actual delay causes incomplete.

#### *2.4.8 Window Snapshot Technique*

The window snapshot method is one of the most commonly used techniques for analysing delays over time. It divides the project into time intervals, each representing a snapshot of progress based on key milestones or major events. Within each window, actual progress is applied to the baseline schedule, while future work remains based on original assumptions. By comparing projected completion dates before and after each update, the delay within that window can be measured. This process continues across all intervals, and total delay is calculated as the sum of all window results. However, it initially focuses on total delay rather than distinguishing between types of delay, which may require additional analysis to assign responsibility.

#### *2.4.9 Windows-But for Technique*

Also known as contemporaneous period analysis, this method combines elements of both as-built data and but-for analysis. It addresses the limitation of static critical paths by applying the collapsing approach across different time windows, allowing changes in project criticality to be reflected more accurately. By removing specific delays within each period, it provides a more precise estimation of impacts. However, the accuracy of this method depends on how the time windows are defined. If critical path changes occur within a window, they may be missed. Additionally, this method may lead to inconsistent results if window boundaries are altered, and it has been criticised for sometimes producing misleading concurrency assessments, requiring careful expert application.

#### *2.4.10 Total Float Management Technique*

The total float method adopts a highly detailed daily analysis approach, differing from broader window-based techniques. It examines the project on a day-to-day basis to identify delays affecting the critical path, assign responsibility for concurrent delays, and evaluate delays on non-critical activities by tracking float consumption. By monitoring how float is used and how criticality shifts over time, this method provides a precise understanding of project delays. Its fine-grained approach allows for a more accurate representation of how each party's actions influence overall project duration and schedule flexibility, often producing results that differ significantly from more aggregated techniques.

### *2.5 Construction Disputes*

Dispute is commonly defined as a conflict over legal rights that is formally resolved through political or legal means. It presupposes the involvement of two or more parties who acknowledge the existence of differences and issues between them, alongside at least one party demonstrating a willingness to resolve the matter. From a practical standpoint, this definition suggests that proactive measures can be taken by contractors to minimise the likelihood of disputes. In another perspective, dispute may be described as a disagreement involving opposing claims or differing interpretations of rights (Merriam Webster's Dictionary of Law, 1996). Conflict and dispute are closely related, as disputes typically arise when involved parties fail to effectively manage underlying conflicts [5].

Over recent decades, construction professionals have attempted to design and apply appropriate contractual frameworks that align with project requirements while reducing the occurrence of disputes. Despite these efforts, construction disputes continue to be frequently reported in the literature. Saseendran et al. [25] identified the leading causes of disputes in North American construction projects during 2014 as errors or omissions in contract documentation, differing site conditions, failure by employers, contractors, or subcontractors to comply with contractual obligations, inadequate contract administration, and poorly prepared or unsubstantiated claims. In contrast, Allen [2] reported that in Middle Eastern construction projects during the same period, the primary causes included ineffective contract administration, weak or unsupported claims, biased project management or engineering oversight, delays in granting extensions of time and compensation, and unrealistic completion deadlines established during the tender stage.

The Global Construction Disputes Report 2015 by ARCADIS analysed dispute values between 2010 and 2014 across different regions. The findings indicated that the highest dispute value occurred in the Middle East in 2011, reaching approximately 112.5 million dollars, whereas the lowest was recorded in the United Kingdom in 2010 at around 7.5 million dollars. Assaf [4] identified 56 causes of disputes related to delays, highlighting that contractual disagreements were among the primary contributors to delays in large-scale building projects. Similarly, Alshdiefat and Aziz [3] conducted a study on public construction projects in Jordan and found that factors such as design issues, change orders, adverse weather conditions, site conditions, late material deliveries, economic instability, and quantity variations contributed to disputes and subsequent project delays. Enshassi et al. [15] further reported that interference, limited contractor experience, financial constraints, payment issues, low labour productivity, and slow decision-making were among the most significant causes of disputes and delays in traditional contract arrangements.

Do et al. [8] identified key sources of disputes, including errors, defects, and omissions in contract documents, initial underestimation of project costs, changing site conditions, and the involvement of multiple stakeholders. In developing countries, public works departments often operate under significant constraints, including limited financial resources, shortages of skilled labour, and material availability challenges, particularly in large infrastructure projects. Such projects are inherently complex, involving intricate planning, design, financing, and legal considerations. The overlapping roles and interdependencies among project participants frequently lead to increased disputes and associated costs between contractors and project owners. Disputes are prevalent in both domestic and internationally funded projects, regardless of project size or funding source. Public sector authorities often work under multiple donor regulations, which can be difficult for contractors to align with local construction practices. Consequently, no project can be considered entirely immune to disputes, and such issues can result in substantial financial losses. The severity of disputes depends on factors such as their nature, underlying causes, and the complexity of contractual arrangements.

In Thailand, Khursheed et al. [20] identified material procurement challenges, delays in information flow, and poor contractor management as major contributors to disputes and delays. Additional factors such as adverse weather conditions, labour shortages, and design-related delays also contribute significantly. The traditional design-bid-build procurement approach remains dominant in Thai public projects, increasing the likelihood of variation orders, which can reduce initial project value. Moreover, quality outcomes may be compromised as public clients often prioritise cost over other factors. Coordination among key stakeholders, including owners, contractors, and consultants, remains a major challenge in the public construction sector. The absence of a unified coordination strategy often leads to communication breakdowns and repeated inefficiencies.

Singapore has addressed this issue by introducing the Quality-Fee-Selection Method (QFM), which emphasises the evaluation of consultants based on experience, capability, and cost considerations, thereby promoting the selection of highly qualified firms [19]. In Hong Kong, contractual provisions such as time-bars have been implemented in lump sum projects to enforce strict timelines for claim notification and submission, ensuring that contractors preserve their contractual rights. Zhu and Cheung [32] found that conflicts at the inter-organisational level can lead to reduced respect and negatively affect performance outcomes. Effective dispute minimisation requires coordinated efforts from legal, design, and construction teams. Therefore, all stakeholders, including owners, consultants, and contractors, must understand the implications of disputes and adopt proactive strategies to prevent them. A key objective in studying dispute issues is to identify recurring causes during the construction phase from the perspectives of owners, consultants, and contractors.

### *2.6 Disputes Resolution*

Sayed-Gharib et al. [26] observed that disputes are not resolved immediately. Even initiating the process requires a considerable amount of time before the involved parties recognise, let alone address, the existence of a dispute. When it becomes clear that the opposing party is committed to pursuing the matter, there is often an underlying expectation among those involved that circumstances may arise which could avoid the need to engage in a difficult and often unpleasant resolution process. In cases where a dispute resolution mechanism is not specified within the contract’s dispute resolution clause, the aggrieved party retains the right to initiate legal proceedings by filing a lawsuit in a court of law within the relevant jurisdiction.

#### *2.6.1 Negotiated Settlement*

The majority of disputes are typically resolved through amicable negotiation, often culminating in agreements that are reached at the end of a project and encompass a complete and final settlement of all claims between the parties. Such agreements are commonly referred to as "accord and satisfaction." These settlements represent modifications to existing contractual obligations and therefore must be agreed upon by duly authorised representatives of the involved parties. In addition, the agreement must be entered into voluntarily and supported by valid consideration. If either party later fails to comply with the agreed settlement, the original contract is not reinstated; instead, the appropriate remedy lies in a claim for breach of the settlement agreement. In principle, such settlements do not require written documentation or formal evidence and remain enforceable even if agreed verbally during a meeting.

### *2.6.2 Alternative Dispute Resolution*

A variety of mechanisms collectively referred to as Alternative Dispute Resolution (ADR) have been developed to support efficient dispute settlement. These procedures are highly flexible and can be adapted to meet the specific requirements of the parties involved [30]. When ADR is initiated under a pre-existing agreement, its terms must be followed unless subsequently modified by mutual consent. However, when ADR is stipulated as a prerequisite to arbitration, it is not considered mandatory in the strict legal sense and may be viewed as an "agreement to agree," which is not enforceable, as it merely obliges parties to undertake procedural steps without guaranteeing a binding outcome.

### *2.6.3 Mediation*

Mediation is a voluntary and non-binding dispute resolution process. Either party retains the right to withdraw at any stage, and upon completion, there is no legal obligation to accept the mediator's recommendations. The process typically involves a neutral professional who examines the dispute and encourages both parties to make concessions, often facilitating compromise. If mediation does not succeed, the dispute is usually escalated to the next level, typically arbitration.

### *2.6.4 Arbitration*

Arbitration constitutes another formal method of resolving disputes and is generally more efficient and cost-effective than court litigation, although complex cases can still require substantial time and resources. Arbitrators, who are often professionals in relevant fields, may not be available continuously, which can result in fragmented hearings and extended timelines. Arbitration is only enforceable if explicitly stated within the contract; it is not implied by default. However, when included in the contract, courts can compel arbitration upon request by either party. Compared to litigation, arbitration proceedings are less formal and are often conducted in private settings. The process may vary in structure depending on the arbitrator's approach and is typically overseen by one or more arbitrators with relevant industry experience, such as lawyers, engineers, architects, or contractors. While they may lack deep legal expertise, their practical knowledge helps maintain focus on technical issues. Arbitration is generally faster than litigation, as administrative processes such as filing, arbitrator selection, and scheduling can occur within months, whereas court proceedings may take years.

### *2.6.5 Litigation*

Litigation refers to dispute resolution through the formal court system. In the absence of arbitration or other agreed mechanisms, parties must seek legal remedies through judicial processes. Court proceedings are highly structured and governed by strict procedural rules that require technically sound claims. The complexity of the case may significantly influence both duration and outcome. Judges and juries, collectively known as the trier of fact, determine the merits of the case.

