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RESEARCH

A systems thinking approach for managing design change complexities in UAE construction projects

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Abstract
This study investigates the complexities of construction delays in the UAE arising from design changes and proposes a system-based approach to improve their management across the project lifecycle. A case study strategy was adopted, employing semi-structured interviews and site observations to capture stakeholder-specific perspectives on the causes, impacts, and mechanisms of design changes. Using thematic analysis, the study integrates systems thinking to map interdependencies between stakeholders, project phases, and design change events. The findings demonstrate that design changes represent multi-dimensional challenges requiring coordinated, stakeholder-sensitive strategies. This study introduces a novel systems thinking-based model incorporating storytelling techniques to support the management of design changes in UAE. By addressing project complexity holistically, the model provides a foundation for improving design change management across diverse project contexts.

Keywords Design changes · Delays · Impacts · UAE · Systems thinking

Introduction

The construction sector in the UAE continually attracts significant attention from researchers and practitioners due to its rapid urban transformation and dynamic project development [1]. Construction delays remain a persistent challenge, driven by complex interactions between financial constraints, material delivery issues, coordination problems, and fragmented stakeholder relationships [2–5]. Among these factors, design changes have emerged as a particularly influential contributor to schedule overruns, especially within fast-paced markets such as the UAE (Elhusseiny et al., 2021; Yap et al., 2017).

Globally, design changes are widely recognised as a significant contributor to construction delays, impacting timelines and budgets [6–8]. In the UAE, the fast-paced construction industry exacerbates the effects of design changes [9, 10]. Mohamed (2023) highlights that delays affect over 55% of residential projects in India, while Sanni-Anibire (2022) emphasises their global prevalence, citing causes such as contractor financial difficulties, poor planning, and delays in approvals [4, 5]. In the UAE, only 30% of residential construction projects meet cost and schedule targets, with design changes emerging as a leading factor [11].

Although design changes are frequently associated with client-driven decisions [1], their occurrence and impact are shaped by the actions and interactions of multiple stakeholders, including architects, consultants, and contractors [12]. Additional contributing factors include ineffective communication [13], contractual issues [14], and financial constraints [15]. Despite the extensive body of research on delay causes, much of the existing literature adopts a static perspective, focusing on the identification and ranking of factors rather than examining how their impacts evolve and interact over time [3, 9]. In particular, the dynamic nature of design changes, where early decisions can trigger cascading effects across subsequent project phases remains insufficiently explored. Furthermore, the absence of structured design management frameworks in the UAE, comparable to stage-based systems such as the RIBA Plan of Work in the UK, increases coordination complexity and uncertainty among stakeholders [1, 12].

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To address these challenges, this study adopts a systems thinking perspective to analyse design changes as a dynamic and interconnected process rather than isolated events. By modelling stakeholder interactions, project lifecycle stages, and feedback relationships, the research aims to provide a more holistic understanding of how design changes generate and amplify delays within UAE construction projects. The primary audience for this research includes project managers, consultants, and contractors who play critical roles in coordinating design-related decisions and managing their implications.

Accordingly, this study makes the following contributions:

- Develops a systems thinking-based model that captures the dynamic interactions and feedback mechanisms associated with design changes and their influence on project delays.
- Provides a lifecycle-oriented analysis demonstrating how the impacts of design changes evolve and propagate across different project phases.
- Examines stakeholder interdependencies, highlighting how coordination challenges and decision processes contribute to delay escalation.
- Introduces a context-specific analytical framework tailored to the UAE construction environment, where formal stage-based design governance is limited.
- Generates practical insights to support more proactive and systematic management of design changes by project managers, consultants, and contractors.

Literature review

Construction delays in the UAE

The construction sector in the UAE contributes significantly to the economy, accounting for approximately 14% of the national GDP and supporting the country's rapid transformation into a globally recognised urban centre [1]. The UAE attracts significant research attention due to its rapid urban transformation, with Dubai being one of the most developed cities worldwide [16]. As with many countries, construction delays remain a persistent issue in the UAE [4, 17]. This is because many projects involve international companies, feature complex levels of execution, and utilise a wide range of technologies [18, 19].

Many studies focus on construction delays in the UAE, as understanding their root causes and effects has significant implications for the long-term maturity and development of the construction industry. For instance, a recent study by Tariq and Gardezi (2023) identified factors leading to delays by contractors, clients, and consultants, concluding that change orders and specification changes were the top factors [12]. Another study conducted a chronological investigation identifying delay factors in construction between 2000 and 2010 [20]. This study, using a questionnaire survey, also found design changes to be the top factor causing delays. In the broader region also, similar trends are observed. In Saudi Arabia, changes made at different stages are a major cause of delays [1, 21]. In Kuwait, design changes were among the top three causes of time delays in a survey of 450 private residential projects [5]. Other studies identified several issues including design variations, payment delays, poor planning and scheduling, lack of site management, labour shortages, and contractor financial issues, which collectively caused 70% of the delays in Saudi residential building projects [22]. Furthermore, change orders were the most frequent cause of claims, with an importance index of 55%, while "delay caused by the owner" ranked second with an importance index of 52.5% in a study by Zaneldin (2020) on construction claims for residential buildings in the UAE [23].

While many studies (e.g. Tariq and Gardezi, 2023; Motaleb and Kishk, 2010) have attempted to identify the top factors causing delays in the UAE [12, 20], few have specifically investigated the impact of design changes. Most of the existing studies are quantitative, which may limit a holistic understanding of specific delay causes and their interdependencies. To address this, the following sections focus more closely on the causes and impacts of design changes, highlighting where existing research does not provide a comprehensive or system-based understanding of these issues.

Causes of design changes

Over the years, many studies have investigated design changes and attempted to identify the primary causes leading to them. Various causes of design changes have been identified by many researchers in different regions. For instance, a recent study by Sanni-Anibire et al. (2022) conducted a meta-analytical review to focus on delays at a global level where design changes were highlighted as one of the causes that is associated with different stakeholders [4]. Another study by Gharaibeh et al. (2021) investigated factors that lead to design changes with particular focus on Jordanian construction projects where the study concluded that the client plays a major role in causing design changes [3]. In the Middle East, recent studies (e.g. Elhusseiny et al., 2021; Gharaibeh et al., 2020; Alsuliman, 2019) have looked into the causes and impacts of design changes [3, 10, 24]; however, these studies were context-specific and did not holistically categorise the causes according to different stakeholders. In a UAE context, three major design variables are recognised as Scope adjustment, regulatory compliances and stakeholder coordination. To provide more informative insight into design changes, the authors deductively compiled different causes (see Table 1) that lead to design changes, and mapped the causes respectively to

