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Developing a Method for Managing Construction Defect Risk in the Residential Sector Case Study: Shiraz Mass Housing Complexes

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Abstract

This study examines structural defects in mass housing complexes in Shiraz and identifies the factors influencing their occurrence. Given the importance of construction quality and its impact on the lifespan of buildings, this research aims to propose effective solutions for reducing defects. The goal of this study is to identify and analyze the factors contributing to structural defects in mass housing complexes in Shiraz. The research follows a qualitative approach, and data has been collected through questionnaires, interviews, observations, and archival research. The study population includes project managers, engineers, and construction industry experts, with sampling conducted using a purposive method. The collected data has been processed and analyzed using MaxQDA software and statistical tools. The research findings indicate that low-quality materials, inadequate supervision, and time pressure to complete projects are key factors leading to structural defects. Additionally, insufficient employee training and adverse weather conditions play a significant role. These findings can contribute to improving construction quality and reducing defects in future projects. By implementing training programs for workers, utilizing high-quality materials, and ensuring continuous supervision of construction processes, maintenance and repair costs can be minimized.

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INTRODUCTION

Building construction plays a crucial role in urban development, demanding careful attention to quality and safety. Despite these efforts, defects and potential failures in the construction process can still arise, impacting the building's overall quality and reliability (Okoye, 2022). There is ample evidence showing that new residential buildings often exhibit defects, which require serious consideration due to their significant consequences for all parties involved in construction projects, as well as for end users. These defects also contribute to the generally low perception of quality within the housing sector in many countries. Researchers have offered various definitions of building defects. Generally, a defect is described as a shortfall in a building's ability to fulfill its intended functions or comply with regulatory standards and occupancy requirements. It can also be defined as a failure to meet the specifications outlined in contract documents, site reports, and other project records, in addition to established building codes and regulations. While it is nearly impossible to eliminate defects entirely in construction, minimizing their recurrence is critical for stakeholders, as it helps avoid unnecessary costs. In the construction industry, defects are classified by different criteria, such as severity, construction stage, type, and cause. Latent defects are those not immediately visible and require thorough inspection to detect, whereas visible defects are apparent upon standard inspection (Shah et al., 2024).

Construction defects are a frequent occurrence in construction projects, particularly in those with poor site performance and inadequate project management. These defects often result from insufficient planning. Within the construction industry, defects are recognized as a significant issue that can diminish the value of a project (Kutsch & Hall, 2010). The industry has long faced criticism for substandard construction and performance, often caused by a combination of rushed work, flawed design, and inadequate maintenance. Employers and end users frequently express dissatisfaction, stating that their housing fails to meet their needs and expectations. Providing high-quality housing is crucial as it fosters social, educational, and economic opportunities, helping to create more equitable communities. However, construction defects remain a persistent challenge, especially in residential projects. Previous research highlights defects as a major contributor to poor quality outcomes, increased costs, and extended schedules. Defects requiring rework are a common concern when evaluating project success because they negatively affect stakeholder satisfaction. Studies indicate that many construction defects are often unavoidable, stemming from both hidden and direct causes. These defects significantly impact the project success criteria cost, time, and quality as well as stakeholder satisfaction. Therefore, timely and effective management of defect resolution is essential. Construction defects usually involve multiple shortcomings in areas such as design, planning, supervision, and execution. Buildings that develop defects during construction typically fail to meet consumer demands. Technically defective work can be viewed as non-compliance with the contractual agreements. The quality of construction execution plays a vital role in the likelihood of defects and failures. Mistakes in the supply or use of materials like concrete, steel, or other structural components can cause structural issues. Additionally, insufficient knowledge of proper construction methods can contribute to defects. Material selection must align with project specifications, as using substandard materials compromises construction quality and leads to defects. Defect management encompasses the planning, coordination, and monitoring of construction activities to minimize inefficiencies, costs, and delays caused by these issues (Kutsch & Hall, 2010).

From the initial design phase through to project completion, construction quality depends on the collaborative efforts of multiple participants working together. The construction industry often faces criticism for the poor quality of its projects, both in terms of the final outcomes and the processes used during design and construction. Common issues include defects such as roof leaks, wall deformation and cracking, insufficient floor thickness, bulging flooring, and the cracking or detachment of interior and exterior facade coatings. Additionally, accidents on construction sites frequently result from unlicensed professionals working without proper authorization. Key functional requirements of any building include strength, stability, climate control, indoor comfort, efficient use, and durability. To meet these requirements, buildings are planned, developed, constructed, and managed according to standards and specifications established by regulatory authorities, professional organizations, and experts who understand user needs and expectations. Construction defects are a serious concern for all project stakeholders because they can arise at any stage of the project lifecycle, leading to costly rework that impacts both budget and schedule. Beyond financial losses, these defects can undermine stakeholder trust. As noted, the expenses associated with repairing construction defects can represent a significant portion of the overall building cost (Aljassmi, Perera, & Han, 2013). Defects arise from various causes, including faulty planning, substandard workmanship, failure to adhere to design specifications, or unforeseen factors not accounted for during planning. Research has also demonstrated that poor workmanship, inadequate management, and insufficient oversight of contractors significantly contribute to defects in housing construction (Yusof, Lai, & Kamal, 2017).

Literature Review

Previous studies have identified several key factors influencing construction defects, including climatic conditions, building location, materials, building form, changes in use, repairs, faulty architecture, and lack of supervision. Additionally, poor planning, substandard workmanship, construction that deviates from design specifications, the influence of unapproved variables, and inadequate supervision during layout are primary causes of building defects. Ensuring these factors are properly managed is crucial for preserving the long-term investment value of buildings (Yusof et al., 2017).