Although they may lack construction-specific expertise, they rely on common sense and legal reasoning. However, complex technical matters, such as off-site overhead costs in delay claims, may be difficult to fully comprehend. While court fees are typically lower than arbitration costs, overall expenses may increase due to extended timelines and procedural demands. Legal proceedings can span months or even years, making them considerably slower than arbitration. Additionally, court cases are part of the public record, meaning all filings and proceedings are accessible to the public, which may be a concern for parties seeking confidentiality.

### *2.7 Disputes Avoidance*

Sayed-Gharib et al. [26] emphasised that the project owner holds responsibility for the timely and satisfactory completion of construction work. However, much of the execution relies on contractors and suppliers. Successful project outcomes depend heavily on both legal and commercial relationships between the owner, contractors, and suppliers. Poor performance by contractors may result in disputes not only between contractors and owners but also among subcontractors. Likewise, failures by the main contractor can impact all stakeholders involved. These disputes often lead to legal claims, which are typically costly and time-consuming and may not resolve issues promptly. Therefore, several key factors must be considered to minimise disputes:

#### *2.7.1 Low Bidding Price*

While cost is a significant factor in selecting contractors, choosing the lowest bid may result in higher overall costs if the contractor lacks the capability or willingness to complete the work effectively.

#### *2.7.2 Familiarity with People*

Engaging with unreliable or unethical parties can significantly increase the likelihood of disputes. Preventing such issues begins at the procurement stage, where parties evaluate potential partners based on reputation, financial stability, experience, and qualifications.

#### *2.7.3 Payment Obligation*

Timely payments by the owner, including progress payments and retention sums, are a frequent source of disputes. Issues may arise from delayed payments or disagreements over valuation of work completed or additional work performed. Contract execution may also require adjustments in payment expectations due to unforeseen circumstances, which, if not carefully managed, can lead to further complications.

#### *2.7.4 Changes*

Contract variations are a common source of disputes in construction. Owners must ensure that contracts clearly define procedures for handling changes, while contractors require assurance that they will be compensated for additional work. Contractors are also concerned about being required to finance extra work for extended periods without clarity on approval or payment, creating conflicting interests that often lead to disputes.

#### *2.7.5 Disputes Procedures*

The inclusion of dispute resolution mechanisms must be carefully considered before contract execution. Without such provisions, disputes can only be resolved if both parties agree after the issue arises, which is often difficult to achieve. It is generally advisable for owners to establish clear procedures and remedies within contracts, requiring contractors to follow prescribed dispute resolution processes and comply with final determinations.

The construction project lifecycle consists of three main phases: conception, design, and construction. The conception phase involves identifying a need and defining the purpose of the project. The design phase translates this concept into detailed technical and architectural plans, ensuring efficiency and alignment with objectives. The construction phase involves the physical execution of the design to produce the final structure. Most project delays occur during construction due to numerous unpredictable factors. Timely completion is a key indicator of successful project management, along with adherence to budget and quality standards. Numerous studies from countries such as Egypt, Saudi Arabia, Jordan, and Nigeria have examined construction delays and related disputes, contributing to the development of research tools such as questionnaires for data collection and analysis.

## 3. Research Methodology

To investigate causes of construction delay disputes, a structured questionnaire was developed based on practitioners with experience ranging from five to over thirty years in Egypt. Participants included senior professionals such as managers, contractors, consultants, and client representatives. The objective was to identify and analyse major issues affecting Egyptian construction projects. The questionnaire comprised 110 identified causes of disputes, grouped into fifteen categories, including financing, owners, contractors, labour, design, site conditions, contractual relationships, contracts, project characteristics, external factors, equipment, regulations, consultants, scheduling, and materials. Responses were rated on a scale from 1 to 5 to assess the significance of each factor.

### *3.1 Questionnaire Description*

The primary objective of the questionnaire was to determine the relative importance of each of the 110 identified causes of construction delay disputes in Egypt and to rank the top fifteen factors. Respondents were selected based on extensive experience in construction projects, and the survey was kept simple to facilitate straightforward analysis.

### *3.2 Sample Size and Description*

The survey was distributed to 989 experts across various disciplines, with 498 responses received. After excluding 98 incomplete responses, 401 valid responses were analysed. These included 139 contractors, 111 owners, and 151 consultants. Educational qualifications included 12 Ph.D., 28 M.Sc., 32 M.Eng., and 329 B.Sc. degrees. Participants' disciplines were Civil (265), Electrical (58), Mechanical (49), and Architectural (29).

### *3.3 Questionnaire Form Design*

The survey instrument was structured into two primary sections as follows:

#### *3.3.1 Section One: Respondent Information:*

Respondent Name, Type of Party, Years of Experience, etc.

#### *3.3.2 Section Two: Experts Details*

Based on the literature review and incorporation of additional factors, a total of 110 causes were identified, encompassing financing, owner, contractor, labour, design, site conditions, contractual relationships, contract issues, project characteristics, external factors, equipment, rules and regulations, consultant-related issues, scheduling and control, and material-related causes. Each factor was assessed using a five-point rating scale, where 1 indicates very low impact, 2 low impact, 3 moderate impact, 4 high impact, and 5 very high impact.

### *3.4 Questionnaires Results*

To enable a robust quantitative evaluation, the gathered data were consolidated through a set of advanced statistical tools and indices developed to assess the comparative influence of different sources of conflict [18]. In particular, the study employed the Importance Index, a formal analytical measure that facilitates the ordered ranking of causes of delay-related disputes by synthesising respondents' inputs to capture both the frequency and intensity of each factor. This method prioritises variables according to their relative significance, thereby offering an impartial framework for identifying the key contributors to project delays and the ensuing legal conflicts. The target population of the study comprised owners, consultants, managers, engineers, and contractors. A systematic random sampling technique was adopted to guarantee that the sample accurately reflects all categories of the intended respondents, using Equation (1).

$$n = \frac{m}{1 + \left(\frac{m-1}{N}\right)} \qquad \text{Eq. (1)}$$

Where: n, m, and N represent the sample size of the limited, unlimited, and available population, respectively. On the other hand, m is estimated by using equation (2):

$$m = \frac{Z^2 \times P \times (1 - P)}{e^2} \qquad \text{Eq. (2)}$$

Where: Z is the statistical value for the confidence level used, i.e., 2.575, 1.96, and 1.645, for 99%, 95%, and 90% confidence levels, respectively; P is the value of the population proportion which is being estimated and e is the sampling error of the point estimate. Since the value of (P) is not known, Sincich et al. [28] recommended adopting a conservative estimate of 0.50 to ensure that the calculated sample size is sufficiently large. This approach guarantees that the minimum required sample size is not underestimated. By applying a 95% confidence level, corresponding to a 5% significance level, the sample size for an effectively unlimited population, denoted as (m), can be estimated as follows:

$$m = \frac{(1.96)^2 \times 0.5 \times (1 - 0.5)}{0.05^2} \simeq 385$$

Accordingly, the total population, denoted as (N), of classified contractors within construction firms in Egypt, specifically those registered as active members of the Egyptian Federation for Construction & Building Contractors (EFCBC) and holding valid memberships across the seven grading levels for integrated building works, was recorded as 19,814 as of January 2021. Based on this population, the sample size was statistically calculated to obtain a representative subset, denoted as (n), ensuring adequate representation of the target population of construction companies, as determined by the following formulation:

$$n = \frac{385}{1 + \left(\frac{385-1}{19.814}\right)} \simeq 378$$

The aggregate number of respondents within each response category for every factor was compiled, and for the purpose of data analysis, the Relative Importance Index for each factor, denoted as (RIIik), was applied. This metric was calculated separately for each experience category (k) across each respondent group (i), enabling a structured comparison of perceived significance. The computation of this index followed the formulation presented in Equation (3) by Jarkas and Bitar [33]:

$$\mathbf{RII}_k^i(\%) = \frac{1 \times (n1) + 2 \times (n2) + 3 \times (n3) + 4 \times (n4) + 5 \times (n5)}{5 \times (n1 + n2 + n3 + n4 + n5)} \times 100$$ Eq. (3)

Where: RIIik (%) in fig (2) is the annual experience percentage of Relative Importance Index of each factor of each group of respondents which is calculated separately corresponding to the corresponding years (k) of experience of grouped respondents; k is the number that represents years experience of grouped respondents (first year experience k= 1 to last year experience k= K); n1; n To assess each factor, the criterion used is the Overall Relative Importance Index (ORII) which in turn integrates the reactions of all participants in the specified groups, which, in this case, are Consultants (i = 5), Managers (i = 4), Engineers (i = 3), Owners (i = 2) and Contractors (i = 1), as shown in Equation (4): This calculation is a combination of the Relative Importance Index values (RIIik) of all the levels of experience taken together. The ORII is calculated as a weighted mean of the RIIik values, which can be written in form of Equation (4):

$$\mathbf{ORII}\ (\%) = \sum_{i=1}^{i=5} \frac{i}{15} \times \left[ \frac{\sum_{k=k}^{k=1} (k \times \mathrm{RII}_k^i)}{\sum_{k=1}^{k=k} (k)} \right]$$ Eq. (4)

Where: ORII (%) is the Overall weighted average percentage of Relative Importance Index of each factor, which is computed based on total years of experiences of all grouped respondents in a common group; k is the number that represents' years of experience of grouped respondents (first year of experience k= 1 to the last year of experience k=K); i is the type of grouped respondents.