Table 1 Causes of design changes in construction projects

Stakeholder	Cause of Design Change	Studies
Client	Requirement and Specification changes	Do et al. (2023); Selcuk et al. (2022); Elhusseiny et al. (2021); Aladağ and Işık (2019)
	Value Engineering (e.g., cost savings)	Gashaw and Jilcha (2023); Selcuk et al. (2022); Shen and Ying (2022); Soman et al. (2020)
	Vagueness of the client brief	Do et al. (2023); Sanni-Anibire et al. (2020); Chen et al. (2020);
	Scope adjustment, addition, or omission	Tariq and Gardezi (2022); Elhusseiny et al. (2021); Chen et al. (2020);
	Extra requirements	Padala and Maheswari (2023); Sanni-Anibire et al. (2020); Aladağ and Işık (2019)
	Change of project financing	Gashaw and Jilcha (2023); Egwin et al. (2021); Soman et al. (2020)
	Ineffective decision-making	Barqawi et al. (2022); Elhusseiny et al. (2021); Soman et al. (2020); Aladağ and Işık (2019)
	Change the usage of the project	Do et al. (2023); Barqawi et al. (2022); Sanni-Anibire et al. (2020); Chen et al. (2020)
Consultant	Lack of coordination between different disciplines	Gurgun et al. (2022); Selcuk et al. (2022); Gunduz and Al-Naimi (2021); Soman et al. (2020).
	Lack of understanding of the owner's requirements	Padala and Maheswari (2023); Selcuk et al. (2022); Soman et al. (2020); Aladağ and Işık (2019)
	Design documents errors or inconsistencies	Selcuk et al. (2022); Gharaibeh et al. (2020); Chen et al. (2020); Viles et al. (2020)
	Constructability issues	Shen and Ying (2022); Tariq and Gardezi (2022); Aladağ and Işık (2019)
	Quality specifications compliance	Stewart and Shirvan (2023); Chen et al. (2020); Bortolini et al. (2019)
Contractor	Change of methods of construction	Egwin et al. (2021); Gharaibeh et al. (2020); Alsuliman (2019)
	Enhancing buildability	Zeng et al. (2022); Barqawi et al. (2022); Chen et al. (2020); Bortolini et al. (2019)
	Material shortage	Gunduz and Al-Naimi (2021); Gharaibeh et al. (2020); Alsuliman (2019)
	Fixing construction errors	Do et al. (2023); Barqawi et al. (2022); Soman et al. (2020); Aladağ and Işık (2019)
	Improvement of work quality	Shen and Ying (2022); Barqawi et al. (2022); Viles et al. (2020); Aladağ and Işık (2019)
	Improving health and safety aspects	Stewart and Shirvan (2023); Aladağ and Işık (2019); Bortolini et al. (2019)
	Coordination of drawings and design due to discrepancies	Padala and Maheswari (2023); Do et al. (2023); Gunduz and Al-Naimi (2021)
	Technical issues from suppliers	Do et al. (2023); Barqawi et al. (2022); Chen et al. (2020); Viles et al. (2020)
	Lack of workers' skills	Gurgun et al. (2022); Aladağ and Işık (2019); Soman et al. (2020)
Site related	Geotechnical Problems	Stewart and Shirvan (2023); Tariq and Gardezi (2022);
	Clash with neighboring structures/buildings	Gurgun et al. (2022); Elhusseiny et al. (2021); Chen et al. (2020)
	Undiscovered utilities or services on site	Egwin et al. (2021); Chen et al. (2020); Alsuliman (2019)

the client, consultant, contractor, and the site-related factors. While many studies have identified causes of design changes, most do not examine them systematically across stakeholder groups. This study addresses this gap by organising the causes in a structured manner to support a clearer understanding of their relationships and implications.

Impacts of design changes

Design changes, aside from being a direct cause of construction delays, can consequently cause a variety of problems. One of the main impacts of design changes is causing 'rework', which can have many implications across various phases within a construction project [14, 25, 26] Abdul-Rahman et al. (2016) summarised design change induced rework as “unnecessary efforts of redoing a process of work or activity due to incorrect implementation at the beginning that arise from design changes” [9]. In this context, rework can be an owner change, designer change or error, contractor change, or error and supplier change or error, and the reasons can appear in design, construction or even start-up stages [27]. It is revealed that design change orders resulting in rework can account for as much as 50% of project cost overrun [28–30]. Similarly, many studies showed that rework costs arising in industrial engineering projects are the result of design changes, errors, and omissions [13]. Design-related rework generates costly ripple effects that create delay and disruption, which eventually leads to cost overruns and schedule delays.

Design changes in construction projects can directly lead to cost overruns or schedule delays [2, 31]. Overruns in project schedule and project cost are key principles for a successful project but are adversely impacted by design changes [2, 25, 32, 33]. Additionally, studies revealed that design changes often have a major impact on the client objectives in construction projects where the cost associated with post contract award design changes typically amounts about 5% to 8% of the contract value [3]. Another study by Chang et al. (2011) reported that design changes resulted in an increased in redesign cost of 2.1% to 21.5% and on average 8.5% of the construction change cost [34]. The authors have summarised (see Table 2) impacts of design changes..

Table 2 Effects of design changes in construction projects

Category	Impact of design changes	Studies
Direct Impact	Rework or revision of work	Zeng et al. (2022); Barqawi et al., (2022); Chen et al. (2020); Bortolini et al. (2019)
	Schedule Delay	Barqawi et al., (2022); Chen et al. (2020); Soman et al. (2020); Aladağ and Işık (2019)
	Cost overruns	Do et al. (2023); Barqawi et al. (2022); Gharaibeh et al. (2020).
Indirect Impact	Excessive claims/disputes	Chen et al. (2020); Bortolini et al. (2019); Gurgun et al. (2022)
	Loss of productivity/work rhythm	Egwin et al. (2021); Gharaibeh et al. (2020); Alsuliman (2019)
	Coordination issues and errors	Stewart and Shirvan (2023); Aladağ and Işık (2019); Bortolini et al. (2019)
	Lower moral of work force	Gurgun et al. (2022); Soman et al. (2020); Aladağ and Işık (2019)
	Poor construction quality	Shen and Ying (2022); Tariq and Gardezi (2022); Aladağ and Işık (2019)

In the UAE construction projects often face delays in completion, there have been some efforts that investigated construction delays (e.g. Motaleb and Kishk, 2010; Motaleb, 2021) where findings indicated that design changes or change orders are the top cause of delays across different construction projects that impose huge impacts in the success of the project [20, 35]. The impacts are exacerbated by the ambitious scale and complexity of projects; hence design changes are seen as one of the biggest hurdles causing cost overruns and delayed handover. Whilst this suggests that design changes are often client-driven, the literature review indicates that they may also originate from contractor, consultant or site-conditions. This can be attributed to the fact that many developed countries (e.g. UK and USA) have standardised guidelines [1] for project delivery such as RIBA which limits many causes for design change-related delays however, this is particularly complex in developing countries such as the UAE where there are no clear guidelines for project delivery. Therefore, the limited holistic investigation of design-change impacts in the UAE highlights the need for a system-based examination of how these changes interact across project phases and stakeholders.

Research methodology

This research identifies the gap through a critical review of existing literature, justifying the rationale behind the research question. The literature spans a wide range of sources addressing construction delays, with a particular focus on design changes as a primary cause of delays within the UAE construction industry. The study adopts a qualitative case study approach to contextualise the phenomenon [36], selecting a high-rise mixed-use development project in the UAE as the case study. Figure 1 illustrates the methodological approach followed in this study.

Primary data collection involved semi-structured interviews with six industry professionals directly involved in the project, identified using purposive sampling. In qualitative case study research, smaller participant numbers are appropriate when the aim is to capture rich, detailed accounts from those with direct and substantial engagement in the phenomenon under investigation. Participants included those from the contractors’, subcontractors’, and consultants’ sides who had direct engagement with design changes in this project. The interviewees’ experience ranged between 10 and 25 years, ensuring that each participant had adequate professional exposure to contribute meaningfully. This approach ensured diverse perspectives while mitigating selection bias through clear, systematic criteria.