Identifying defects is essential for maintaining building quality and sustainability. Defects can emerge from design flaws, construction processes, material deficiencies, or maintenance issues. Rapid urban growth and diverse environmental conditions highlight the importance of understanding common defect types and their causes. A thorough knowledge of frequent defects is vital to preserve building integrity and occupant safety. Thus, defect identification involves analyzing and recognizing problems that threaten building quality and safety (Fhloinn & Maire, 2019).

Early detection of defects during construction is critical, as it facilitates timely project completion within budget and schedule by minimizing costly rework. Correcting defects at an early stage helps prevent future errors (Alshboul et al., 2023).

Beyond identification, researchers emphasize strategies to reduce defects because they significantly impact building performance. Construction defects increase maintenance costs, jeopardize user health and safety, shorten building lifespan, and cause environmental damage through resource depletion (Lambers, 2019).

Effective strategies to minimize defects include improving workmanship quality, ensuring accountability, holding regular progress meetings, selecting quality materials, employing modern construction techniques, enhancing the ability to interpret drawings, adhering strictly to specifications, conducting thorough inspections, strengthening quality control, and improving supervision. Inspection is recognized as the most effective approach to defect reduction. Moreover, integrating stakeholders and adopting new technologies also help mitigate defect-related issues. Additional recommended measures include design quality control, specialist training, human resource management, fostering cooperation and communication, and raising awareness about defects (Lambers et al., 2023).

Various mathematical models have been developed to estimate defect frequency and severity, identify causes of poor workmanship, and propose solutions. Defects not only affect the final construction cost but also generate significant maintenance expenses throughout a building's lifecycle, potentially leading to total project failure. The construction industry is rapidly advancing globally, supported by information technology. Housing represents a major societal investment, and construction defects have become a critical global challenge addressed by researchers and professionals worldwide. Defects greatly influence project success by affecting construction time, costs, sustainability, productivity, and client satisfaction (Gyamfi et al., 2022).

Recent studies suggest that defects may become predictable components of construction projects. This study aims to improve management responses to defects by examining residential building defects, particularly in mass housing complexes. A case study of projects in Shiraz will analyze key causes, underlying factors, and risk management strategies. The research provides a comprehensive framework for defect cause and management prioritization, guiding efforts to improve critical areas.

The study follows a mixed-method approach. The first phase involves defining research objectives, designing methodology, and conducting a thorough literature review using journals, articles, books, online sources, newspapers, fieldwork, existing documents, and informal expert consultations. The second phase focuses on data collection through expert interviews and surveys. The third phase involves data interpretation and analysis. This research expands knowledge of common residential defects and their management, examines practical industry challenges, and investigates root causes. Finally, it proposes a risk management method for frequent defects based on theoretical and empirical findings. This method is designed to help industry practitioners prevent defects by considering relevant residential building codes and offering a wide range of risk management strategies. Validation will be performed through focus group discussions with experienced building professionals.

Strategies for Managing Construction Defects in the Residential Sector

Risk management is a widely studied subject in construction research, encompassing areas such as public-private partnerships, supply chain management, quality control, project planning, asset management, and the influence of organizational culture. Despite its prominence, academic literature indicates that many existing risk management approaches lack practical applicability. For instance, Rostami et al. (2015) highlight that conventional project risk management methods often fail to address the specific needs of small and medium-sized construction firms, restricting their real-world utility. A key challenge lies in the disconnect between on-the-ground project realities and the rigid theoretical frameworks of risk management, which impedes effective organizational implementation. Current risk management practices frequently rely on experiential knowledge, informal rules, and subjective judgments, leading to ad hoc behavioral responses to risks. Supporting this observation, Kutsch and Hall (2010) argue that subjective risk decision-making poses a significant barrier to effective project risk management, as cognitive biases and oversight by decision-makers can result in inaccurate risk assessments and the neglect of critical threats.

Effective risk management strategies play a crucial role in the residential construction sector, where challenges such as construction defects significantly impact quality performance and project costs (Lambers et al., 2023). These defects frequently result in costly rework and schedule delays, underscoring the need for robust risk mitigation approaches to enhance project outcomes. Existing research has explored various dimensions of construction defects, focusing on their identification, root causes, and management. Lambers et al. (2023) introduced a novel methodology for detecting common residential construction defects and their underlying causes, with the goal of developing a practical framework for defect risk management. Their approach combined a literature review, archival data analysis, and surveys to establish a theoretical foundation and identify key defect drivers. Further reinforcing these findings, Lambers (2019) conducted an in-depth study on residential construction defects, cataloging prevalent issues and analyzing their causes and mitigation strategies. The research highlights that risk management approaches and defect origins vary across construction specialties, necessitating tailored solutions for effective defect prevention and control.

Beyond construction defects, Royal et al. (2023) conducted a cross-national comparative study of home warranty schemes, systematically analyzing active programs worldwide to identify key similarities and differences. Their research underscores the need for well-designed public policies on residential building warranties to enhance consumer protection and promote housing production. Building on this work, Royal et al. (2022) developed a standardized framework for evaluating and comparing international home warranty schemes. The study outlines defining characteristics of these programs and proposes a comprehensive coding system to assess their effectiveness. This framework addresses critical knowledge gaps in warranty scheme design, offering valuable insights for policymakers and industry stakeholders.