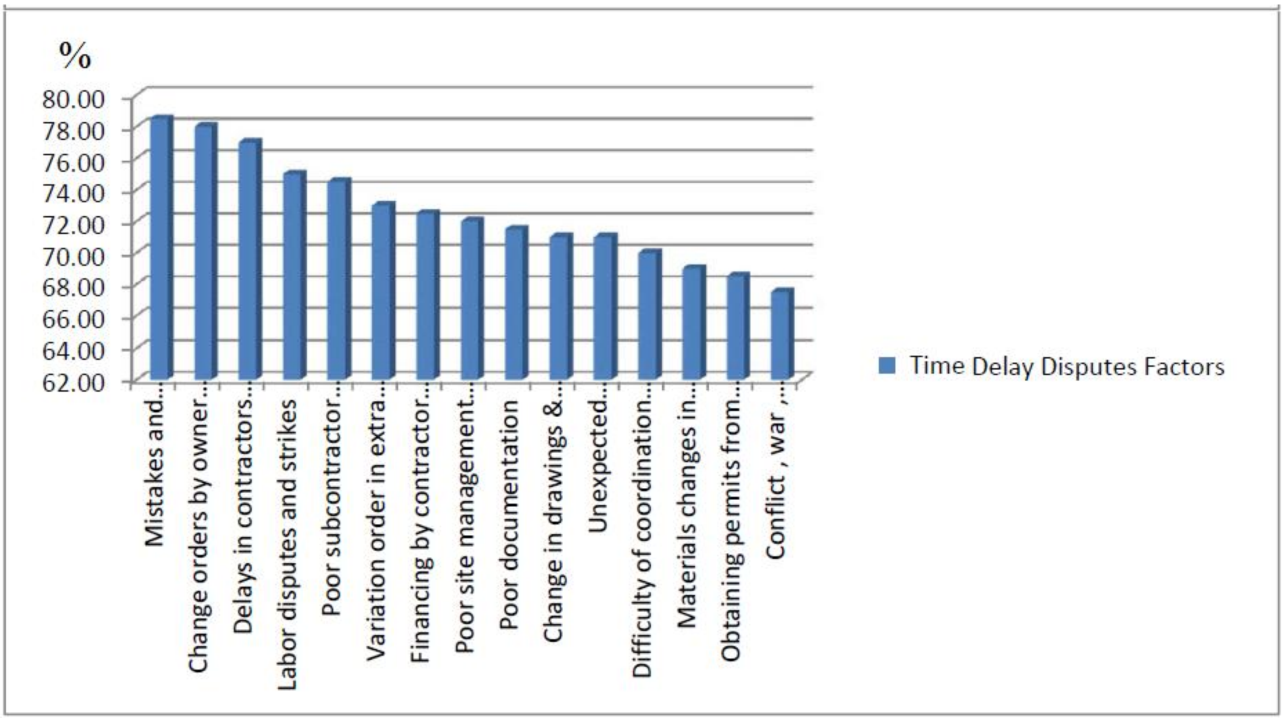


**Fig.2:** Relation between ORII (%) with Top Fifteen Time Delay Disputes Factors

### *3.5 Time Delay Disputes Prediction Proposed Model*

After analysing the collected data and identifying the fifteen highest-ranked factors, it became essential to develop a comprehensive predictive framework capable of estimating time delay disputes while also offering practical recommendations for mitigating each identified cause. To address this need, a simplified predictive system was formulated and designated as the "TDDPM". This model was implemented using Microsoft Excel and structured into six interconnected sheets: the first serves as a welcome interface, the second captures project-related information, the third allows users to input probability percentages for each cause of delay disputes, the fourth conducts data analysis using three selectable weighting approaches (manual, equal, or automatic), the fifth generates the primary output indicating the expected percentage of disputes, and the sixth provides targeted recommendations corresponding to the five most significant contributing factors. In addition, the model was further enhanced using C# programming to deliver a user-friendly interface, ensuring ease of use and accessibility. The system incorporates seven functional modules, namely a previous Microsoft Excel-based model, welcome wizard, projects, project information, input data, data analysis, expected dispute percentage, and recommendations.

### *3.6 Proposed Model Architecture*

The overall structure of the TDDPM is outlined, with a detailed breakdown of each phase of construction dispute analysis, including contractual, financial, contractor-related, material-related, and external factors. The framework offers flexibility in selecting the weighting approach for these factors, allowing users to choose between manual, equal, or automatic weighting methods. 1) The architecture of the C#-based rule system comprises three core components, as illustrated in Fig (3): A) Input, which includes project information criteria, the fifteen primary time delay dispute factors, their associated probability values, and corresponding weights. B) Process, which involves IF-THEN logic statements combined with computational equations to estimate the expected dispute percentage. C) Output, which presents results in the form of percentages, categorical grades, recommendations, and comprehensive reports.

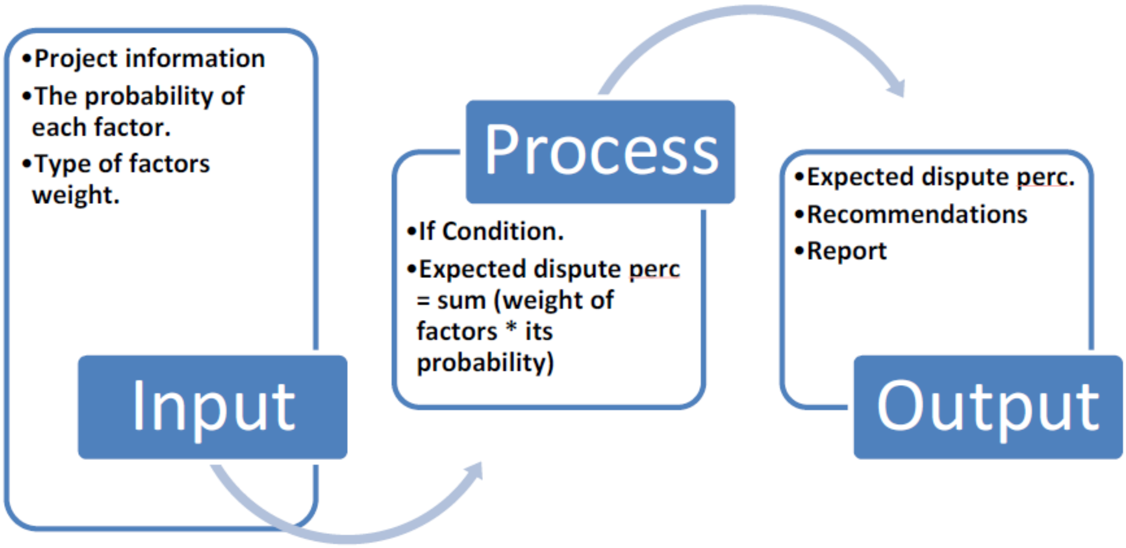


**Fig.3:** Time Delay Disputes Prediction Model Architecture

The proposed system was developed with a focus on simplicity and ease of operation, providing a user-friendly interface. In other words, the operating environment is designed to be intuitive, incorporating a series of menu screens that function in a sequential and structured manner. To initiate the use of the TDDPM, the following steps should be followed: 1) Install the program. 2) Select T.D.D.P.M. from the programs listed in the Start menu. 3) The initial interface, known as the Welcome Wizard, will be displayed as illustrated in Fig. (4). 4) The user can navigate across all modules through the vertical menu on the left-hand side, which provides continuous access from the Welcome Wizard to the final Recommendations section. 5) The model is organised into seven main modules, briefly described as follows:

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**Fig.4:** Time Delay Disputes Prediction Model Welcome Wizard

This is the welcome wizard, which displays the name of the model along with information about the individuals who prepared and verified it. It also contains a vertical navigation list that includes all processes within the model, enabling the user to move seamlessly between each stage, namely project information, input data, data analysis, expected dispute percentage, and recommendations, as illustrated in Fig. (5).


**Fig.5:** Time Delay Disputes Prediction Model Projects

The second wizard, referred to as Projects, consists of a left vertical navigation list and a set of horizontal windows. The vertical list contains all the processes of the model, allowing the user to navigate seamlessly between project information, input data, data analysis, expected dispute percentage, and recommendations. This vertical navigation structure is consistently repeated across all wizards. The horizontal section is divided into three main windows: the first displays the list of projects saved within the model, the second provides options to open or close any stored project, and the third allows the creation of a new project. Additionally, a graphical representation is included to illustrate the comparison between dispute and non-dispute percentages for the three most recent projects, as shown in Fig. (6).

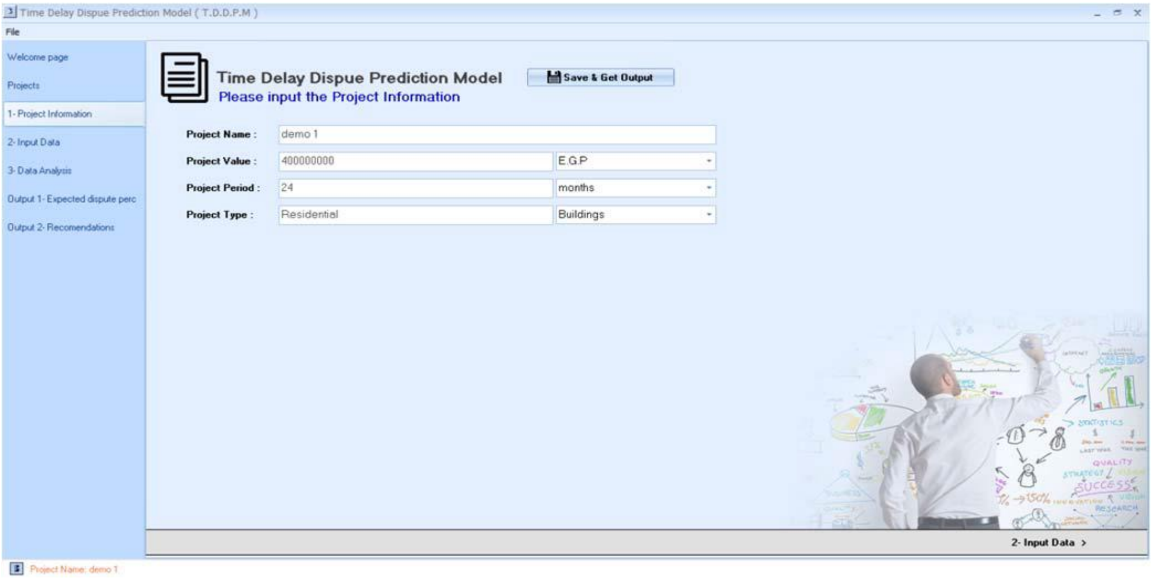


**Fig.6:** Time Delay Disputes Prediction Model Project Information

The third wizard, titled Project Information, encompasses essential input fields including the project name, project value, project duration, and project type. The user is provided with flexibility in data entry, as the project value can be specified in either Egyptian pounds or US dollars, while the project duration can be entered in months or years. Furthermore, the project type can be selected from predefined categories, namely buildings, industrial, roads and bridges, infrastructure, or others, as illustrated in Fig. (7).