To enhance credibility and confirmability, the interviews were supplemented with observational data (such as site photographs, meeting notes, marked-up drawings, and on-site documentation). These observations were analysed using the same

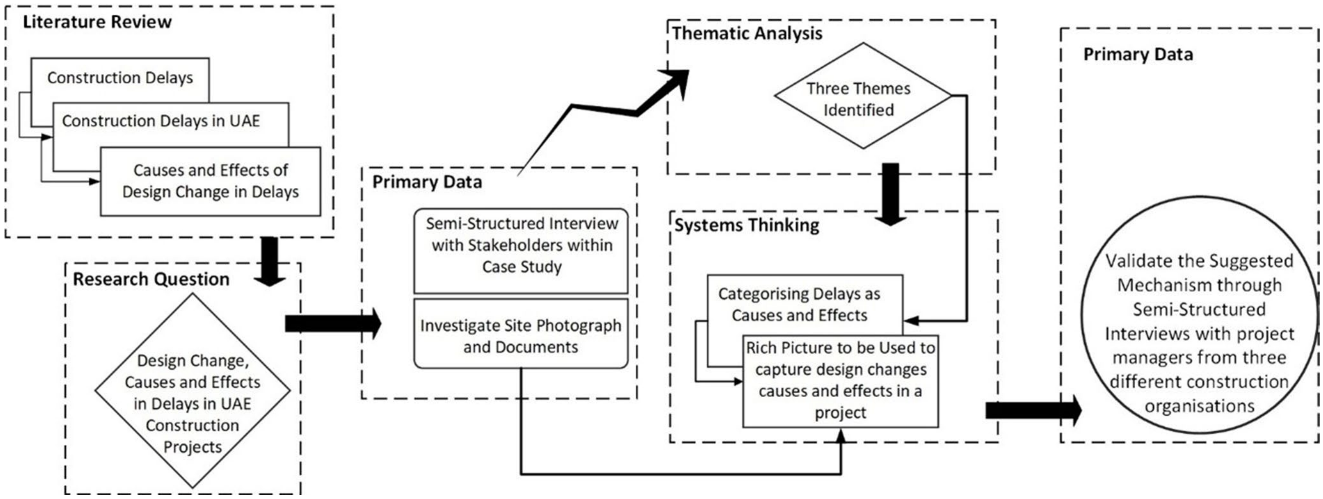

Fig. 1 Proposed research methodology

thematic procedures to ensure consistency and traceability, and the triangulation of multiple data sources is widely acknowledged to strengthen the robustness of qualitative findings [37].

The case study project, a 260-metre-tall 67-storey tower comprising a podium, hotel, sky lobby, and residential apartments, was originally valued at $18.2 million USD. The "260-metre" refers to the vertical height of the tower, as opposed to floor area. Initially designed as a hotel, the project scope was altered to a mixed-use property to align with market demands. Construction, underway during data collection, was delayed by over two years due to COVID-19 restrictions, design changes, and scope variations.

The interviews explored participants' experiences (see Table 3), incidents, and perceptions to holistically understand the causes and effects of design changes. Questions were categorised into four groups: (1) introductory questions about the participants' backgrounds, (2) general and project-specific delays, (3) design change causes, and (4) recommendations for delay prevention. Saturation was achieved when no new themes emerged from the interviews, ensuring comprehensive evidence collection.

Qualitative data were analysed using thematic analysis, a widely recognised method for identifying, interpreting, and reporting patterns within qualitative datasets [38]. NVivo software was used to facilitate a systematic and structured coding process, ensuring consistency and traceability across multiple data formats, including interview transcripts, photographs, and documents [39]. The identified themes provided insights into the systemic nature of design-induced delays, revealing interdependencies between stakeholder decisions, procurement processes, and site operations.

The themes generated from the analysis were subsequently synthesised into a systems Thinking model. The process for constructing the model followed standard systems-thinking procedures, including rich-picture development, feedback loop identification, and mapping of cause–effect relationships. This allowed the interconnected dynamics of project delays and their cascading effects to be conceptualised visually.

To validate the proposed model, structured interviews were conducted with six participants from three construction companies located in the UAE. These validation interviews were separate from the initial data collection and involved different individuals, ensuring that the validation process was unbiased and not limited to those who contributed the original data. Participants were asked to evaluate the clarity, accuracy, and practical relevance of the model, confirming its applicability and scalability to similar UAE construction projects.

Table 3 List of participants in the study

Interviewee	Stakeholder	Designation
#1	Contractor	Construction Manager
#2	Contractor	Senior Architectural Engineer
#3	Sub-contractor	Senior Project Manager
#4	Consultant	Senior Project Manager
#5	Consultant	Project Engineer
#6	Sub-contractor	MEP Coordinator

Results and analysis

Thematic analysis of interview data

Causes and effects of delays

Interviewees unanimously identified design changes due to client requests as the primary cause of delays in the case study. Interviewee #1 noted that functional design changes necessitated new finishing materials, which led to delays. Interviewee #2 added that slow decision-making further compounded delays due to the cascading impact of design alterations. From contractors' and subcontractors' perspectives, consultants play a critical role in minimising delays caused by design changes. According to Interviewee #1, poor planning and scheduling by consultants contributed to project delays, while Interviewee #2 emphasised miscommunication and lack of coordination as major issues: "If there are any changes, they should be highlighted to all parties."

Several participants highlighted delays stemming from contractors and subcontractors. For example, Interviewee #3 stated, "Our work depends on the contractor; they have to cast the slab first so we can embed the channel for glass balustrade." Interviewee #5 noted discrepancies between site conditions and drawings, requiring redesigns to match actual conditions. Subcontractors were also impacted by contractor delays. Interviewee #2 cited a case where a façade subcontractor's proposed sliding door system failed a mock test, causing delays until the issue was resolved. Other contributing factors included site accessibility, logistical issues, and storage challenges, which collectively resulted in time and cost overruns. For summary on causes and effects, please see Fig. 2.

Figure 2 shows the causes of delay based on the interview responses. The causes are grouped according to the four main stakeholder categories involved in the project: client, consultant, contractor, and subcontractor. The structure of the figure is intended to distinguish the origin of each delay factor rather than imply hierarchy or severity. This helps clarify how responsibilities and causes are distributed across stakeholders, in line with the thematic analysis.

Delays due to design changes

The interviewees were asked specifically to share their points of view about delays occurring due to design changes. Interviewee #2, #3, #4 and #5 stated that the primary driver of design changes is the client. Interviewee #2, #4 and #5 agreed that the type of market that exists in the UAE influences design changes. The interviewee also mentioned there were cases that the client decides to reduce the budget of the project even without market changing. Interviewee #3 stated that most of the clients look for high quality and low price. Interviewee #2 agreed on that, and he added: "In the tendering stage when the contractor sees a low quality and material selection, they might not prefer to go for low-quality materials. So basically, the client starts at a high level and then when they choose the contractor, they can reduce the quality". Interviewee #1 supported that by stating that most of the times the Bill of Quantities (BOQ) and the finishing schedule are subject to change due to market fluctuations. From another angle, design changes can be unprecedented events, for instance, interviewee #3 indicated "the change in project scope also required changing material type to suit appropriate façade type for hotels" and interviewee #2 added "we were required to review the required opening for