The critical role of robust risk management strategies and the necessity for stronger legal frameworks addressing construction defects have been further explored in academic research. Partlett (2007) analyzes the evolution of contractor liability for construction defects, particularly examining the consequences of holding contractors accountable for economic damages. Meanwhile, Fhloinn and Maire (2019) investigate the deficiencies in Ireland's residential construction legal systems, identifying gaps in current defect resolution mechanisms and advocating for comprehensive legal reforms.

The construction management industry has historically struggled to learn from past errors. A study of 450 Australian contracting firms revealed significant limitations in collaborative learning practices (Yusof et al., 2017). Beyond knowledge management challenges, many organizations demonstrate reluctance to engage in post-occupancy evaluations, often resisting feedback on building performance after project completion. This resistance may stem from insufficient understanding of knowledge management benefits, compounded by the industry's persistent reliance on manual record-keeping systems. Given these challenges, further research is needed to explore how knowledge management systems could enhance defect prevention and remediation—a theoretical premise this study adopts (Yusof et al., 2017).

Defect Management Strategies

While previous studies have employed the *Swiss cheese model* to examine the origins of defects, a substantial body of research has proposed a **three-layer framework** to better understand the causes and management of construction defects:

- **Organizational Influences:** Decisions made at the top management level shape the performance and priorities of supervisory staff. These high-level choices cascade downward, often setting the stage for faulty practices.
- **Defective Supervision:** Supervisors, influenced by organizational decisions, directly affect worksite conditions. Poor or inadequate supervision contributes to an environment where defects are more likely to occur.
- **Preconditions for Defective Actions:** This layer encompasses factors such as worker conditions, environmental influences, and personal circumstances. These elements are typically viewed as the immediate or proximate causes of defective actions.

This hierarchical framework underscores that construction defects are rarely the result of a single error; rather, they emerge from interconnected systemic weaknesses. By addressing organizational culture, supervisory processes, and worker-level factors simultaneously, construction firms can better prevent recurring defects and enhance project quality performance.

Risk Management in Residential Construction Projects

Risk management is a structured and continuous process aimed at identifying, assessing, prioritizing, and mitigating risks that may affect an organization's capacity to achieve its objectives. It involves analyzing uncertainties stemming from diverse sources, including financial volatility, technological shifts, regulatory changes, natural disasters, and human error. The process typically begins with identifying potential risks through internal and external analysis, followed by evaluating their likelihood and potential impact. Based on this assessment, risks are prioritized to allow efficient allocation of resources.

Mitigation strategies such as avoidance, transfer, reduction, or acceptance are then developed in alignment with the organization's risk appetite. Because risks evolve over time, continuous monitoring and periodic reassessment are essential to maintaining effective risk control. When properly implemented, risk management enables organizations to anticipate challenges, protect assets and reputations, and promote long-term sustainability.

Kishan et al. (2014) conducted a study on risk management in construction projects, focusing on risks contributing to delays, cost overruns, and quality issues. Given the industry's inherently unpredictable nature, the study emphasized the necessity of a systematic risk management process that integrates identification, analysis, response planning, and control. A total of 47 risk factors were identified across multiple categories, including design, logistics, legal, financial, and political domains. Despite the availability of formal risk management tools, the study found that they are often applied informally in practice. Consequently, Kishan et al. (2014) highlighted the importance of adopting **structured and** standardized approaches to enhance project outcomes and reduce the likelihood of recurring issues.

Construction Defect Risk Management in the Residential Sector

Risk management for construction defects in residential projects encompasses multiple interrelated components and is influenced by a wide range of external and internal factors. A systematic understanding of these elements enables more effective prevention, mitigation, and control of risks throughout the project lifecycle.

Core Aspects and Definitions

- **Defect Identification:** The process of detecting potential problems and weaknesses that may arise during the design, construction, or maintenance phases of residential buildings.
- **Risk Assessment:** Involves evaluating the likelihood and potential impact of each identified risk to help prioritize mitigation efforts.
- **Risk Mitigation:** Refers to the development and implementation of strategies aimed at minimizing the probability and consequences of defects. This may include design modifications, process improvements, or enhanced maintenance and monitoring.
- **Monitoring and Review:** A continuous and iterative process that ensures risk mitigation measures remain effective and responsive to evolving project conditions.

Successful risk management in residential construction thus relies on early detection, proactive mitigation, and continuous improvement—helping safeguard occupant safety, prevent financial losses, and extend the overall lifespan of buildings.

Influencing Factors

1. Economic Factors

- **Market Fluctuations:** Variations in the cost and availability of construction materials can affect project budgets and timelines, occasionally leading to the use of substandard materials.
- **Interest Rates and Access to Finance:** Changes in credit policies or financing conditions influence project feasibility and cash flow.
- **Inflation:** Persistent price increases elevate project costs, often pressuring contractors to adopt lower-cost alternatives that may compromise quality (Kishan et al., 2014).

2. Environmental Factors

- **Weather Conditions:** Extreme events such as heavy rain, strong winds, or temperature fluctuations can delay construction, damage materials, and undermine structural integrity.
- **Natural Disasters:** Earthquakes, floods, and fires present substantial risks, emphasizing the importance of robust emergency preparedness and response mechanisms.
- **Environmental Pollution:** Air and soil contamination negatively affect worker health and may reduce the durability of building materials.

3. Legal and Regulatory Factors

- **Building Codes:** National and local regulations govern design and construction practices; non-compliance can result in fines, delays, and reputational damage.
- **Building Permits:** The complexity and duration of permitting processes can hinder progress; failure to obtain proper authorization may halt projects entirely.
- **Regulatory Changes:** Sudden amendments to construction-related laws can require significant procedural or design modifications during implementation.

