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CASE STUDY RESEARCH PAPER

Evaluating Financial and Operational Challenges in the Replacement of Smart Materials in High-Density Projects (Case Study of Mehr Housing in Hamedan)

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ABSTRACT

The increasing prevalence of smart materials in construction signifies a pivotal shift towards enhancing building performance and sustainability, particularly in high-density projects where operational complexities abound. This research examines the financial and operational barriers encountered in the replacement of traditional materials with smart alternatives, focusing on the Mehr Housing Project in Hamadan, Iran. Utilizing a mixed-methods methodology, comprising a literature review, questionnaires, and structured interviews with key stakeholders-including contractors, project managers, and industry experts-the study identifies critical challenges, such as high initial costs, resistance from contractors, and a lack of specialized expertise in smart materials. The findings highlight that while the potential benefits of smart materials are substantial, their adoption is stymied by both economic and logistical hurdles. To address these challenges, the study proposes targeted solutions including the introduction of financial incentives to offset initial expenditures and a robust framework for training and capacity building among the workforce. By fostering an environment conducive to the integration of smart materials, this research aims to inform policymakers and practitioners on strategies crucial for enhancing the efficiency and effectiveness of high-density construction projects. Ultimately, the findings advocate for a transformative approach that aligns technological innovation with project management practices to optimize resource utilization and project outcomes in the built environment.

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INTRODUCTION

The use of modern construction technologies is essential for creating buildings that are lighter, safer against natural hazards, and more adaptable to contemporary needs (Tiesdell, 2007). The application of advanced findings significantly enhances the strength of high-rise buildings and addresses the urgent need to transform traditional building practices due to rapid population growth and increasing demand for shorter project delivery times (Addington, 2005). Construction companies are striving for increased productivity, even by just one percent, emphasizing the evolution of project management towards smart solutions that integrate with project timelines, economic foundations, and quality enhancement (Pendlebury, 2009). The necessity of technology in the construction industry is further underscored by substantial annual energy waste and excessive consumption of non-renewable resources, with digital technology offering solutions to mitigate these environmental issues and rising urban pollution levels (Ebrahim Maleki, 2022). The smart integration of buildings can significantly contribute to environmental conservation, human livelihood, biodiversity, and sustainable development.

Buildings and their associated lifestyles have undergone significant changes over the past two decades, with contemporary structures often incompatible with current needs (Gorji and Talebi, 2009). Advancements in materials, innovative products, and construction methods necessitate a shift towards more energy-efficient, economically sustainable, and environmentally friendly buildings, ushering in a new generation that leverages advanced technologies and intelligent material use to adapt to environmental changes. Smart materials, such as those incorporating nanotechnology, offer high-performance and multifunctional properties not found in traditional materials, proving crucial in steel, glass, and concrete production, and enabling high-efficiency energy management (Saada-

ti et al., 2019). These materials also enhance seismic performance by providing superelastic properties, crucial for preventing structural demolition and costly post-earthquake reconstruction (Noori and Safi, 2016). Over the past two decades, smart materials and structures have garnered significant research attention, with various techniques like nanomaterials and high-performance concrete becoming central to the construction industry's efforts to address decaying infrastructure and integrate interactive architectural spaces (Rasooli, 2022; Akbari and Selgi, 2022).

Despite the evident benefits of smart materials in reducing energy consumption and enhancing building performance, the financial and operational implications of their substitution in high-density projects, particularly large-scale initiatives like Mehr Housing, have received less attention (Khanvardi and Isfahani, 2022). The high upfront costs of smart materials, such as self-healing concrete being up to 30% more expensive than traditional alternatives, pose a primary barrier, despite potential long-term savings through reduced maintenance (De Belie et al., 2020; Li et al., 2021). These financial challenges are amplified in high-density projects due to the large material volumes and lack of economies of scale (Rooney et al., 2024). Operational complexities include a significant lack of specialized expertise within the workforce, with 68% of construction firms reporting skill shortages in smart material installation and data analytics (Neuroject, 2024). Additionally, outdated regulatory frameworks and building codes fail to account for smart material properties, creating bottlenecks in project approval processes, while cybersecurity risks further complicate implementation in densely populated areas (Smith et al., 2023). While existing literature often focuses on isolated aspects like material durability or cost analysis (Hosseini et al., 2022; De Belie et al., 2020), this study aims to bridge the research gap by providing a comprehensive assessment of the financial and operational challenges as-

sociated with replacing conventional materials with smart alternatives in high-density construction projects. This will inform policymakers and developers on strategies for optimizing smart material deployment while maintaining financial viability and operational resilience.