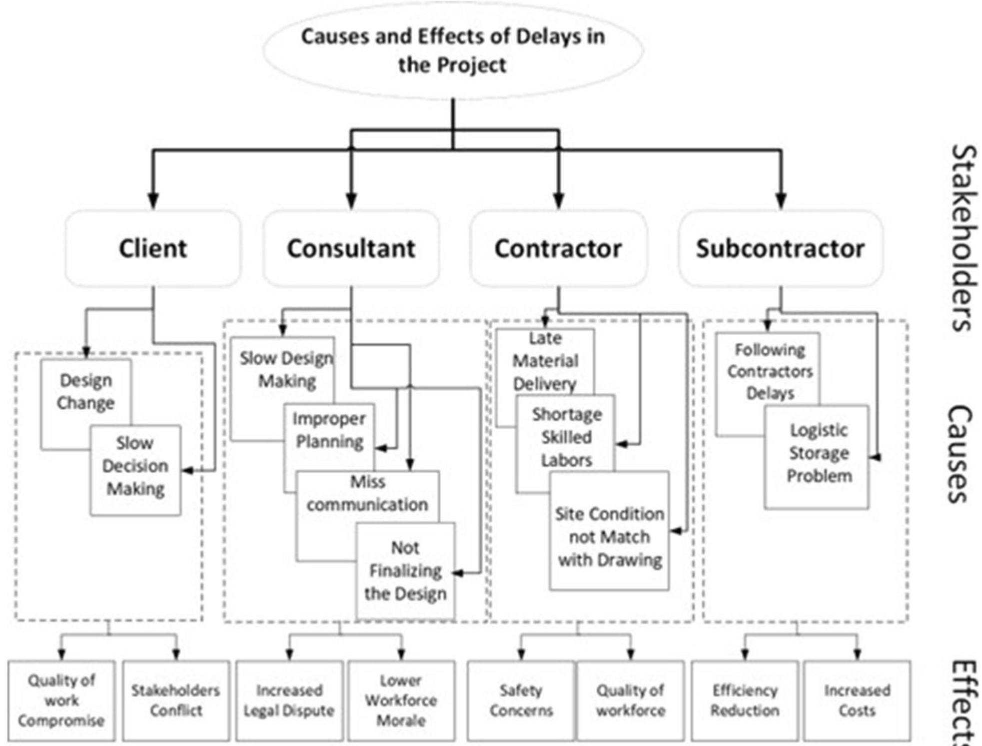

Fig. 2 Causes and effects of delay based on the responses

residential building is not the same as the hotel therefore, the contractor had to wait for the final design to be able to reflect it in structure". The interviewees collectively agreed that the implications of design changes are difficult to quantify or even assert, and the impacts can be across different phases of the project. Figure 3 summarises the delays due to design change based on participants' responses.

Figure 3 presents the delays arising from design changes, categorised according to client, consultant, authorities and contractor. The arrangement of elements is intended to map the flow of impacts associated with design change events rather than indicate ranking or severity. This would help to understand the interconnetion between delays caused by design changes, which are used to inform the rich picture in the discussion section.

Delay mitigation strategies

Participants suggested various strategies to mitigate delays. Early design freezes were recommended by Interviewees #1 and #2 as critical to managing client-driven changes. Interviewee #1 also emphasised maintaining a risk register and leveraging lessons learned from past projects. Interviewee #5 highlighted the importance of clear contracts, while Interviewee #3 stressed selecting experienced professionals early in the project lifecycle. Other strategies included accelerating project schedules when needed, establishing timely claim mechanisms, and enforcing delay penalties.

While technologies such as BIM was deemed valuable, interviewees agreed it is not a standalone solution for addressing delays caused by design changes. Interviewee #1 explained, "BIM is useful to identify clashes, especially for MEP, but it doesn't directly reduce project durations because it doesn't address the root causes of delays." Instead, effective project management was identified as the key to delay mitigation, particularly in the UAE's complex construction landscape. Timely and accurate information sharing was seen as essential for mitigating delays in fragmented supply chains. Interviewee #6 advocated conducting simulations and setting baseline targets with time buffers from the design stage to prevent delays. Figure 4 summarises delay mitigation strategies derived from the N-vivo analysis.

Figure 4 outlines the general measures suggested by participants to minimise or mitigate delays caused by design changes. These measures support understanding that design changes are not single phase-related, but rather measures that need considering across multiple phases.

Observational analysis of design change processes

This case study used observational data to complement insights from semi-structured interviews. The observations provided real-world perspectives on the causes and impacts of delays within a high-rise mixed development project in the UAE. This approach aimed to capture the complexities and events directly contributing to project delays. Observations were categorised into three areas: the impact of design changes on construction progress, stakeholder interactions, and shifts in construction site dynamics.

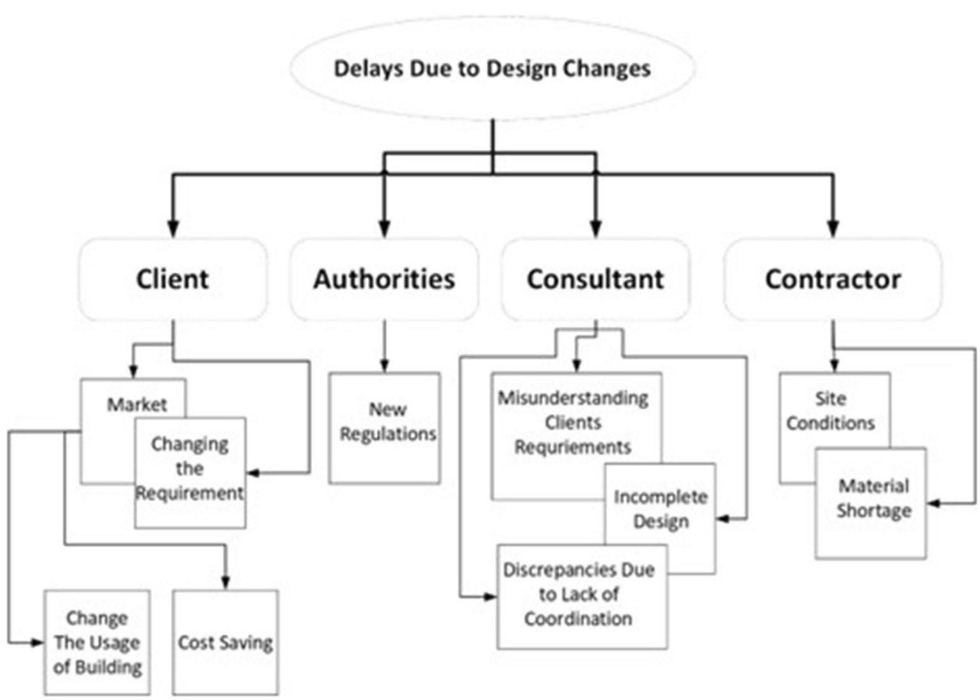

Fig. 3 Delays due to design changes

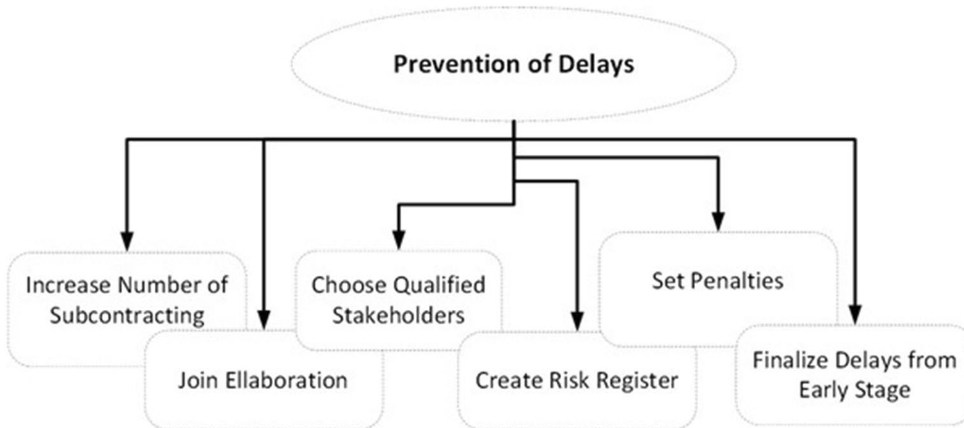

Fig. 4 Suggested measures to prevent delays

Impact of design changes on construction progress

Observation: The introduction of design changes frequently caused disruptions in the construction schedule. A notable instance was the redesign of the hotel lobby, which necessitated the removal and reconstruction of several interior partitions. This not only delayed the lobby construction by approximately two weeks but also had a cascading effect on related tasks, such as electrical and plumbing work.

Examples observed:

- Façade Material Change: The decision to use a different façade material for the residential section (floors 37 to 63) delayed construction due to longer procurement times. This also required additional structural support adjustments to accommodate the new material specifications.
- HVAC system Overhaul: The shift to a more advanced HVAC system than initially planned for the podium section demanded significant changes in the floor plans, resulting in a slowdown in construction. This alteration required additional engineering assessments and modifications to existing ductwork layouts.

Stakeholder interactions and meetings

Observation: The stakeholder meetings were key forms for decision-making, where the implications of design changes were intensely debated. These discussions often revolved around the trade-offs between project vision and practical constraints such as time and budget.