4. Management Factors

- **Quality of Project Management:** Effective leadership, scheduling, and supervision are essential to control costs, maintain timelines, and ensure compliance with quality standards.
- **Team Capabilities:** The competence, experience, and commitment of contractors and laborers significantly affect project success.
- **Communication and Coordination:** Clear communication channels among stakeholders reduce errors and facilitate timely problem-solving.

5. Technical Factors

- **Design and Engineering:** Detailed, accurate design and engineering work minimizes the likelihood of errors during construction.
- **Construction Technologies:** Adoption of advanced methods, digital tools, and high-

quality materials can dramatically reduce defect risks.

- **Supervision Systems:** Continuous inspection and real-time monitoring ensure adherence to quality and safety standards.

6. Social Factors

- **Cultural Considerations:** Cross-cultural understanding within project teams enhances collaboration and minimizes conflict.
- **Working Conditions and Safety:** Maintaining safe and fair working environments promotes productivity and quality consistency.
- **Community Engagement:** Engaging local communities builds trust, prevents resistance, and promotes smoother project implementation.

Table 1. Theoretical and proposed framework

Stage	Description
Identifying risks	Repeated visits, analysis of past records, use of questionnaires and interviews
Risk assessment	Qualitative and quantitative analysis, use of relative importance index (RII), modeling and simulation
Prioritizing risks	Preparing risk matrix, value at risk (VaR) analysis
Developing risk reduction strategies	Risk avoidance, risk transfer, risk reduction, risk acceptance
Continuous monitoring and review	Periodic reviews, use of monitoring and warning systems
Education and knowledge gradation	Holding training courses, improving technical knowledge through participation in conferences and workshops
Documentation and continuous improvement	Accurately record all steps, use feedback for continuous improvement

Research Methodology

Qualitative Research Approach

In construction management, qualitative research methods are extensively employed due to the project-oriented nature of the field and its focus on human-centered processes. Data collection typically involves a combination of interviews, surveys, questionnaires, observations, and archival research, allowing researchers to explore complex project dynamics and stakeholder experiences in depth. The research process begins with defining objectives and designing the methodology, which is informed by an extensive review of scholarly literature, industry reports, field observations, online resources, and informal consultations with experts and practitioners.

Data Collection and Information Sources

Data collection involves multiple complementary methods to ensure comprehensive coverage of the research problem. Field methods include selecting experienced experts such as project managers, engineers, and specialists, preparing detailed interview guides, and conducting interviews in person, online, or by phone. Project-specific databases and company archives are reviewed to extract information related to costs, schedules, risks, and outcomes, while library-based approaches involve systematically reviewing books, theses, journal articles, and scientific databases such as Google Scholar, PubMed, and IEEE Xplore. Questionnaires, organizational documents, and online networks are also utilized as data sources, ensuring triangulation and enhancing the reliability of findings.

Data Processing, Analysis, and Research Objectives

Collected data are processed using software tools such as MaxQDA for qualitative coding and complemented by statistical analyses to assess consistency and compare insights across respondent groups. Surveys are reviewed by construction experts, and findings are validated through focus group discussions to confirm accuracy and mitigate errors. The study aims to (1) identify the factors contributing to construction defects in Shiraz mass-construction complexes, (2) assess the impact of these factors on project outcomes, and (3) develop an effective management approach for addressing construction defects, providing a robust framework to guide both industry practitioners and policymakers.

Research findings

Coding Process

The core objective of the data analysis presented in this section is to address the research question: "How can a method be developed to manage the risk of construction defects in the residential sector? A case study of mass housing complexes." To answer this question, data were examined through two sources: responses from the employee questionnaire and insights derived from the qualitative analysis of interview data.

The qualitative findings, based on interviews, were processed using a structured coding approach consisting of four stages:

Narrative Documentation: Interview audio files were transcribed into text, and relevant evidence was systematically extracted for further analysis.

Primary Coding: Initial codes were generated by identifying and categorizing key pieces of evidence from the interview narratives. This phase was conducted using MaxQDA software to ensure rigor and transparency in qualitative data handling.

Table 2. Primary codes of construction defects in Shiraz mass-construction complexes

Points mentioned
Wall cracks, water leaks, installation problems - Use of low-quality raw materials, reduced building strength - Inconsistency between architectural and engineering drawings and actual construction - Gas leaks, problems with ventilation systems - Inconsistency between doors and windows with standard sizes - Insulation and thermal insulation problems - Inconsistency between electrical and mechanical drawings and actual implementation
Low quality of raw materials - Lack of adequate and detailed supervision of the construction process - Time pressure to complete projects - Deficiencies in project planning and management - Lack of adequate training and skills of construction employees and workers
Adverse weather conditions - Incompatibility of government regulations with construction realities - Sudden changes in government regulations - Local laws and regulations do not match the actual land and construction conditions - Failure to predict weather conditions during project planning and implementation - Restrictive government regulations, increasing costs and reducing construction quality

Table 3. Initial codes for evaluating factors affecting construction defects in Shiraz mass-construction complexes