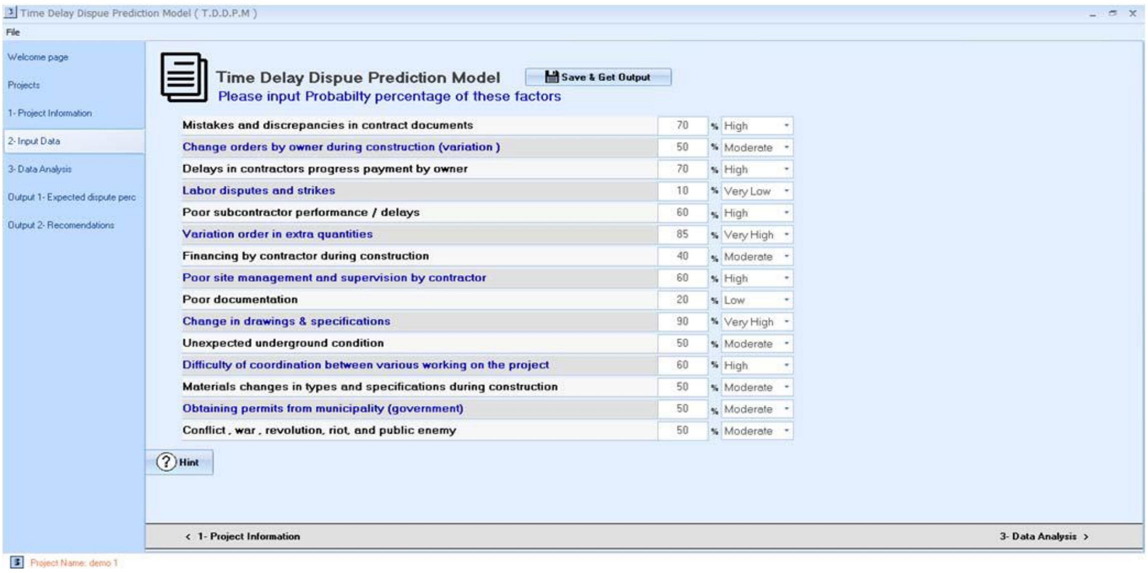


**Fig.7:** Time Delay Disputes Prediction Model Input Data

The fourth wizard, titled Input Data, enables the user to specify the probability percentage for the fifteen most significant causes of time delay disputes, ranging from 0% to 100%, or alternatively, to assign values using a graded scale from very low to very high, as illustrated in Fig. (7). The entered percentages and grades are interlinked, ensuring consistency between both input methods.

Additionally, a guidance note is provided below the input section to clarify the relationship between the assigned grades and their corresponding percentage values, as shown in Fig. (8).

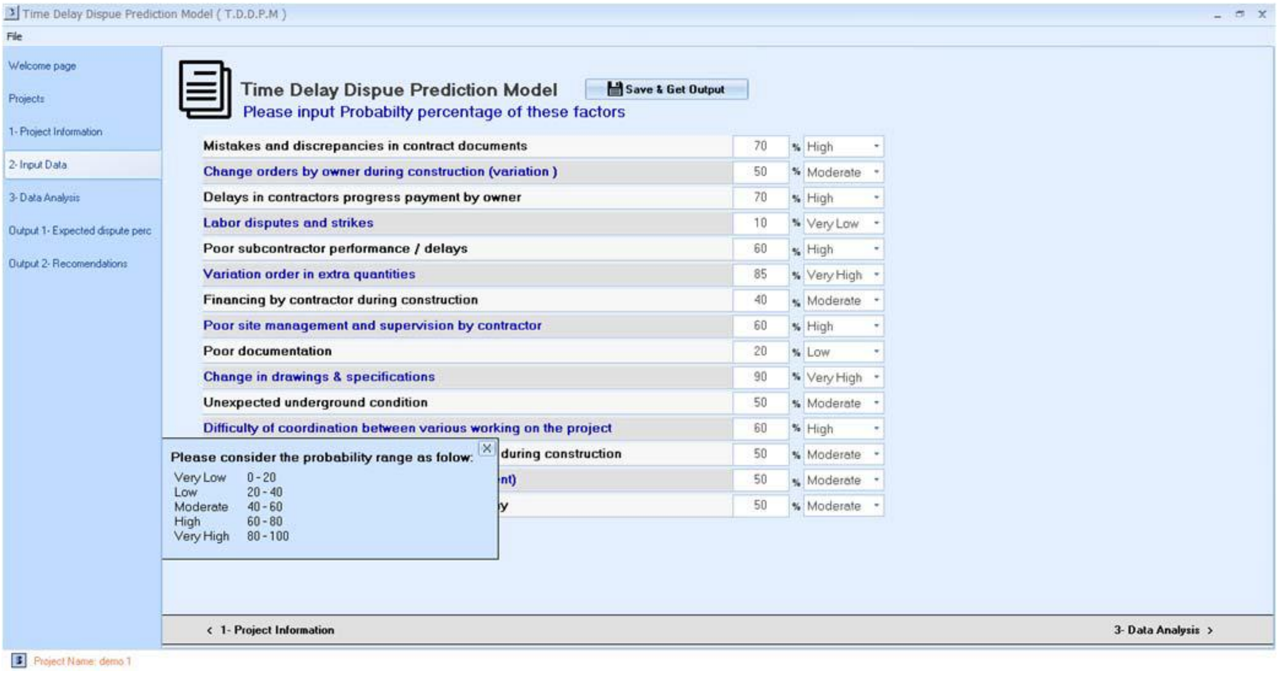


**Fig.8:** Time Delay Disputes Prediction Model Input Data Hints

The fifth wizard, Data Analysis, allows the user to select the desired analysis approach, offering three options: manual weighting determined by the user, equal weighting applied uniformly across all factors, or automatic weighting based on predefined values stored within the model derived from the questionnaire analysis, as illustrated in Fig. (9).

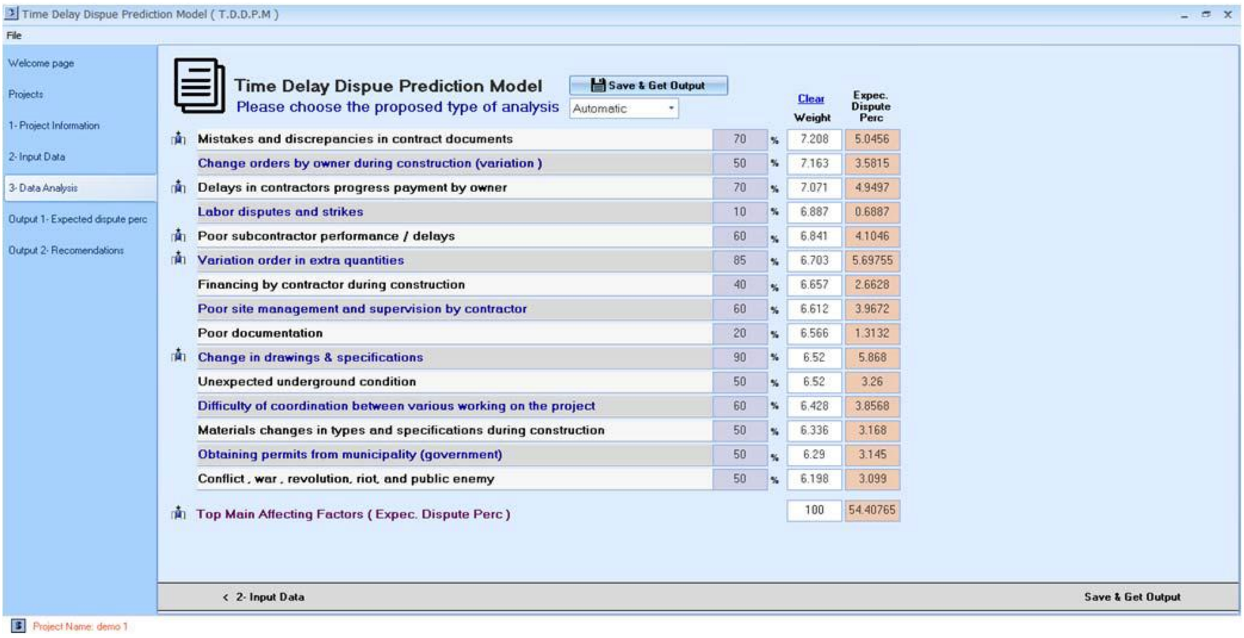


**Fig.9:** Time Delay Disputes Prediction Model Data Analysis

The sixth wizard represents the first segment of the model's output, where the system presents the expected percentage and corresponding grade indicating the likelihood of dispute occurrence. In addition, a pie chart is provided to visually compare the proportions of dispute and non-dispute outcomes, as shown in Fig. (10).