Examples observed:

- Interior Design Theme Revision: A major meeting led to the decision to revamp the interior design theme of the hotel. The meeting highlighted divergent views on aesthetic appeal versus cost implications, eventually reaching a consensus that balanced both aspects.
- Subcontractor's Concerns on Late Changes: A subcontractor expressed significant concerns over the late introduction of a design change, pointing out the logistical challenges and potential budget overruns. This prompted a problem-solving session, focusing on minimising disruptions while adhering to the new specifications.

Construction site dynamics

Observation: The on-site dynamics underwent noticeable changes post-design alterations. The workforce showed resilience and adaptability, but not without initial periods of decreased efficiency and reorientation to new objectives and methods.

Examples observed:

- Sky Lobby Design Modification: The redesign of the sky lobby led to significant adjustments in construction workflow. This change was initially met with logistical challenges, as crews needed to familiarise themselves with the new design and coordinate effectively to minimise disruption.
- Training for New Techniques: Certain design changes necessitated upskilling or briefing sessions for workers, particularly when new construction techniques or unfamiliar materials were introduced. This process, while essential, temporarily diverted resources from active construction tasks.

The observations highlighted the multifaceted impact of design changes on construction projects. Redesigning the hotel lobby, façade material changes, and HVAC system upgrades underscored the cascading delays caused by such alterations. Stakeholder meetings were pivotal in balancing project vision against practical constraints, while the on-site workforce demonstrated resilience in responding to evolving project demands, albeit with initial challenges. These findings underline the need for meticulous planning, early design finalisation, and proactive communication among stakeholders to mitigate the ripple effects of design changes. They emphasise the significant influence of decision-making and coordination on project success and timelines. By identifying these dynamics, the study offers actionable insights for managing design changes in complex construction projects.

Discussion and practical implications

Development of the systems thinking model

This study investigated the causes and impacts of delays due to design changes in a UAE construction project. A holistic approach was adopted to move beyond generic stakeholder solutions. Systems thinking was used to address the complexity of project delays by broadening perspectives and clarifying interdependencies [40, 41]. While it does not provide definitive solutions, it helps to minimise problem severity and support informed decision-making (Michael, 2019). The methodology involved developing rich pictures, which visually represent interactions, clarify concepts, and enhance understanding [28, 41]. In this study, a Rich picture was created from case study data, illustrating how design changes triggered reinforcing feedback loops that compounded project delays. Client-driven modifications disrupted procurement, subcontractor scheduling, and site execution, creating self-perpetuating cycles of inefficiency. Additionally, fragmented stakeholder decision-making and misalignment between consultants and contractors further exacerbated delays. However, balancing feedback loops were identified, where mitigation strategies such as early design freezes, structured communication, and contractual controls helped to counteract these effects. By applying a systems thinking perspective, this research moves beyond linear cause-and-effect models, demonstrating that project delays emerge from dynamic interdependencies. This highlights the need to identify strategic leverage points such as improved stakeholder coordination, predictive simulation tools, and adaptive governance to disrupt these cycles and enhance project resilience.

Figure 5 presents the Rich picture, which illustrates the complexity of design changes, their impact on stakeholders, and the interaction between causes and effects.

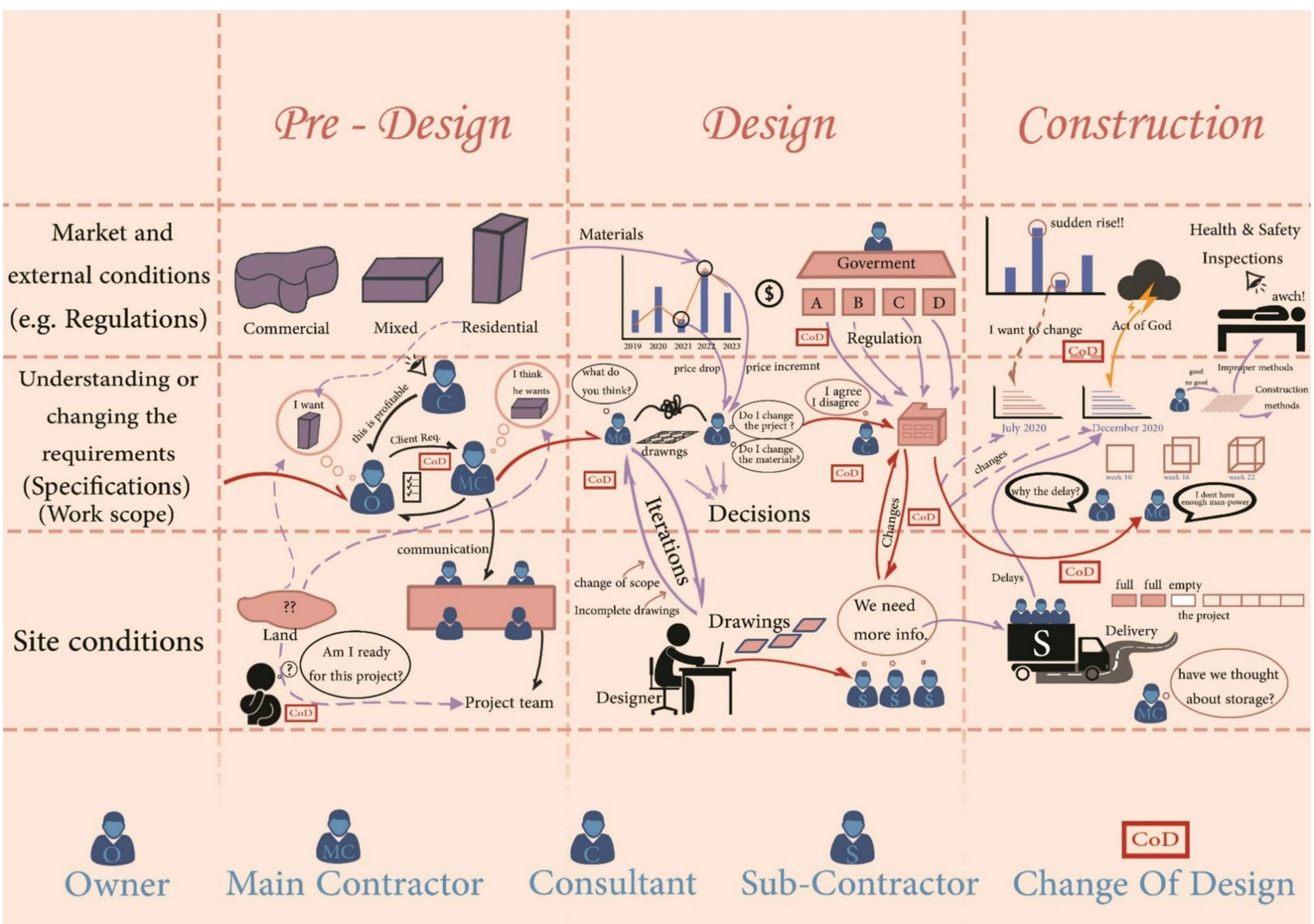

Fig. 5 Rich picture presenting different interconnections between stakeholders to understand causes and impacts of design changes

The causes of delays are categorised into market changes, regulatory requirements, and site conditions, and aligned with construction stages across the lifecycle (pre-design, design, and construction). Early-stage design changes are typically less disruptive than later ones, while market fluctuations often lead to adjustments in finishes or materials. External triggers, such as regulatory updates or unforeseen incidents, also contribute to delays. The Rich picture uses arrows to depict relationships: red arrows represent project-stage progression, while purple and dotted arrows indicate direct and indirect impacts. This visual tool helps to clarify interdependencies and the systemic nature of delays.