Points mentioned
Using statistical analysis and regression models - Periodic monitoring and inspection and recording data related to construction defects - Using quality control systems and analyzing data from previous projects - Empirical analysis and feedback from past projects - Using project management software and accurate data recording - Holding review and evaluation meetings with the presence of all team members - Comparing similar projects under different conditions and analyzing their data
Low quality of raw materials - Lack of careful and continuous supervision of the construction process - Time pressure to complete projects - Deficiencies in project planning and management - Lack of adequate training and skills of construction employees and workers - Adverse weather conditions - Lack of coordination between different engineering, architectural and executive teams
Analyzing the quality of raw materials and its impact on construction defects in a project in the north of the city - Analyzing the role of project management and monitoring construction quality in another project - Investigating the impact of weather conditions and climate change in a project in the south of the country - Analyzing the role of coordination between different engineering and architectural teams in a project in the west of the country - Investigating the impact of time pressure on construction quality and the occurrence of defects in a project in the city center - Analyzing the impact of employee training and skills in a project in the east of the country - Investigating the role of new technologies in reducing construction defects in a project in the suburbs

Table 4. Initial codes for developing a method for managing construction defects in Shiraz mass-construction complexes

Points mentioned
Developing and implementing training programs for employees and engineers - Using quality raw materials and reputable standards - Continuous monitoring and detailed inspection at all stages of construction - Developing standard instructions and strictly observing them - Holding periodic review and evaluation meetings with the presence of all team members - Using quality control systems and modern management tools - Analyzing data from past projects and using the experiences and knowledge gained
Using specialized teams to investigate and correct defects as soon as they are identified - Developing advanced monitoring systems and using modern technologies - Creating information and management systems to accurately record and track defect data - Developing standard methods for evaluating and correcting defects and strictly observing them - Using project management software and accurately recording defect data - Holding workshops and training sessions to increase the awareness and skills of employees and engineers - Using experiences and knowledge gained from previous projects to develop effective methods
Using project management software and digital tools - Developing advanced monitoring systems and using new technologies such as artificial intelligence and machine learning - Using digital tools and advanced software for data analysis and defect identification - Developing information and management systems for accurate recording of defect data and their analysis - Using new technologies such as 3D printing and nanomaterials - Developing digital platforms and online tools for holding virtual meetings and training - Using advanced management tools such as (Building Information Modeling) BIM

Developing and implementing training and empowerment programs for employees and engineers - Using project management systems and advanced software to accurately record and track data - Developing standard guidelines and frameworks for evaluating and correcting defects and strictly adhering to them - Holding periodic review and evaluation meetings with the presence of all team members - Using experiences and knowledge gained from previous projects - Utilizing new technologies and modern management tools - Creating specialized teams and interdisciplinary cooperation to review and manage defects

At this stage, a total of 3 codes were identified based on the in-depth interview.

Focused coding: At this stage, the initial codes were identified based on the degree of similarity of the categories and the elimination of duplicates, and the desired concepts were identified. In order to categorize the sub-criteria, 3 main criteria were introduced, in each of which the total number of sub-criteria was categorized, and the names were assigned based on the concepts of the sub-criteria, so at this stage, 7 secondary codes were introduced. The codes identified as the main codes have a subset of the introduced codes. An example of these concepts and the corresponding initial codes is presented in Table 3.

Table 5. Centralized coding of construction defects in Shiraz mass-construction complexes

Subcategory	Points mentioned
Type of construction defects observed	Wall cracks, water leaks, installation problems - Use of low-quality raw materials, reduced building strength - Inconsistency between architectural and engineering drawings and actual construction - Gas leaks, problems with ventilation systems - Inconsistency between doors and windows with standard sizes - Insulation and thermal insulation problems - Inconsistency between electrical and mechanical drawings and actual implementation
Internal factors	Low quality of raw materials - Lack of adequate and detailed supervision of the construction process - Time pressure to complete projects - Deficiencies in project planning and management - Lack of adequate training and skills of construction employees and workers
External factors	Adverse weather conditions - Incompatibility of government regulations with construction realities - Sudden changes in government regulations - Local laws and regulations do not match the actual land and construction conditions - Failure to predict weather conditions during project planning and implementation - Restrictive government regulations, increasing costs and reducing construction quality

Table 6. Centralized coding of the assessment of factors affecting construction defects in Shiraz mass-construction complexes

Subcategory	Points mentioned
Methods for assessing the impact of factors	Using statistical analysis and regression models - Periodic monitoring and inspection and recording data related to construction defects - Using quality control systems and analyzing data from previous projects - Empirical analysis and feedback from past projects - Using project management software and accurate data recording - Holding review and evaluation meetings with the presence of all team members - Comparing similar projects under different conditions and analyzing their data
Factors with the most influence	Low quality of raw materials - Lack of careful and continuous supervision of the construction process - Time pressure to complete projects - Deficiencies in project planning and management - Lack of adequate training and skills of construction employees and workers - Adverse weather conditions - Lack of coordination between different engineering, architectural and executive teams
Examples of past projects	Analyzing the quality of raw materials and its impact on construction defects in a project in the north of the city - Analyzing the role of project management and monitoring construction quality in another project - Investigating the impact of weather conditions and climate change in a project in the south of the country - Analyzing the role of coordination between different engineering and architectural teams in a project in the west of the country - Investigating the impact of time pressure on construction quality and the occurrence of defects in a project in the city center - Analyzing the impact of employee training and skills in a project in the east of the country - Investigating the role of new technologies in reducing construction defects in a project in the suburbs

Table 7. Centralized coding of method development in construction defect management in Shiraz mass construction complexes