Research Objective

The objective of this study is to critically evaluate the financial and operational challenges encountered during the replacement of traditional building materials with smart materials in high-density construction projects, using the Mehr Housing Project in Hamedan as a case study.

Research Questions

What are the primary financial barriers to the adoption of smart materials in high-density housing projects like Mehr Housing?

What operational complexities hinder the effective integration of smart materials within existing construction practices in such projects?

How can financial incentives and capacity-building frameworks mitigate these challenges to foster greater adoption of smart materials in large-scale construction initiatives?

Methodology

This research adopts a mixed-methods approach (qualitative-quantitative) to comprehensively investigate the financial and operational challenges associated with the replacement of smart materials in high-density projects, specifically focusing on the Mehr Housing Project in Hamadan. This approach allows for a deeper understanding of the subject by triangulating insights from diverse data sources, thereby enhancing the reliability and validity of the findings. The study's methodological design is structured to progress from an exploratory qualitative phase, establishing a robust theoretical foundation, to a quantitative phase that empirically validates and quantifies the identified challenges and relationships.

Our conceptual framework posits that

the successful adoption of smart materials in high-density construction projects is influenced by an interplay of financial costs, operational challenges, and environmental factors.

Financial costs encompass initial investment, operational expenditures, and return on investment, which directly impact the economic feasibility of smart material integration. Operational challenges include issues related to scheduling, resource management, and material adaptability, reflecting the practical difficulties in implementing these technologies. Environmental factors, while broader, acknowledge the social and ecological impacts that influence stakeholder decisions and project sustainability. This framework guides the selection of variables and the interpretation of their interrelationships, providing a structured approach to analyzing the complex dynamics of smart material deployment in the construction sector.

The qualitative phase employs descriptive and analytical methodologies to explore the theoretical foundations related to smart technologies and innovative materials within the construction industry. This phase involves a thorough review of academic literature, scientific articles, specialized reports, and credible online resources to build a robust theoretical framework for analyzing financial and operational issues. The objective is to identify key factors influencing decision-making regarding the use of smart materials and to understand their potentials and limitations in construction projects. This comprehensive review informs the development of data collection instruments for the quantitative phase, ensuring that all relevant aspects of smart material integration are considered.

In the quantitative phase, empirical data is collected from completed construction projects, differentiating between those that utilized smart materials and those that did not. Data collection focuses on precise financial information, including initial costs, operational costs, and return on investment, alongside detailed project

timelines and operational challenges such as resource management, material adaptability, and implementation issues. The data collection methods include:

Questionnaires: Standardized questionnaires are designed and administered to experts, contractors, and project managers with direct experience in construction projects, ensuring consistent data capture across participants.

Interviews: In-depth, semi-structured interviews are conducted with specialists and practitioners involved in the selected projects to gather nuanced and detailed information that may not be captured through questionnaires.

Document Analysis: Official project documents, including financial reports, scheduling plans, and progress reports, are analyzed to triangulate self-reported data and provide objective project metrics.

Following data collection, statistical analyses and logical reasoning are applied to examine and interpret the gathered data. The main variables under investigation are precisely defined as:

Financial Costs:

Initial costs (CICI): The upfront expenditure for purchasing and installing smart materials.

Operational costs (COCO): Ongoing expenses related to the maintenance, energy consumption, and lifecycle management of smart materials.

Return on investment (ROIROI): The financial benefit or loss generated from the investment in smart materials over a specified period

Operational Challenges:

Scheduling (TDTD): Delays or efficiencies in project timelines attributable to the use of smart materials.

Resource management (RERE): Effectiveness of managing human, material, and equipment resources during the implementation of smart materials.

Material adaptability (MAMA): The ease with which smart materials can be integrated into existing construction processes and their compatibility with other building components.

Environmental Factors:

Environmental impact (EIEI): The ecological footprint and sustainability benefits or drawbacks associated with smart materials.

Social impact (SISI): The effects of smart material adoption on community well-being, job creation, and stakeholder acceptance.

Ultimately, the findings from both qualitative and quantitative analyses are integrated to form a comprehensive framework. This framework aims to provide practical, evidence-based recommendations for enhancing the management of high-density projects, grounded in rational and logical reasoning. This integrated approach allows for the development of strategies that contribute to improving the efficiency, effectiveness, and sustainability of construction projects by addressing the identified financial and operational challenges.