CoD Events: Beyond Isolated design changes

This research provides an improved and holistic visualisation of design changes across the lifecycle of a construction project. Whilst many of the reported causes and impacts of design changes by participants align with former studies [2, 4, 15], the proposed mechanism using soft system analysis has shed light on two significant elements.

The first element is visualising design changes as lifecycle events rather than isolated decisions. This supports understanding the interrelationships between causes and impacts, illustrating how a single design change can propagate across pre-design, design, and construction stages, with varying levels of disruption. The identification of these interrelationships has reflected the complexities associated with design changes as a major cause of delays. The reveal of these complexities was possible through abstract conceptualisation of project boundaries (e.g. site conditions) in the Rich picture and mapping causes and impacts across multiple stages of the project lifecycle.

The Rich picture revealed that most complexities associated with design changes arise from the interactions that occur during pre-design and design stages, which is consistent with broader literature indicating that early-phase uncertainty, poor clarity of requirements, and limited coordination increase design volatility [2, 13, 42]. This finding therefore reflects a case-specific observation that is also supported by existing studies, which helps validate the interpretation.

The second element is the need to visualise design changes as a series of CoD (Change of Design) events with both immediate (short-term) and downstream (long-term) impacts [5]. The term “CoD event” is used to denote a discrete design-change incident that triggers multiple interconnected consequences, illustrating its systemic nature. Visualising these CoD events from an early stage can therefore help stakeholders anticipate impacts and mitigate ripple effects. For instance, referring to the case scenario in Fig. 6, the CoD event identified impacts on relevant stakeholders in one stage, but this can extend to other actors depending on the complexity of the project.

To validate the mechanism proposed in this research, the researchers proposed a hybrid model (see Fig. 6) that supports capturing the causes and impacts of change of design (CoD) in a project. The proposed hybrid model illustrates the connectivity between different phases (bottom side of the triangle), project factors (right side of the triangle), which can vary in terms of their significance across different phases in different projects, and finally the importance of having an integrated approach (left side of the triangle) between different stakeholders across the whole lifecycle.

Validation and practical implication systems thinking

To assess the content validity, practical relevance, and operational feasibility of the proposed hybrid model, a structured expert validation process was conducted with six project managers from three different construction companies in the UAE (two from each organisation). Importantly, these validation participants were not the same individuals involved in the initial semi-structured interviews. This ensured that the validation process was independent of the original data collection and avoided potential bias from participants evaluating a model derived from their own responses. The use of six participants is justified on the basis that content validation seeks expert judgement rather than statistical generalisation. Expert validation exercises typically rely on relatively small panels (between 5 and 10 participants), where the emphasis is placed on the depth of expertise and the quality of feedback rather than sample size. By selecting managers from three different firms, the exercise incorporated diverse organisational practices and perspectives, thereby reducing the risk of single-company bias and enhancing the robustness of the validation exercise.

Participants were first introduced to the Rich picture (see Fig. 5), hybrid model (see Fig. 6), with explanations of their purpose and scope (see example in Table 4). Structured interview questions were then used to evaluate five thematic areas: (i) construct coverage, (ii) causal accuracy, (iii) operational feasibility, (iv) applicability, and (v) predictive and solution-oriented value. Results from the validation are presented in Table 4.

Overall, the validation results indicated a high level of agreement regarding the relevance and practical value of the proposed model. Participants confirmed that the identified constructs, stakeholder relationships, and feedback mechanisms were consistent with their project experience and reflective of common design change dynamics within the UAE construction context.

The validation process highlighted two contextual factors that were incorporated into the interpretation of the model: (i) the role of supply chain constraints as amplifiers

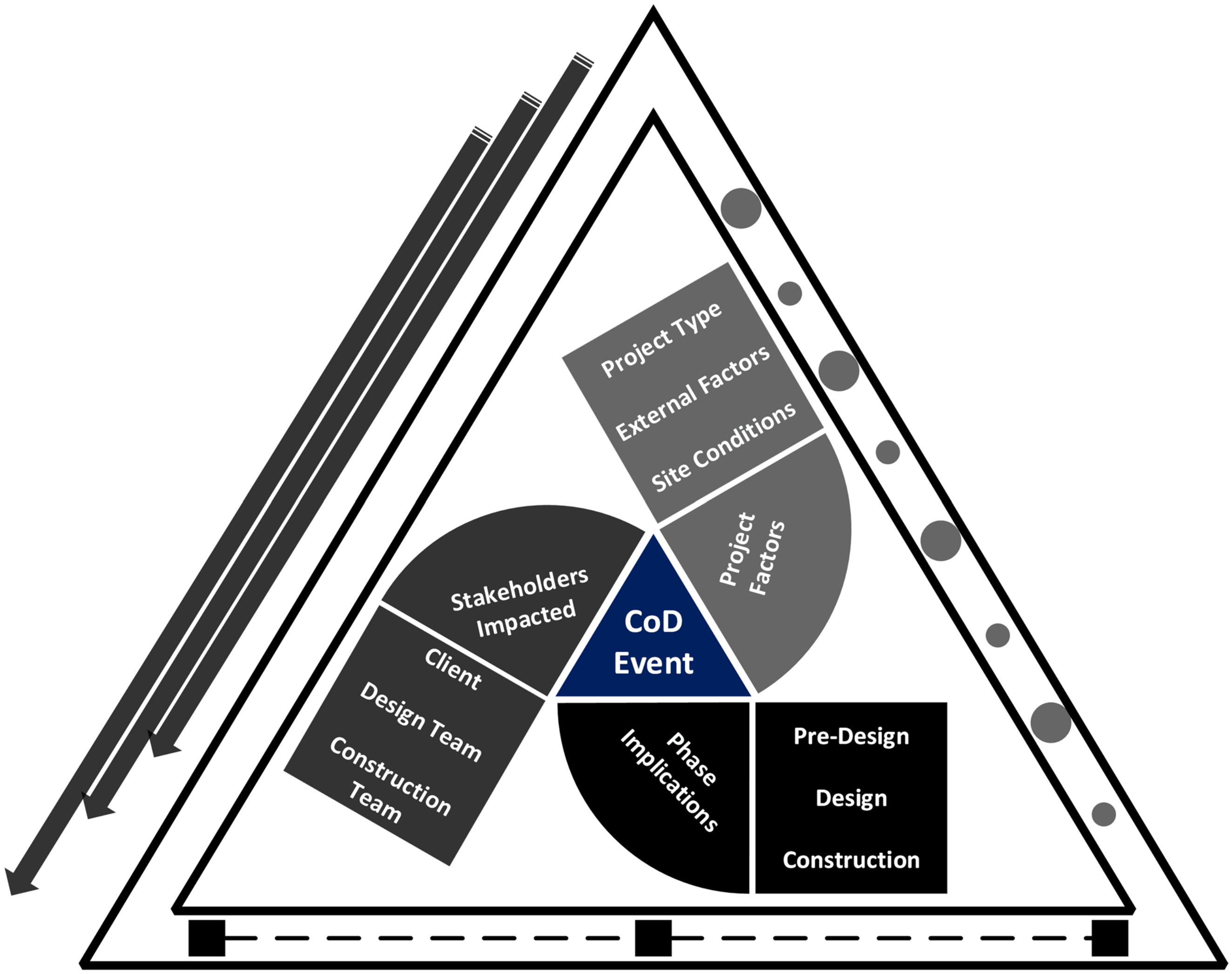

Fig. 6 Proposed hybrid model proposed to tackle delays because of design changes in projects table i: causes of design changes in construction projects

Table 4 Examples on how to use the model developed to manage CoD events

CoD event	Stakeholders Impacted	Implications on Project Phases	Project factors
Change of Curtain Wall System specification	Design Team: • Design Adjustment • Structural calculations Contractor Team: • Procurement Client: • Budget Implications	Design: • Miscoordination between project team members Construction: • Procurement and scheduling Post-construction: • Maintenance Management	Site Conditions: • Site machinery requirements • Logistics Waste

of design change impacts, particularly where changes affect imported or long-lead materials, and (ii) the strong influence of regulatory and authority approvals in triggering iterative redesign cycles. These insights enhanced the contextual accuracy and practical relevance of the framework. In addition, participants confirmed that the model aligns well with existing project records (e.g., RFIs "Request for Information", change orders, and approval logs), indicating that the framework can be operationalised using data already available within industry practice.