Subcategory	Points mentioned
Prevention strategies	Developing and implementing training programs for employees and engineers - Using quality raw materials and reputable standards - Continuous monitoring and detailed inspection at all stages of construction - Developing standard instructions and strictly observing them - Holding periodic review and evaluation meetings with the presence of all team members - Using quality control systems and modern management tools - Analyzing data from past projects and using the experiences and knowledge gained
Management and correction methods	Using specialized teams to investigate and correct defects as soon as they are identified - Developing advanced monitoring systems and using modern technologies - Creating information and management systems to accurately record and track defect data - Developing standard methods for evaluating and correcting defects and strictly observing them - Using project management software and accurately recording defect data - Holding workshops and training sessions to increase the awareness and skills of employees and engineers - Using experiences and knowledge gained from previous projects to develop effective methods
Using new technologies	Using project management software and digital tools - Developing advanced monitoring systems and using new technologies such as artificial intelligence and machine learning - Using digital tools and advanced software for data analysis and defect identification - Developing information and management systems for accurate recording of defect data and their analysis - Using new technologies such as 3D printing and nanomaterials - Developing digital platforms and online tools for holding virtual meetings and training - Using advanced management tools such as (Building Information Modeling) BIM
Implementation methods	Developing and implementing training and empowerment programs for employees and engineers - Using project management systems and advanced software to accurately record and track data - Developing standard guidelines and frameworks for evaluating and correcting defects and strictly adhering to them - Holding periodic review and evaluation meetings with the presence of all team members - Using experiences and knowledge gained from previous projects - Utilizing new technologies and modern management tools - Creating specialized teams and interdisciplinary cooperation to review and manage defects

Axial Coding: At this stage of the research, the key components influencing the study pattern for identifying and validating effective factors in personal knowledge management among postgraduate students at top universities in the country were identified. Based on their nature, these components were organized into seven primary dimensions. The results are presented in Figure 4-10.

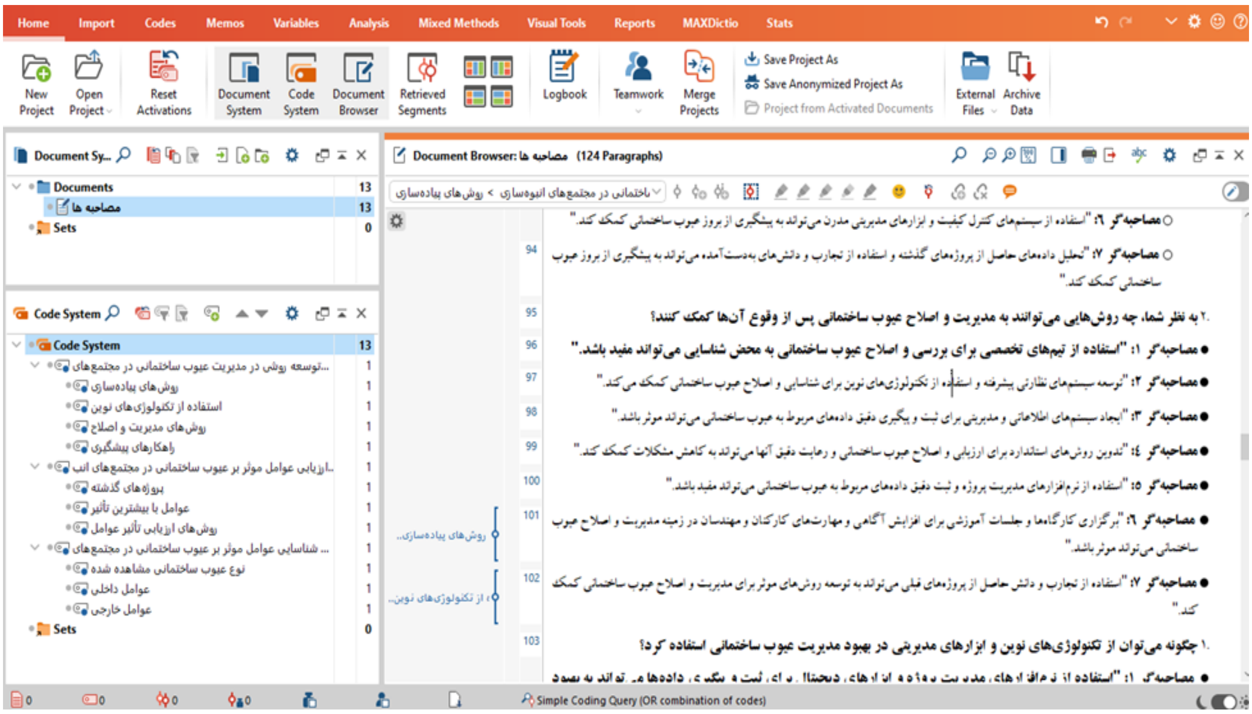

Fig 1. Main dimensions

Table 8. The most important codes and main factors of construction defects in Shiraz mass construction complexes

Main category	Subcategory	Points mentioned
Identifying defects	Type of construction defects observed	Wall cracks, water leaks, installation problems - Use of low-quality raw materials, reduced building strength - Inconsistency between architectural and engineering drawings and actual construction - Gas leaks, problems with ventilation systems - Inconsistency between doors and windows with standard sizes - Insulation and thermal insulation problems - Inconsistency between electrical and mechanical drawings and actual implementation
Factors affecting defects	Internal factors	Low quality of raw materials - Lack of adequate and detailed supervision of the construction process - Time pressure to complete projects - Deficiencies in project planning and management - Lack of adequate training and skills of construction employees and workers
	External factors	Adverse weather conditions - Incompatibility of government regulations with construction realities - Sudden changes in government regulations - Local laws and regulations do not match the actual land and construction conditions - Failure to predict weather conditions during project planning and implementation - Restrictive government regulations, increasing costs and reducing construction quality