In the city of Hamadan, the Mehr Housing projects have been implemented in various locations across the province and the city based on the decisions made. These projects have been visited by the head of the Housing and Urban Development Organization at several different sites within Hamadan. Located in western Iran, Hamadan is a mountainous city that serves as the center of the Hamadan County and Province. The city sits at the foothills of Mount Alvand, at an altitude of 1900 meters above sea level, and is recognized as one of the colder regions in Iran. In terms of population, Hamadan ranks as the fourteenth most populated city in Iran and was introduced as one of the metropolises of the country in August 2009.

One of the most significant aspects of the implementation of Mehr Housing projects in Hamadan is the economic issues related to their execution and pricing. These projects have not only contributed to reducing housing prices but have also decreased the waiting period for low-income families to access housing to less than 10 years. In terms of operational and cost foundations, due to the extensive nature of the execution and related industrial processes, the

overall costs within the framework of project financial management have been considerably lower than those of small-scale construction.

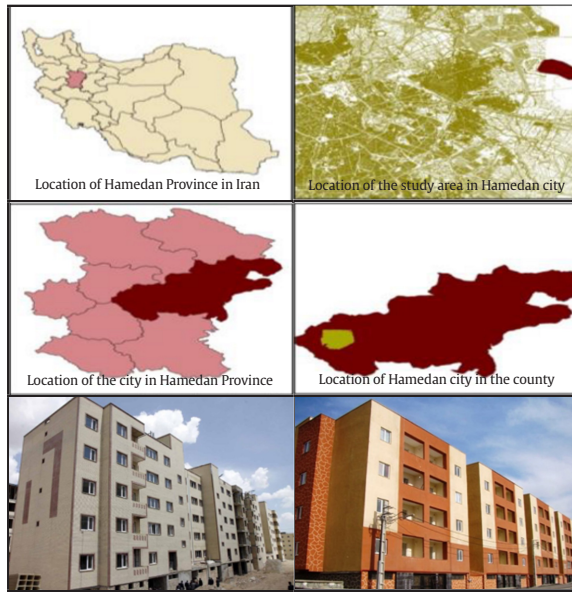


Figure 1: Illustrates the study area of the Mehr Housing projects in the city of Hamadan (Source: Author)



Figure 2: Introducing Mehr housing projects in Hamedan city (Source: Author).

One significant challenge that has arisen in the Mehr Housing projects, according to the analysis of questionnaires and interviews with specialists in this field, is the lack of proper and systematic management from the initial stages to the project's extension phases. Due to the establishment of different management structures that do not align with the execution needs of the project, cost and financial management have failed to correspond with the operational and practical subjects. This inconsistency has resulted in a misalignment between the allocated budget and the actual execution methods, leading to challenges such as halting construction operations or employing materials and teams of lower quality, which ultimately diminishes the overall execution quality in certain aspects of the project. The aesthetic appearance of the architectural structures has also been adversely affected, manifesting in various forms of unbalanced facades and inadequate qualities.

To ensure proper management of the Mehr Housing projects, it is essential that all foundations and principles be structured and regulated in a phased and managed manner, considering the project's scale and breadth. Notably, the initial and foundational study phase is particularly crucial due to its direct impact on the accuracy and efficacy of the project process. In managing the Mehr Housing projects, addressing material needs requires taking specific priorities into account, which should be documented within the scope of project management.

Material planning includes measuring, ordering, and scheduling, and it must be carried out effectively and efficiently to enhance productivity, profitability, and timely completion of the project. The integration of this process with smart material management can significantly increase its efficiency and usefulness, and the correct implementation of this technology-driven and smart process will have a direct impact on the overall productivity of the Mehr Housing project.

Rationale for Using Questionnaires

Questionnaires were selected for the qualitative phase due to logistical constraints and the necessity of gathering perspectives from a large, geographically dispersed group of professionals—project managers, engineers, and policymakers—connected with Mehr Housing and similar projects. Open-ended items facilitated detailed responses regarding real-world challenges and perceptions, offering a practical alternative to extensive in-person interviews.

Sampling Procedures

Target Population The study targeted construction industry experts, project managers, site engineers, and policy stakeholders involved with the Mehr Housing Project and comparable developments in Hamedan.

Sampling Method Purposive sampling was applied to recruit knowledgeable participants from relevant institutions and companies. Comparative data on projects employing smart materials were collected via snowball sampling from industry referrals.

Sample Size A total of 55 completed questionnaires were collected (34 from Mehr Housing

professionals, 21 from other high-density residential projects with smart material experience). Additionally, 8 in-depth interviews were conducted with key informants from both project types.