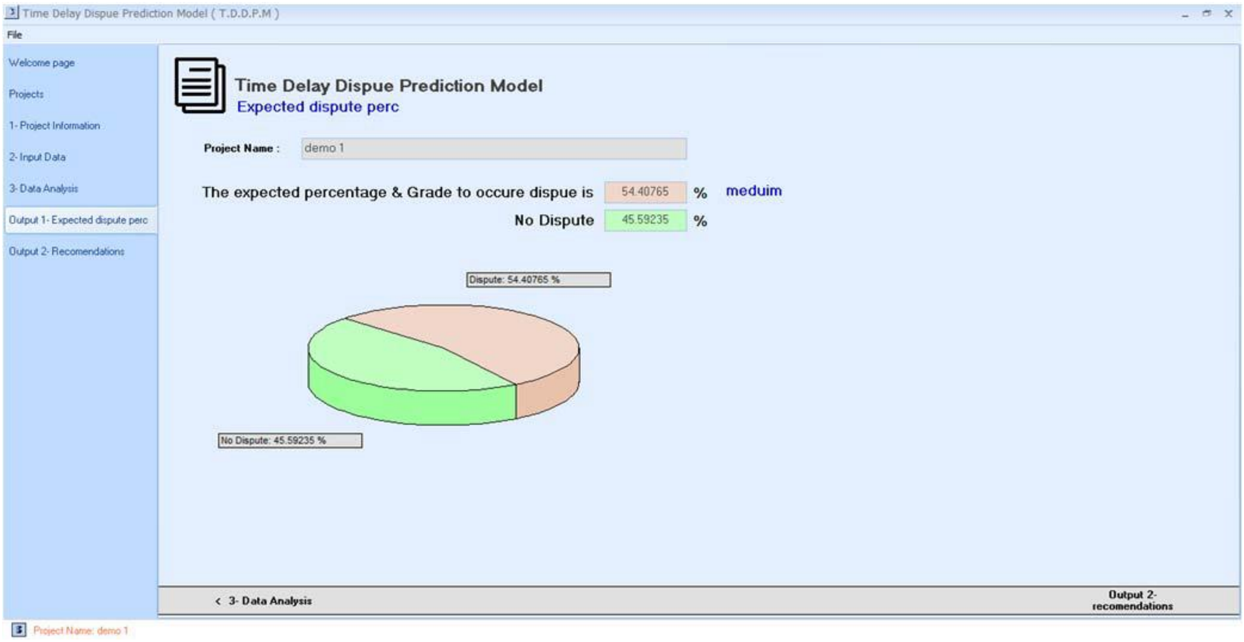


**Fig.10:** Time Delay Disputes Prediction Model Expected Dispute Percentage

The seventh wizard constitutes the second segment of the model's output, where the system presents the user with key recommendations aimed at reducing the occurrence of time delay disputes, as illustrated in Fig. (11).

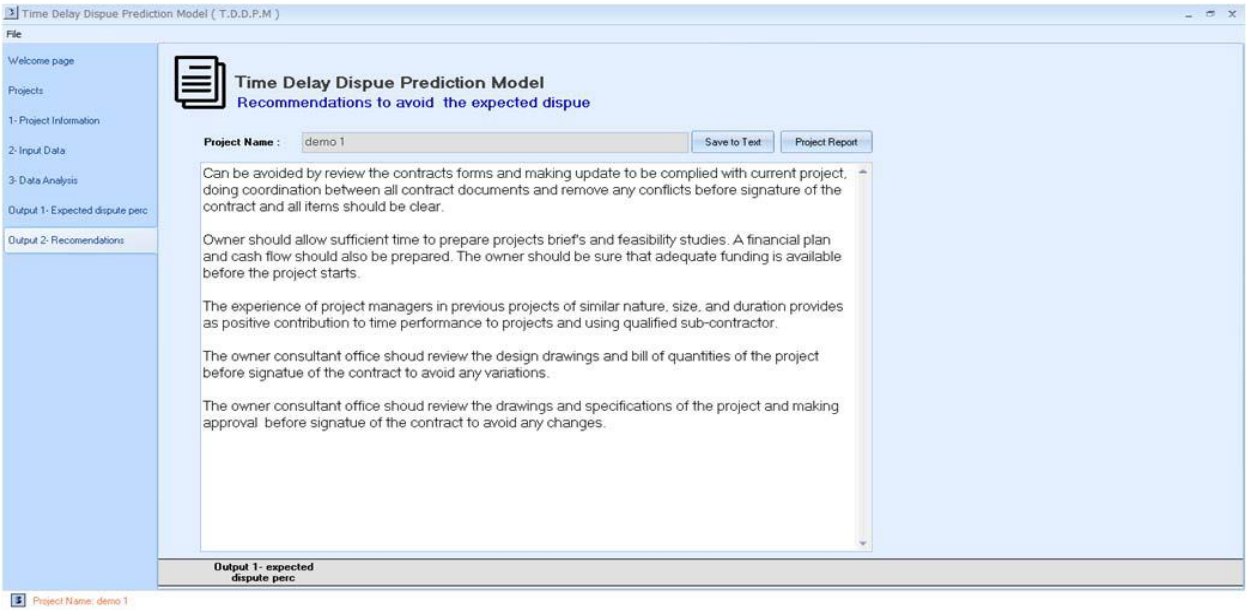


**Fig.11:** Time Delay Disputes Prediction Model Expected Recommendations

The model is capable of generating a concise report for the selected project, which includes key project details, the chosen type of data analysis, the calculated dispute percentage, a pie chart illustrating the distribution between dispute and non-dispute, and the most significant recommendations for preventing disputes within the project, as shown in Fig. (12). Additionally, the user has the option to print or save the generated report.

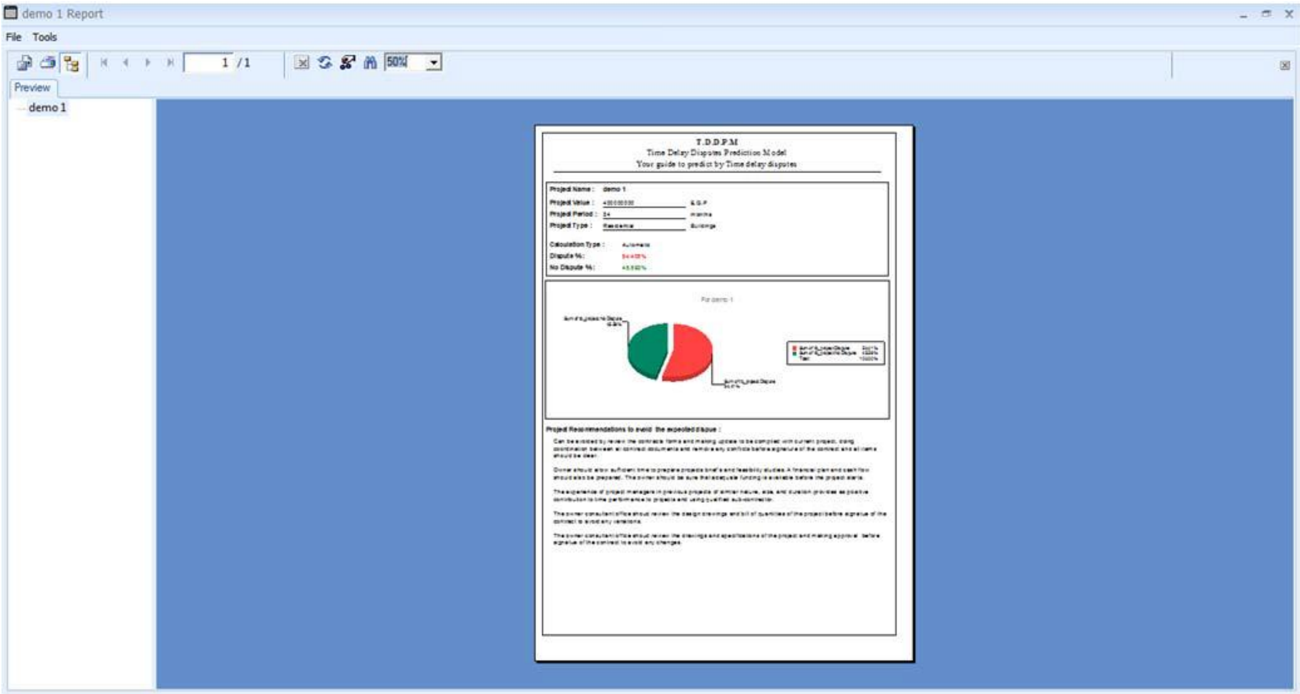


**Fig.12:** Time Delay Disputes Prediction Model Expected Report

## 4. Case Study: (Arbitration Case)

It is applied case study on arbitration case between two governmental organizations, namely The General Authority for Implementation of Industrial and Mining Projects and Arab Contractors Company, under arbitration request number (39) in 2010.

### *4.1 Project Information*

The Project: Completion of the remaining works from Eldikhila Port Project, orders no. 21 & 45 in 1989. Owner: The General Authority for Implementation of Industrial and Mining Projects. Contractor: Arab Contractors Company. Contract value: 114,247,670 EGP. Duration: Three years, from 01-07-1994 to 30-06-1997.

### *4.2 Dispute Causes*

1) Extra works (exceeding 100%), 2) Change Orders, 3) Delay in inspection and handover, 4) Late payment (more than one year), 5) Work termination by the owner (three months every two years), and 6) Imposition of delay penalties on the contractor by the owner amounting to 29,252,968 EGP.