Table 9. The most important codes and main factors for evaluating factors affecting construction defects in Shiraz mass construction complexes

Main category	Subcategory	Points mentioned
Assessing the impact of factors	Methods for assessing the impact of factors	Using statistical analysis and regression models - Periodic monitoring and inspection and recording data related to construction defects - Using quality control systems and analyzing data from previous projects - Empirical analysis and feedback from past projects - Using project management software and accurate data recording - Holding review and evaluation meetings with the presence of all team members - Comparing similar projects under different conditions and analyzing their data
	Factors with the most influence	Low quality of raw materials - Lack of careful and continuous supervision of the construction process - Time pressure to complete projects - Deficiencies in project planning and management - Lack of adequate training and skills of construction employees and workers - Adverse weather conditions - Lack of coordination between different engineering, architectural and executive teams
	Examples of past projects	Analyzing the quality of raw materials and its impact on construction defects in a project in the north of the city - Analyzing the role of project management and monitoring construction quality in another project - Investigating the impact of weather conditions and climate change in a project in the south of the country - Analyzing the role of coordination between different engineering and architectural teams in a project in the west of the country - Investigating the impact of time pressure on construction quality and the occurrence of defects in a project in the city center - Analyzing the impact of employee training and skills in a project in the east of the country - Investigating the role of new technologies in reducing construction defects in a project in the suburbs

Table 10. The most important codes and main factors for developing a method for managing construction defects in Shiraz mass construction complexes

Main category	Subcategory	Points mentioned
Preventing defects	Prevention strategies	Developing and implementing training programs for employees and engineers - Using quality raw materials and reputable standards - Continuous monitoring and detailed inspection at all stages of construction - Developing standard instructions and strictly observing them - Holding periodic review and evaluation meetings with the presence of all team members - Using quality control systems and modern management tools - Analyzing data from past projects and using the experiences and knowledge gained
Defect management and correction	Management and correction methods	Using specialized teams to investigate and correct defects as soon as they are identified - Developing advanced monitoring systems and using modern technologies - Creating information and management systems to accurately record and track defect data - Developing standard methods for evaluating and correcting defects and strictly observing them - Using project management software and accurately recording defect data - Holding workshops and training sessions to increase the awareness and skills of employees and engineers - Using experiences and knowledge gained from previous projects to develop effective methods

Main category	Subcategory	Points mentioned
Improve defect management	Using new technologies	Using project management software and digital tools - Developing advanced monitoring systems and using new technologies such as artificial intelligence and machine learning - Using digital tools and advanced software for data analysis and defect identification - Developing information and management systems for accurate recording of defect data and their analysis - Using new technologies such as 3D printing and nanomaterials - Developing digital platforms and online tools for holding virtual meetings and training - Using advanced management tools such as (Building Information Modeling) BIM
Implementing defect management methods	Implementation methods	Developing and implementing training and empowerment programs for employees and engineers - Using project management systems and advanced software to accurately record and track data - Developing standard guidelines and frameworks for evaluating and correcting defects and strictly adhering to them - Holding periodic review and evaluation meetings with the presence of all team members - Using experiences and knowledge gained from previous projects - Utilizing new technologies and modern management tools - Creating specialized teams and interdisciplinary cooperation to review and manage defects

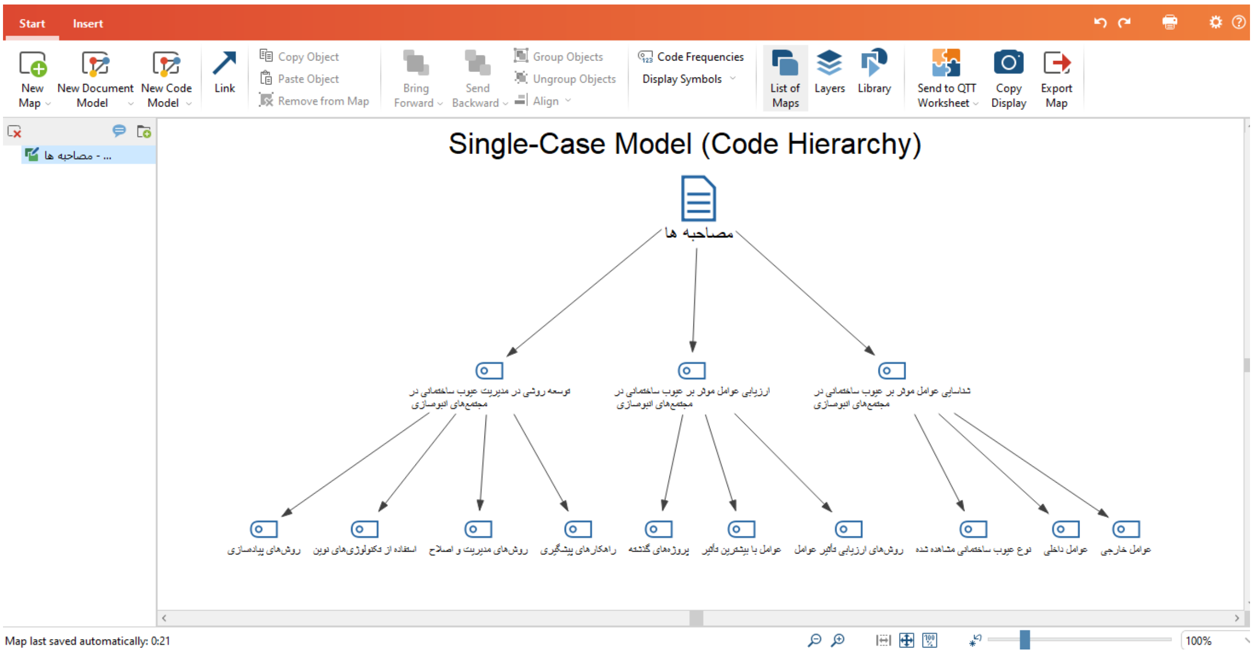

Fig 2. Conceptual framework of components and dimensions in the concept (analysis)