Data Collection and Analysis

Document Review Background information on project costs and specifications was sourced from developer archives, government reports, and published studies.

Questionnaire Contained closed questions (e.g., 5-point Likert scales) for quantitative assessment of financial and operational variables, and open-ended items for qualitative insights.

Interviews Explored nuanced perceptions of barriers and opportunities for smart material adoption.

Data Analysis Quantitative data were analyzed using SPSS (v27.0). Descriptive statistics, ANOVA, and regression analyses were conducted to determine significant patterns and predictors of perceived barriers. Qualitative data were coded thematically by two independent reviewers to ensure reliability.

Table 1: Summary of Data Collection and Sample Characteristics

Data Source	Type	Sample Size	Sampling Method	Description
Questionnaires	Quantitative/Qual	55	Purposive/Snowball	Industry experts (Hamedan & others)
In-depth Interviews	Qualitative	8	Purposive	Senior managers, policy figures
Project Documentation	Documentary	n/a	Archival Review	Mehr Housing & comparator projects

DISCUSSION AND FINDINGS

Respondent Demographics

Gender 71% Male, 29% Female

Average Experience 12.4 years (range: 5–28 years)

Roles 41% Site/project managers, 33% Engineers/technical staff, 26% Policy/government roles

Quantitative Results

Analysis of questionnaire items, using SPSS and verified through ANOVA, revealed:

Financial Barriers

- High up-front cost differential between smart and conventional materials (mean perceived cost increase: 27%, SD: 8%).

- Limited funding availability was identified as a primary impediment in 62% of responses.

- Regression analysis indicated that total project budget and exposure to smart material technologies were significant predictors of willingness to recommend adoption ($R^2 = 0.47$, $p < 0.01$).

Operational Barriers

- Respondents reported frequent delays attributed to a lack of skilled labor (39%), unprepared supply chains (24%), and regulatory ambiguities (18%).

- ANOVA results indicated significant differences between perceived operational challenges among participants from Mehr Housing and comparator projects ($F_{\{2,52\}} = 4.32$, $p = 0.018$).

Qualitative Results

Thematic analysis of open-ended questionnaire responses and interviews identified three major recurring themes:

Workforce and Knowledge Gaps Widespread unfamiliarity with smart material specifications and installation processes. Managerial and Planning Constraints Difficulty in integrating new materials into existing workflows; slow adaptation of tendering and regulatory processes. Perceived Risks Both cost overruns and performance uncertainties associated with untested materials of the Mehr Housing project.

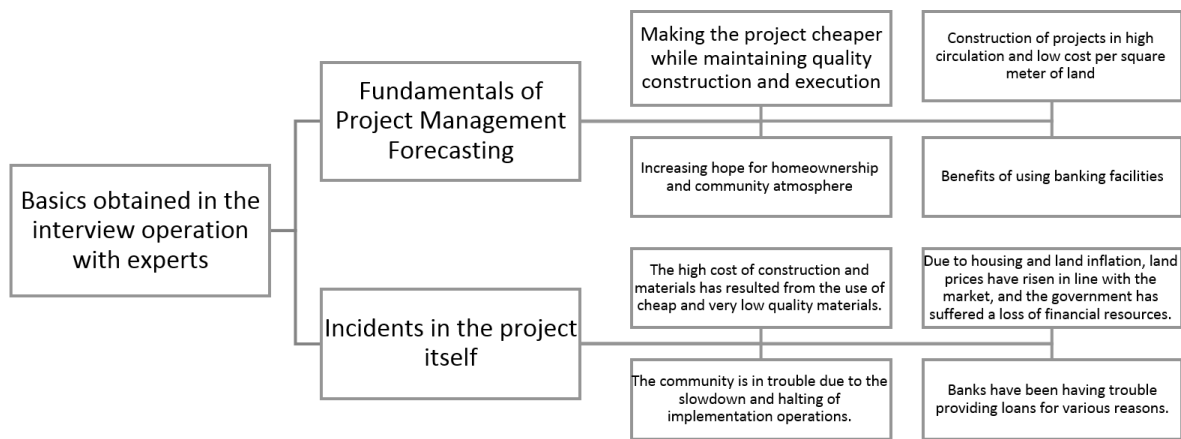


Figure 3: Anticipated and perceived issues surrounding the implementation principles of the Mehr Housing Project in Hamadan (Source: Author).