### *4.3 Owner Requests*

1) The contractor was requested to pay 24,000,816 EGP to the owner, representing the difference between the delay penalty of 29,252,968 EGP and the amounts owed to the contractor.

2) The contractor was also requested to pay 918,662 EGP as compensation for adverse outcomes resulting from delayed project handover beyond the scheduled completion date (31/03/1999) until final completion on 27/02/2007.

### *4.4 Contractor Requests*

The contractor requested the owner to pay a total of 12,048,876 EGP, comprising: 1) Final invoice and its adjustments: 1,284,092 EGP, 2) Retention amount: 5,642,208 EGP, 3) Wage escalation and inflation adjustments, 4) Compensation for price increases due to exchange rate liberalisation under Prime Minister’s Decision No. 1864/2003: 651,206 EGP, 5) Fees for extension of the initial guarantee letter (12-04-2007 to 16-02-2010): 106,819 EGP, 6) Fees for extension of the final guarantee letter (04-04-2007 to 01-09-2010): 106,819 EGP, 7) Refund of the initial guarantee letter: 2,540,174 EGP, and 8) Refund of the final guarantee letter: 6,708,217 EGP.

### *4.5 Arbitration Committee Decisions*

The arbitration panel examined the dispute, evaluated evidence from both parties, and reviewed relevant legal provisions, concluding that: 1) The owner must pay the contractor 9,300,459 EGP plus 5% interest from the claim date (21-09-2010) until full settlement, 2) Refund of the initial guarantee letter: 2,540,174 EGP, 3) Refund of the final guarantee letter: 6,708,217 EGP, 4) Rejection of the remaining contractor claims, and 5) Rejection of two claims submitted by the owner.

## 5. Comparison Between Disputes Causes In Questionnaire And Case Study

The comparative analysis between the questionnaire results and the case study indicates that all identified dispute causes in the case are reflected within the questionnaire framework and ranked as follows: Change Orders (rank 2), Late Payment (rank 3), Extra Works (rank 6), Delay in Inspection and Handing Over (rank 10), and Termination of Work by the Owner (rank 15), all classified under combined party factors.

### *5.1 Proposed Model Application On Case Study*

The percentage weights derived from the questionnaire were applied and compared with the dispute factors in the case study as follows: Extra Works (more than 100%) = 1.0686, Change Orders = 1.1418, Delay in inspection and handover = 0.8856, Late Payment (more than one year) = 1.1271, and Termination of work by the owner = 0.9002. Among these, only three factors were found to align significantly: Extra Works, Change Orders, and Late Payment. Their relative weights were determined as: Extra Works = 32, Change Orders = 34, and Late Payment = 34. Based on the case documentation, both Extra Works and Change Orders exceeded 100%, thus their probability was set at 100%. Late Payment extended beyond one year (approximately 1.5 years), and given a project duration of three years, its probability was estimated at 50%. Data entry into the model is straightforward, beginning with project information as shown in Fig. (13).

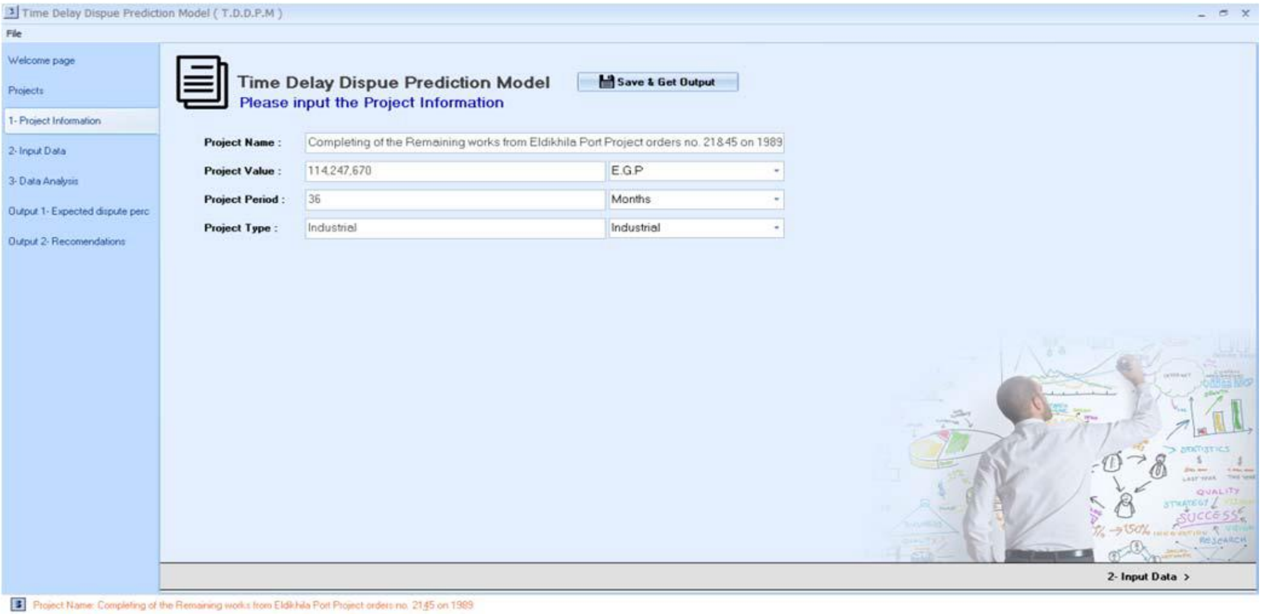


**Fig.13:** Time Delay Disputes Prediction Model for Studied Project Information

By entering the input data in terms of the probability percentages for the relevant factors and selecting the proposed analysis method as manual using the suggested weights, as illustrated in Figs. (14 & 15).