Following the validation, it is important to highlight that the model offers the following contributions:

- **Thinking Mechanism**: It aids in understanding the multifaceted nature of design changes, providing a conceptual framework to explore and analyse the problem space in a holistic manner.
- **Solution-Oriented Approach**: It suggests a practical tool for stakeholders to identify, anticipate, and address the causes and impacts of design changes, aiming to reduce delays and associated costs in construction projects.

These contributions extend the ongoing work (e.g., Alajmani et al., 2023) relating to construction delays caused by design changes in developing countries such as the UAE [43]. More importantly, the model offers deeper insight into interconnectivity across different project phases, demonstrating that CoD events prompt stakeholders to pay attention to wider implications that can affect time, cost, and quality [44]. Additionally, the strength of such an approach in the UAE context lies in its capacity to provide a systemic method for examining the multiple factors contributing to design modifications, allowing stakeholders to better recognise the complexity and interdependencies inherent within construction projects.

To illustrate the model's applicability, the project managers used a common "change of design" example frequently encountered in the UAE such as a change in the specification of the curtain wall or façade system. Table 5 demonstrates how the model can be used to enhance the management of

Table 5 Responses from the validation session conducted with the three construction firms in the U.A.E

Thematic Area	Validation Focus	Summary of Responses
Construct Coverage	Captures key triggers of design changes and stakeholder roles	Participants consistently agreed that the model accounted for the main drivers of design changes in UAE projects, such as client-initiated variations, regulatory and authority approvals, incomplete or late design information, and design coordination clashes. All six project managers confirmed that the major stakeholders were well represented (client, consultants, contractors, subcontractors, and authorities). One participant noted that the model could more explicitly acknowledge the role of project management consultants (PMCs), who often mediate design changes on large projects. Overall, no critical omissions were identified, and the breadth of coverage was regarded as comprehensive.
Accuray of capturing issues	Accuracy of relationships, feedback loops, and escalation paths	The feedback loops linking design changes, rework, and downstream scheduling delays were described as "realistic" and "directly reflective of on-site experience." Several participants highlighted the usefulness of representing escalation pathways, such as how unresolved design clashes can trigger ripple effects across multiple disciplines. One participant from Firm B suggested greater emphasis on supply chain constraints as amplifiers of design change delays, particularly for imported materials. Others recommended clarifying the strength of influence between regulatory approvals and subsequent redesign cycles, as this was seen as a particularly strong cause of delay in the UAE context.
Operational Feasibility	Alignment with available project records and data sources	All participants confirmed that the constructs mapped well onto existing project documentation, such as RFI logs, change orders, shop drawing submissions, and authority approval records. This was viewed as a strength because it means the model can be operationalised using data that project teams already collect. However, two managers raised concerns about the variability in the quality of subcontractor documentation, which can limit data accuracy. Another participant noted that while the model was data-friendly, smaller firms may face challenges in systematically capturing the required information without digital tools.
Applicability	Transferability across project types and procurement contexts	The model was generally regarded as applicable to both building and infrastructure projects under common UAE procurement arrangements. Project managers noted that the logic of design change impacts holds across a variety of project sizes, from mid-rise commercial developments to large-scale infrastructure. Nonetheless, one participant cautioned that projects with highly specialised technical requirements, such as oil and gas facilities, may require additional constructs (e.g., interface with international safety standards). Another suggested that adaptation may also be needed for design-and-build contracts, where contractor-led design introduces different dynamics of change.
Predictive and Solution-Oriented Value	Ability to anticipate CoD-related delays and support proactive decisions	Participants unanimously highlighted the potential of the model as a forward-looking tool. They reported that it could help anticipate design-related risks by making causal pathways more transparent. Several noted that the model could support practical mitigation measures such as establishing clear design freeze points, resequencing activities to absorb late design inputs, or strengthening change management protocols. One project manager commented that the model "would help to avoid a major dispute on a previous project" by clarifying the chain of causation for a design-related delay claim. This reinforced the view that the model has tangible value in both risk management and dispute avoidance.

such a CoD event by mapping the affected stakeholders, lifecycle stage implications, and relevant project factors.

Conclusions and future work

This study proposed a hybrid model designed to address the complexities of design changes in UAE construction projects. By integrating systems thinking with storytelling, the model offers a comprehensive framework for understanding and managing design changes, functioning as both a cognitive and practical tool. This innovative approach contributes to the field by providing new insights into mitigating the causes and impacts of design changes. The model's adaptability and scalability make it a valuable resource for construction project management, particularly for practitioners seeking to improve coordination, anticipate risks, and manage change more proactively.

The model is designed to provide an effective thinking mechanism and a solution-oriented approach that equips stakeholders with structured strategies to navigate and mitigate the implications of design changes in a holistic manner. It extends the existing body of knowledge by unfolding the interconnected complexities of design changes as a major driver of other delay causes, thereby offering construction project managers wider awareness of the breadth and depth of their impacts. In doing so, the study aligns with ongoing efforts to enhance project delivery performance within dynamic and fast-paced contexts such as the UAE.

However, this research acknowledges certain limitations, including the need for further exploration of the model's scalability across different project scales and typologies, and the need for richer insights into context-specific project factors. Future research should investigate the model's applicability in different geographical settings and examine the potential integration with digital technologies such as Building Information Modelling (BIM) and Artificial Intelligence-based tools to enhance predictive capability and operational utility.

By developing and implementing this hybrid model, the research provides a foundation for more adaptive, resilient, and efficient construction project management practices, offering clear value for industry professionals responsible for managing design changes within complex project environments.

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References

1. El-Sayegh S, Ahmad I, Aljanabi M, Herzallah R, Metry S, El-Ashwal O (2020) Construction disputes in the UAE: causes and resolution methods. Buildings 10(10):171. https://doi.org/10.3390/buildings10100171
2. Barqawi M, Chong H-Y, Lopez R (2023) Effects of critical success factors, BIM implementation strategies, and barriers on employer-initiated delays. Int J Constr Manag 23(16):2788–2803. https://doi.org/10.1080/15623599.2022.2097041
3. Gharaibeh LG, Matarneh ST, Arafeh M, Sweis G (2020) Factors leading to design changes in Jordanian construction projects. Int J Prod Perform Manag 70(4):893–915. https://doi.org/10.1108/IJPPM-08-2019-0412
4. Sanni-Anibire MO, Zin RM, Olatunji SO (2022) Causes of delay in the global construction industry: a meta analytical review. Int J Constr Manag 22(8):1395–1407. https://doi.org/10.1080/15623599.2020.1716132
5. Mayouf M, Gilligan C (2024) Synthesis towards unveiling the complexity underlying underpayment for subcontractors in construction. J Financ Manag Prop Constr 29(1):168–192. https://doi.org/10.1108/JFMPC-06-2022-0026
6. Hwang B-G, Zhao X, Toh LP (2014) Risk management in small construction projects in Singapore: status, barriers and impact. Int J Proj Manag 32(1):116–124. https://doi.org/10.1016/j.ijproman.2013.01.007
7. Love PED, Ahiaga-Dagbui DD, Irani Z (2016) Cost overruns in transportation infrastructure projects: sowing the seeds for a probabilistic theory of causation. Transp Res Part A Policy Pract 92:184–194. https://doi.org/10.1016/j.tra.2016.08.007
8. Mayouf M, Jones J, Elghaish F, Emam H, Ekanayake EMAC, Ashayeri I (2024) Revolutionising the 4D BIM process to support scheduling requirements in modular construction. Sustainability 16(2):476. https://doi.org/10.3390/su16020476
9. Rahman HA, Chen W, Yap J, Hui B (2017) Impacts of design changes on construction project performance: insights from a literature review. J quantity surveying Constr Bus, 7, 1