The findings of this study highlight the critical role of construction quality and process supervision in mitigating defects in Shiraz's mass housing complexes. The results are analyzed and compared with existing literature below:

Material Quality and Supervision

The study reveals that poor-quality raw materials and inadequate construction supervision are primary contributors to defects. These findings align with Saraji et al. (2023), who identified material quality and improper construction methods as key issues. Similarly, Abda... et al. (2022) emphasize the significance of supervision and material standards, suggesting a recurring theme across research.

Human Factors and Project Management

Insufficient worker training, skill gaps, and project time pressures were identified as major defect drivers. This corroborates Lu et al. (2022), who advocate for digital quality management systems to enhance processes. Additionally, Taye et al. (2020) stress the influence of construction management and human factors on project outcomes.

Weather Conditions and Regulatory Compliance

Adverse weather and misaligned government regulations were found to exacerbate defects. Hawasheda et al. (2022) similarly highlight these factors, particularly in regional contexts where environmental and regulatory conditions significantly impact construction quality.

Defect Management and Remediation

The study underscores the need for specialized defect-inspection teams and advanced monitoring systems. These results resonate with Al-Amari (2022), who emphasizes defect classification and systematic management. Further support comes from Ahmad et al. (2018), who advocate for technology-driven solutions in defect tracking.

Preventive Measures and Maintenance

Training programs and high-quality materials were proposed as key preventive strategies. This aligns with Avasho and Alimo (2023), who stress routine maintenance and rigorous supervision. Waziri (2016) further notes that such measures can reduce long-term repair costs.

Answering research questions

-What factors have the greatest impact on the occurrence of construction defects in Shiraz mass-construction complexes? According to the research results, the factors affecting the occurrence of construction defects in Shiraz mass-construction complexes include low quality of raw materials, insufficient supervision of the construction process, time pressure to complete projects, and lack of adequate training and skills of employees. Also, adverse weather conditions and lack of coordination between different engineering teams are also important factors.

- How can these factors be categorized and identified? Factors affecting construction defects can be divided into two categories: internal and external. Internal factors include the quality of raw materials, supervision of the construction process, and employee skills, while external factors include weather conditions, changes in government regulations, and their inconsistency with construction realities. This classification can be done using statistical analyses and regression models.

- What is the impact of each of the identified factors on the occurrence of construction defects? According to the results, low quality of raw materials and lack of careful supervision of the construction process have the greatest impact on the occurrence of construction defects. Time pressure to complete projects and lack of employee training also have a significant impact. For a more accurate assessment, statistical analysis and periodic monitoring can be used.

- Which factors are of the greatest importance and priority for managing and reducing defects? The factors with the greatest importance for managing and reducing defects include low quality of raw materials, lack of careful supervision, and time pressure to complete projects. These factors should be prioritized in order to achieve improved construction quality and reduced construction defects.

- What methods and strategies can be used to manage and reduce construction defects? The following methods can be used to manage and reduce construction defects:

- Developing and implementing training programs for employees and engineers.
- Using quality and standard raw materials.
- Continuous monitoring and careful inspection at all stages of construction.
- Using quality control systems and modern management tools.
- Holding periodic review and evaluation meetings with the participation of all team members.

- How can these methods be implemented and evaluated in real projects? Project management software and digital tools can be used to implement and evaluate these methods in real projects. Also, holding workshops and training sessions to increase the awareness and skills of employees and engineers, and using the experiences and knowledge gained from previous projects can help improve processes. Creating specialized teams and interdisciplinary cooperation can also be effective in identifying and managing defects.

Results

The findings of this study corroborate existing literature on construction defects, emphasizing the pivotal roles of material quality, construction process supervision, effective project management, and environmental conditions in the emergence of defects. Furthermore, the integration of modern technological tools and targeted educational initiatives emerges as a promising strategy to mitigate construction deficiencies. Based on these insights, several practical measures are recommended: establishing rigorous material standards enforced by municipal authorities, delivering continuous professional training programs for engineers and construction workers, implementing robust project monitoring systems to detect defects early, adopting advanced digital tools such as defect management platforms, and designing comprehensive defect prevention frameworks incorporating scheduled inspections, quality audits, and systematic evaluations throughout the construction lifecycle. Collectively, these strategies provide a structured approach to improving construction quality, minimizing defects, reducing maintenance costs, and enhancing the long-term durability and performance of residential projects.

Despite the valuable contributions of this research, several limitations must be acknowledged. The study's focus on Shiraz mass housing complexes restricts the generalizability of findings to other regions with differing construction practices, climates, or regulatory environments. Data accessibility constraints, limited sample sizes, and unexamined external variables—such as economic fluctuations, political transitions, and social dynamics—may have influenced the results. Additionally, rapid advancements in construction technologies and regulatory standards may affect the applicability of these findings over time. Factors related to human expertise, decision-making, and the complex interactions underlying defect causes were not exhaustively explored, highlighting the need for future research to expand the scope and depth of investigation, refine preventive strategies, and enhance industry-wide implementation of defect management practices.

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