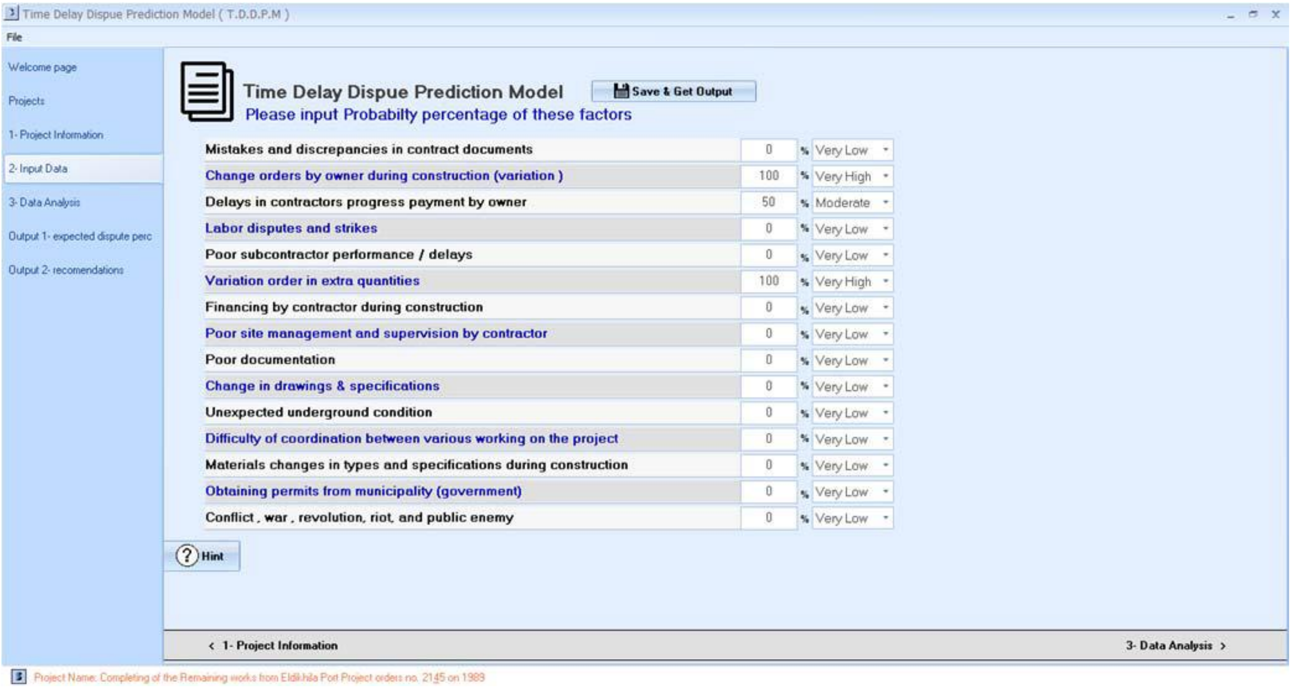


**Fig.14:** Time Delay Disputes Prediction Model for Studied Project Input Data

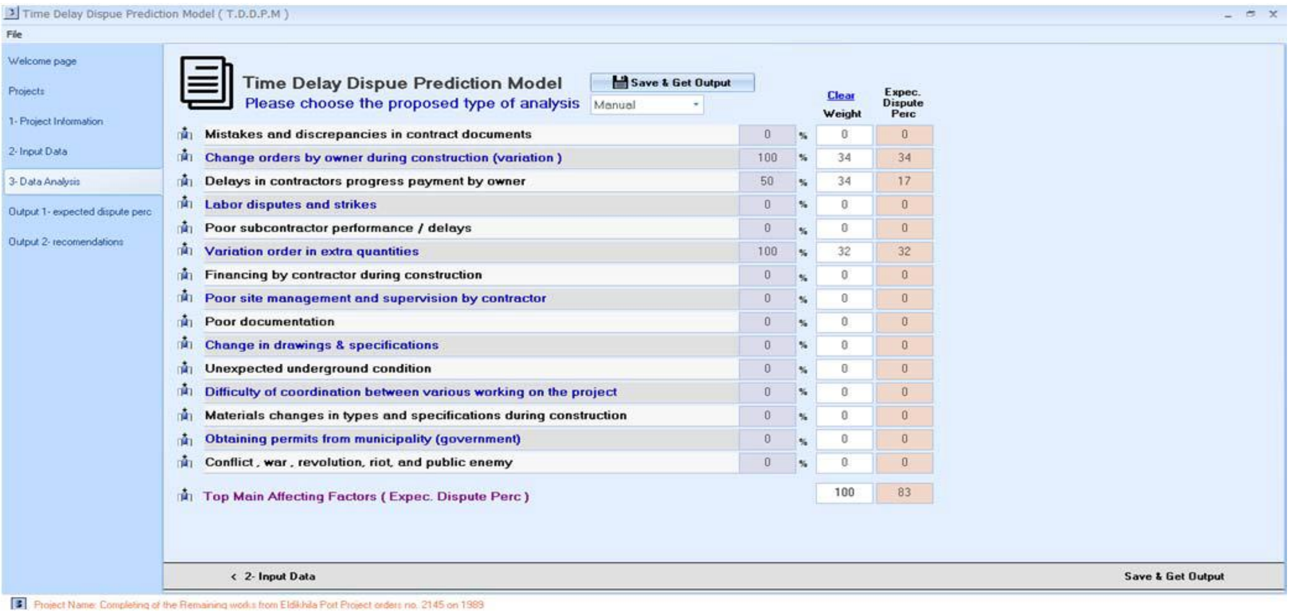


**Fig.15:** Time Delay Disputes Prediction Model for Studied Project Data Analysis

After entering the previously specified data, the user proceeds by selecting the “Save & Get Output” button. The model then performs the necessary analysis and computations to determine the expected dispute percentage, which is calculated as 89.9%, along with a corresponding grade of “very high” for dispute occurrence. This result is also visually represented through a pie chart, as illustrated in Fig. (16).

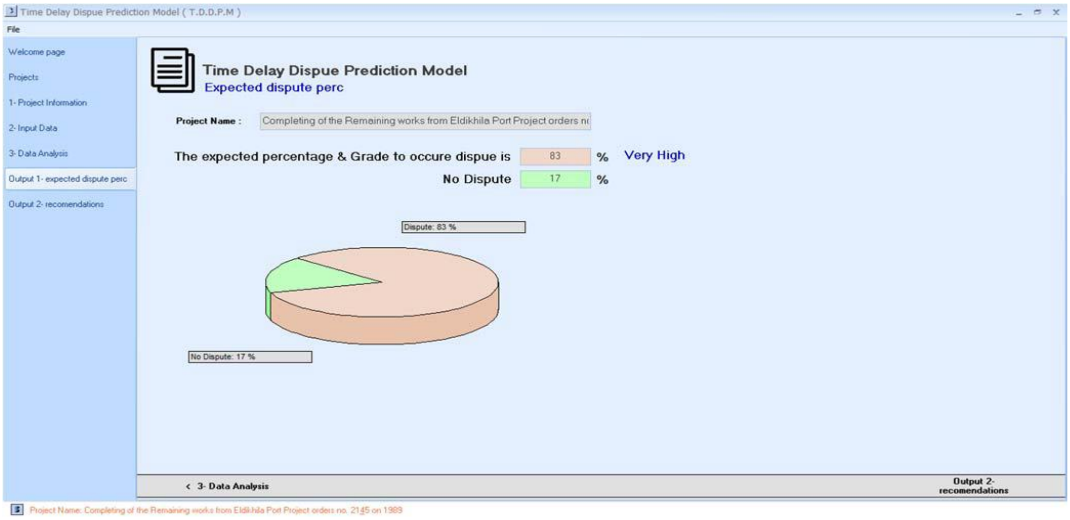


**Fig.16:** Time Delay Disputes Prediction Model for Studied Project Expected Dispute Percentage

Also, the model provides the user with key recommendations aimed at minimizing disputes during either the project study phase or the project construction phase, as outlined below: When the dispute percentage exceeds 70%, it is not advisable to proceed with awarding the project if the contract has not yet been signed, indicating that the project remains in the study phase. Project management organisations should establish a robust control system to formulate appropriate plans for managing unexpected variations and thereby reduce delays. The owner's consultant office should carefully review the project design to prevent potential variations. Sufficient time should be allocated by the owner for the preparation of project briefs and feasibility studies, while also ensuring that a comprehensive financial plan and cash flow analysis are developed. It is essential that the owner confirms the availability of adequate funding prior to the commencement of the project.

Furthermore, the owner's consultant office should thoroughly examine design drawings and the bill of quantities before contract signing to mitigate the risk of variations, and should also review and approve all drawings and specifications prior to contract execution to prevent subsequent changes. In addition, the government should strengthen and streamline the permitting system to facilitate efficient approval processes. The party responsible for obtaining permits should initiate all required procedures during the preconstruction stage, as shown in Fig. (17).

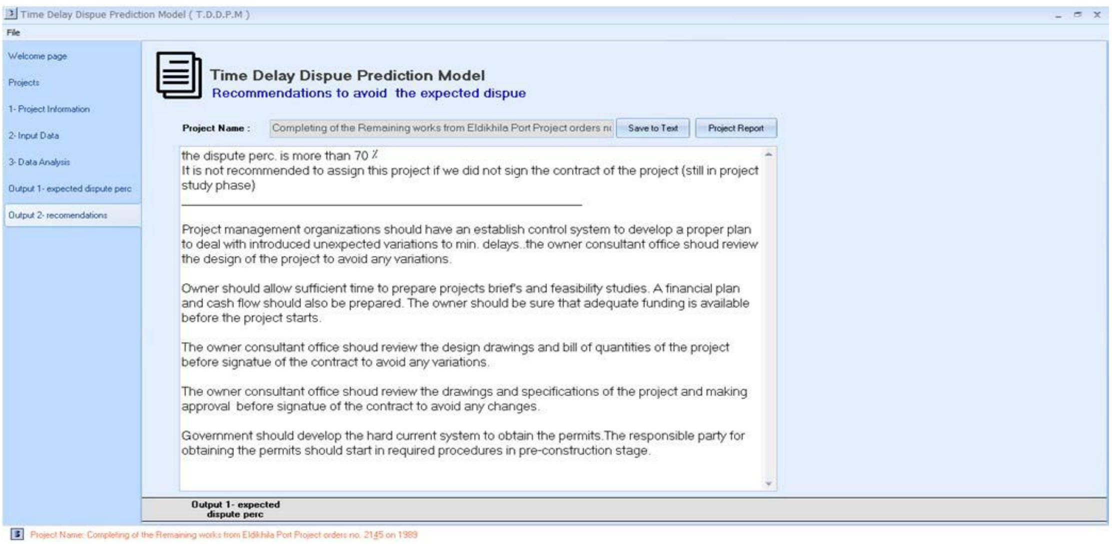


**Fig.17:** Time Delay Disputes Prediction Model for Studied Project Recommendations

Finally, the model generates a consolidated report for the project, which includes the project information, the expected dispute percentage, and the most important recommendations, all presented in a single document, as illustrated in Fig. (18).

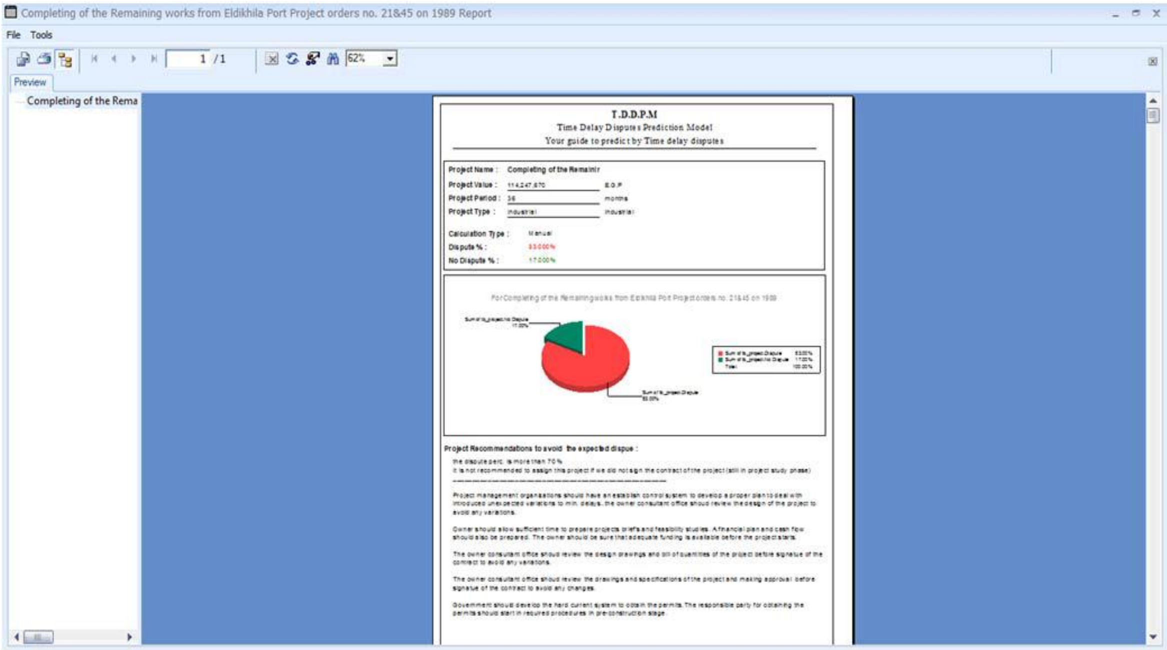


**Fig.18:** Time Delay Disputes Prediction Model for Studied Project Report

### *5.2 Comparison Between Case Study and Model Output*

It is clearly evident that there is a strong correspondence between the case study findings and the model's output. The model estimated the likelihood of dispute occurrence at 83%, categorised as "very high", while the case study itself confirms the existence of a dispute between the owner and the contractor, resulting in compensation awarded to the contractor.