10. Elhusseiny HO, Nosair I, Ezeldin AS (2021) Developing a user plug-in to assess delay causes' impact on construction projects in Egypt. Ain Shams Eng J 12(4):3553–3568. https://doi.org/10.1016/j.asej.2021.04.013
11. Ahmed Marey Alhammadi AS, Memon AH (Sep. 2020) Ranking of the Factors Causing Cost Overrun in Infrastructural Projects of UAE. Int J Sustainable Constr Eng Technol 11(2). https://doi.org/10.30880/ijscet.2020.11.02.025
12. Tariq J, Gardezi SSS (2023) Study the delays and conflicts for construction projects and their mutual relationship: a review. Ain Shams Eng J 14(1):101815. https://doi.org/10.1016/j.asej.2022.101815
13. Gurgun AP, Koc K, Kunkcu H (2024) Exploring the adoption of technology against delays in construction projects. Eng Constr Archit Manage 31(3):1222–1253. https://doi.org/10.1108/ECAM-06-2022-0566
14. Stewart WR, Shirvan K (2023) Construction schedule and cost risk for large and small light water reactors. Nucl Eng Des 407:112305. https://doi.org/10.1016/j.nucengdes.2023.112305
15. Soman RK, Molina-Solana M, Whyte JK (2020) Linked-data based constraint-checking (LDCC) to support look-ahead planning in construction. Autom Constr 120:103369. https://doi.org/10.1016/j.autcon.2020.103369
16. Cherian A (2008) The Construction Industry in the Perspective of an Economic Boost of The United Arab Emirates (UAE). Int Res J Eng Technol, 9001, [Online]. Available: www.irjet.net
17. Arantes A, Ferreira LMDF (2021) A methodology for the development of delay mitigation measures in construction projects. Prod Plan Control 32(3):228–241. https://doi.org/10.1080/09537287.2020.1725169
18. Gunduz M, Al-Naimi NH (2022) Construction projects delay mitigation using integrated balanced scorecard and quality function deployment. Eng Constr Archit Manage 29(5):2073–2105. https://doi.org/10.1108/ECAM-12-2020-1082
19. Ajayi BO, Chinda T (2022) Impact of construction delay-controlling parameters on project schedule: DEMATEL-system dynamics modeling approach. Front Built Environ. https://doi.org/10.3389/fbuil.2022.799314
20. Motaleb O, Kishk M (2013) An investigation into the risk of construction projects delays in the UAE. Int J Inf Technol Project Manag 4(3):50–65. https://doi.org/10.4018/jitpm.2013070104
21. Faridi AS, El-Sayegh SM (2006) Significant factors causing delay in the UAE construction industry. Constr Manag Econ 24(11):1167–1176. https://doi.org/10.1080/01446190600827033
22. Johnson RM, Babu RII (2020) Time and cost overruns in the UAE construction industry: a critical analysis. Int J Constr Manag 20(5):402–411. https://doi.org/10.1080/15623599.2018.1484864
23. Zaneldin EK (2020) Investigating the types, causes and severity of claims in construction projects in the UAE. Int J Constr Manag 20(5):385–401. https://doi.org/10.1080/15623599.2018.1484863
24. Alsuliman JA (2019) Causes of delay in Saudi public construction projects. Alex Eng J 58(2):801–808. https://doi.org/10.1016/j.aej.2019.07.002
25. Bortolini R, Formoso CT, Viana DD (2019) Site logistics planning and control for engineer-to-order prefabricated building systems using BIM 4D modeling. Autom Constr 98:248–264. https://doi.org/10.1016/j.autcon.2018.11.031
26. Aladağ H, Işık Z (2019) Design and construction risks in BOT type mega transportation projects. Eng Constr Archit Manag 26(10):2223–2242. https://doi.org/10.1108/ECAM-08-2018-0351
27. Lee C (2023) Evaluating construction delays using productivity-based resource reallocation for economic feasibility. Eng Constr Archit Manag 30(4):1679–1696. https://doi.org/10.1108/ECAM-09-2019-0503
28. Mayouf M, Boyd D, Cox S (2014) Different perspectives on facilities management to incorporate in bim
29. Khidir Ibnouf Adham T, Paper program S (2023) Investigating the causes of contractor-related delays in construction projects and mitigation proposal. Int J Progressive Sci Technol (IJPSAT 37(1):646–670
30. Egwim CN, Alaka H, Toriola-Coker LO, Balogun H, Sunmola F (2021) Applied artificial intelligence for predicting construction projects delay. Mach Learn Appl 6:100166. https://doi.org/10.1016/j.mlwa.2021.100166
31. Do ST, Nguyen VT, Tran CNN, Aung ZM (2023) Identifying and evaluating the key claim causes leading to construction delays. Int J Constr Manag 23(12):1999–2011. https://doi.org/10.1080/15623599.2022.2030508
32. Chen Q, Adey BT, Haas C, Hall DM (2020) Using look-ahead plans to improve material flow processes on construction projects when using BIM and RFID technologies. Constr Innov 20(3):471–508. https://doi.org/10.1108/CI-11-2019-0133
33. Zeng N, Liu Y, König M (2023) 4D BIM-enabled look-ahead scheduling for early warning of off-site supply chain disruptions. J Constr Eng Manag. https://doi.org/10.1061/(ASCE)CO.1943-7862.0002433
34. Chang A-T, Shih JS, Choo YS (2011) Reasons and costs for design change during production. J Eng Des 22(4):275–289. https://doi.org/10.1080/09544820903425218
35. Motaleb O (2021) Risk response development in construction projects delay: multiple case studies from UAE. ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A: Civil Engineering. https://doi.org/10.1061/AJRUA6.0001151
36. Yin RK (2017) Case Study Research and Applications: Design and Methods. SAGE, Thousand Oaks, CA
37. Carter N, Bryant-Lukosius D, DiCenso A, Blythe J, Neville AJ (2014) The use of triangulation in qualitative research. Oncol Nurs Forum 41(5):545–547. https://doi.org/10.1188/14.ONF.545-547
38. Nowell LS, Norris JM, White DE, Moules NJ (2017) Thematic Analysis, *Int J Qual Methods*, vol. 16, no. 1, Dec. https://doi.org/10.1177/1609406917733847
39. Rogers M (2023) Coding Qualitative Data. Varieties of qualitative research methods: selected contextual perspectives. pp 73–78. https://doi.org/10.1007/978-3-031-04394-9_12
40. Boyd D, Mayouf M, Cox S (2016) Clients' and Users' Perceptions of BIM: a study in Phenomenology, in *CIB World Building Congress*
41. Feldman G, Kirkham S (2017) Using Rich pictures to Represent Stakeholders' Role during Enterprise Systems Upgrade Decisions, in *3rd International Workshop on Socio-Technical Perspective in IS development*, Essen, Germany
42. Padala SPS, Maheswari JU (2023) Modeling a construction project in a matrix-based framework for managing requirement changes. Int J Constr Manag 23(14):2369–2390. https://doi.org/10.1080/15623599.2022.2059739
43. Alajmani H, Ahmed S, El-Sayegh SM (2024) Factors causing delays in the UAE construction industry amid the Covid-19 pandemic. J Financ Manag Prop Constr 29(1):135–151. https://doi.org/10.1108/JFMPC-02-2023-0006
44. Purushothaman MB, San Pedro LNR, GhaffarianHoseini A (2024) Construction projects: interactions of the causes of delays. Smart Sustain Built Environ. https://doi.org/10.1108/SASBE-11-2023-0334