## 6. Recommendations For Minimizing Time Delay Disputes

It is clearly observed that there is a strong alignment between the case study outcomes and the model outputs. The model estimates the likelihood of dispute occurrence at 83%, classified as very high, which corresponds closely with the case study findings. The case confirms the existence of a dispute between the owner and the contractor, along with compensation claims awarded to the contractor.

### *6.1 Extra Works*

Extra works represent one of the most frequent sources of time delay disputes initiated by the owner. In several instances, the owner may request an increase in the scope or quantity of the contract at short notice during the construction phase, resulting in significant delays. To mitigate such issues, a comprehensive project brief should be developed by the design team in consultation with the owner. Additionally, consultant offices and project management organisations should implement robust control systems to establish effective plans for managing unforeseen variations and minimising delays.

### *6.2 Change Orders*

Change orders are also among the primary causes of time delay disputes initiated by the owner. Often, instructions for changes are issued abruptly during the construction phase, leading to substantial delays. In some cases, these changes are extensive, necessitating major redesigns that further exacerbate delays. Such variations frequently result in project overruns, particularly when introduced midway through construction. Therefore, a complete and well-defined design should be prepared by the design team and agreed upon with the owner. Furthermore, a project brief should be prepared and reviewed collaboratively, while consultant offices and project management organisations should maintain effective control systems to manage unexpected variations and minimise delays.

### *6.3 Financing Problems (Late Payment)*

The owner should ensure adequate time is allocated for the preparation of project briefs and feasibility studies. A well-structured financial plan and cash flow analysis must also be developed. It is essential that sufficient funding is secured before the commencement of the project to prevent financial disruptions and associated delays.

### *6.4 Termination Work by Owner*

The owner should conduct thorough studies and assessments before initiating the project to avoid unforeseen circumstances that may lead to project termination. The contract should clearly define the responsibilities of all involved parties in such situations to prevent ambiguity and potential disputes.

## 7. Conclusion

The construction industry in Egypt plays a vital role in economic development, supporting sectors such as infrastructure, energy, transport, and housing. However, construction projects are typically long-term and complex, often facing disputes that hinder timely completion and increase costs. These disputes arise across project phases and are driven by factors such as delays, variations, additional works, changing site conditions, contractual issues, and unforeseen events. They often lead to negotiations aimed at adjusting time or cost to compensate affected parties. Previous studies have consistently classified delay causes into key groups, including owner, contractor, consultant, financial, labour, material, environmental, and contractual factors. Common delay causes identified in the literature include acceleration, coordination issues, differing objectives, design and quality problems, site conditions, and variations. Dispute resolution is typically addressed through mediation, arbitration, and litigation. Preventive measures emphasise realistic pricing, stakeholder familiarity, proper payment practices, and effective change management. From a technical perspective, delays are systematically classified based on origin, timing, and legal liability, distinguishing between excusable and non-excusable delays, as well as compensable and non-compensable ones. Various forensic delay analysis methods, such as as-planned versus as-built and time impact analysis, are used to determine responsibility and quantify impact. Building on questionnaire data covering 110 causes grouped into 15 categories, responses from 40 valid participants were analysed and ranked from multiple perspectives. Based on these findings, a predictive system (TDDPM) was developed with seven modules, enabling users to input project data, define probabilities, select analysis methods, and obtain predicted dispute outcomes along with recommendations. A case study involving an arbitration dispute between a governmental authority and Arab Contractors confirmed strong alignment with the questionnaire results. Application of the model to this case produced a predicted dispute probability of 83% (very high), closely matching the actual dispute outcome. The model therefore demonstrates consistency and provides effective guidance for reducing time delay disputes.

### *7.1 The Main Fifteen Causes of Time Delay Disputes*

After applying the questionnaire and completing the analysis, the fifteen most significant causes of time delay disputes were identified as follows:

#### *7.1.1 Mistakes and Discrepancies in Contract Documents*

This was ranked as the primary cause of time delay disputes, with a questionnaire score of 78.50% and an automatic model weight of 7.208%. The issue mainly arises from reliance on outdated or standardised contract forms without proper updates or coordination with related documents and project-specific requirements.

#### *7.1.2 Variation Orders*

Variation orders appeared in multiple rankings as key contributors to delays: as change orders by the owner during construction (78.00%, 7.163%), as extra quantities (73.00%, 6.703%), and as changes in drawings and specifications (71.00%, 6.520%). These delays are largely driven by unforeseen ground conditions, necessary design modifications, owner-initiated changes, and inconsistencies between design and site conditions. Comparative studies, including Ogunlana et al. (1996) similarly highlight variation orders as a major global cause of delays, with Egypt showing patterns comparable to Thailand.

#### *7.1.3 Financing Factors*

Financing issues ranked third and seventh, including delayed contractor payments (77.00%, 7.071%) and contractor financing during construction (72.5%, 6.657%). These problems are primarily linked to cash flow constraints, payment delays by owners, and economic fluctuations. Similar findings are reported in studies by Ogunlana et al. [23] although financing ranks relatively lower in Egypt and Thailand compared to Saudi Arabia, where it is a leading cause.

#### *7.1.4 Labour Disputes and Sub-Contractors Performance*

Labour disputes (75.00%, 6.887%) and poor subcontractor performance (74.5%, 6.841%) are significant contributors, often caused by political instability, skill shortages, poor workmanship, and the use of unqualified personnel.

#### *7.1.5 Poor Site Management and Supervision by Contractor*

This factor ranked eighth (72.00%, 6.612%) and is attributed to weak site control, low productivity, and inadequate supervision. Similar conclusions were drawn in studies such as Elinwa and Joshua [13], where site management was a key delay factor, with Egypt and Nigeria showing comparable trends.

#### *7.1.6 Contractual Relationships Factors*

Poor documentation and coordination difficulties ranked ninth (71.50%, 6.566%) and twelfth (70.00%, 6.428%). These issues stem from outdated contracts, complex project structures, poor communication, and unclear responsibilities among stakeholders.

#### *7.1.7 Unexpected Underground Condition*

Ranked eleventh (71.00%, 6.520%), this factor results from insufficient site investigations and unforeseen subsurface conditions such as soil variation or groundwater issues.

#### *7.1.8 Materials Changes in Types and Specifications During Construction*

This factor ranked thirteenth (69.00%, 6.336%) and is mainly due to material shortages, specification changes, and inadequate pre-construction planning. Comparative studies, including those by Ogunlana et al. [24] and Hiyassat et al. [17], confirm material-related delays as a common global issue, though with varying severity across countries.

#### 7.1.9 Obtaining Permits From Municipality (Government)

Ranked fourteenth (68.50%, 6.290%), this delay is mainly due to bureaucratic complexity, lengthy procedures, and involvement of multiple authorities in the approval process.

#### 7.1.10 Conflict, War, Revolution, Riot, and Public Enemy

Ranked last (67.50%, 6.198%), this factor reflects the impact of political instability and external disruptions, which can significantly affect project execution and all involved parties.

## 8. Recommendations

### 8.1 Mistakes and Discrepancies in Contract Documents

Such issues can be minimised through thorough review and updating of contract forms to align with current project requirements, ensuring full coordination among all contract documents, eliminating inconsistencies prior to signing, and maintaining clarity in all clauses.

### 8.2 Variations

Change orders are a major source of time delay disputes, particularly when issued at short notice during construction, often leading to significant delays and costly redesigns. To mitigate this, a well-defined and comprehensive design should be prepared and agreed upon in advance. A detailed project brief must be developed and reviewed with the owner, while consultant offices and project management teams should implement robust control systems to manage unforeseen variations and reduce delays.

### 8.3 Financing Problems

The owner should allocate sufficient time for preparing project briefs and feasibility studies, supported by a solid financial plan and cash flow analysis. It is essential to ensure adequate funding is secured before project commencement to avoid financial disruptions.

### 8.4 Labour Disputes and Sub-Contractors Performance

Labour disputes can be reduced by ensuring fair treatment, promoting skill development, and recognising labour as a key project resource. For subcontractors, selecting experienced and qualified firms, along with effective project management based on prior experience, enhances performance and reduces delays.

### 8.5 Poor Site Management and Supervision by Contractor

Delays can be minimised by appointing qualified project managers, implementing effective site management systems, and maintaining strict control over resources while continuously monitoring labour productivity.

### 8.6 Contractual Relationships Factors

Strong communication among all stakeholders and clear definition of roles and responsibilities are essential to prevent misunderstandings and disputes.

### 8.7 Unexpected Underground Condition

Inadequate site investigation often leads to major delays due to unforeseen ground conditions. Conducting comprehensive and detailed geotechnical investigations during the tender stage helps minimise risks, reduce design changes, and avoid delays.

### *8.8 Materials Changes in Types and Specifications During Construction*

Efficient procurement and material management systems should be established. Designers and consultants must consider material availability and avoid specifying materials that are difficult to source, especially imported items, to prevent delays.

### *8.9 Obtaining Permits from Municipality (Government)*

The permitting system should be streamlined and improved. The responsible party should initiate all necessary procedures during the preconstruction phase to avoid administrative delays.

### *8.10 Conflict, War, Revolution, Riot, and Public Enemy*

Contracts should clearly define the roles and responsibilities of all parties in the event of such exceptional circumstances to ensure proper risk allocation and minimise disruptions.

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