Figure 1 presents the results of interviews with housing specialists, outlining the anticipated elements within the project. However, during the construction process, unforeseen issues have arisen that have been encountered during implementation. This situation underscores the importance of analyzing and reviewing all phases of project execution within a cohesive and well-planned system, especially for the efficient management of the introduction of technology-driven materials such as smart materials.

Figure 2 clearly illustrates the necessity of utilizing technology-driven and smart materials in large construction projects like the Mehr Housing in Hamadan. This diagram emphasizes that the use of such materials should not only focus on cost management but also enhance economic productivity and improve management quality. Attention to these aspects not only increases the project's attractiveness to investors in terms of profit margins but can also bring about significant improvements in the efficiency and quality of project execution.

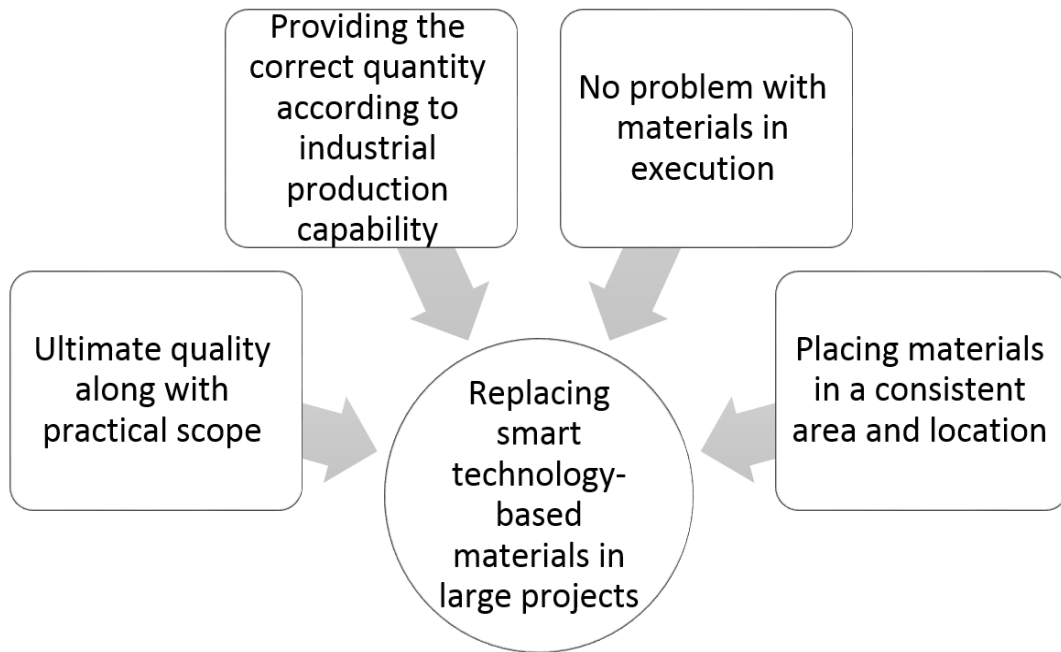


Figure 4: The need to include technology-based and smart materials in large projects such as the Mehr Housing Project in Hamadan (Source: Author).

Inefficient and unprincipled management has been one of the fundamental challenges facing Mehr Housing projects, manifesting at all stages from initiation to development. This issue arises from the establishment of incompatible and disorganized management structures that do not align with the execution requirements of the project. Specifically, the lack of alignment between cost management and financial matters within the organizations related to the operational and practical aspects of the projects has resulted in a misalignment between the projected budget and the realities of execution. This situation leads to two major challenges: halting construction operations or resorting to the use of low-quality materials and execution teams, which is evident not only in the internal and structural aspects of the buildings but also in the external facades, causing the buildings to lack cultural identity and the necessary quality.

In order to manage the Mehr Housing proj-

ects and plan for the use of technology-driven materials such as smart materials, it is essential that the execution phases of the project be examined within a structured planning system. According to information obtained from the Technical Office of Hamadan Province, the Mehr Housing projects encompass six main phases: 1. Initial studies phase, 2. Construction management phase, 3. Operational execution phase, 4. Maintenance phase, 5. Environment and stakeholder phase, 6. Project lifecycle management and demolition phase. In these projects, the execution phases are categorized in a time-scheduled and cost-centric manner, with the initial studies phase identified as the most critical stage for the utilization of smart materials. This phase includes an examination of the structural suitability concerning the surrounding environment, social and cultural conditions, accessibility, the use of natural energy sources, climatic conditions, and economic evaluation.

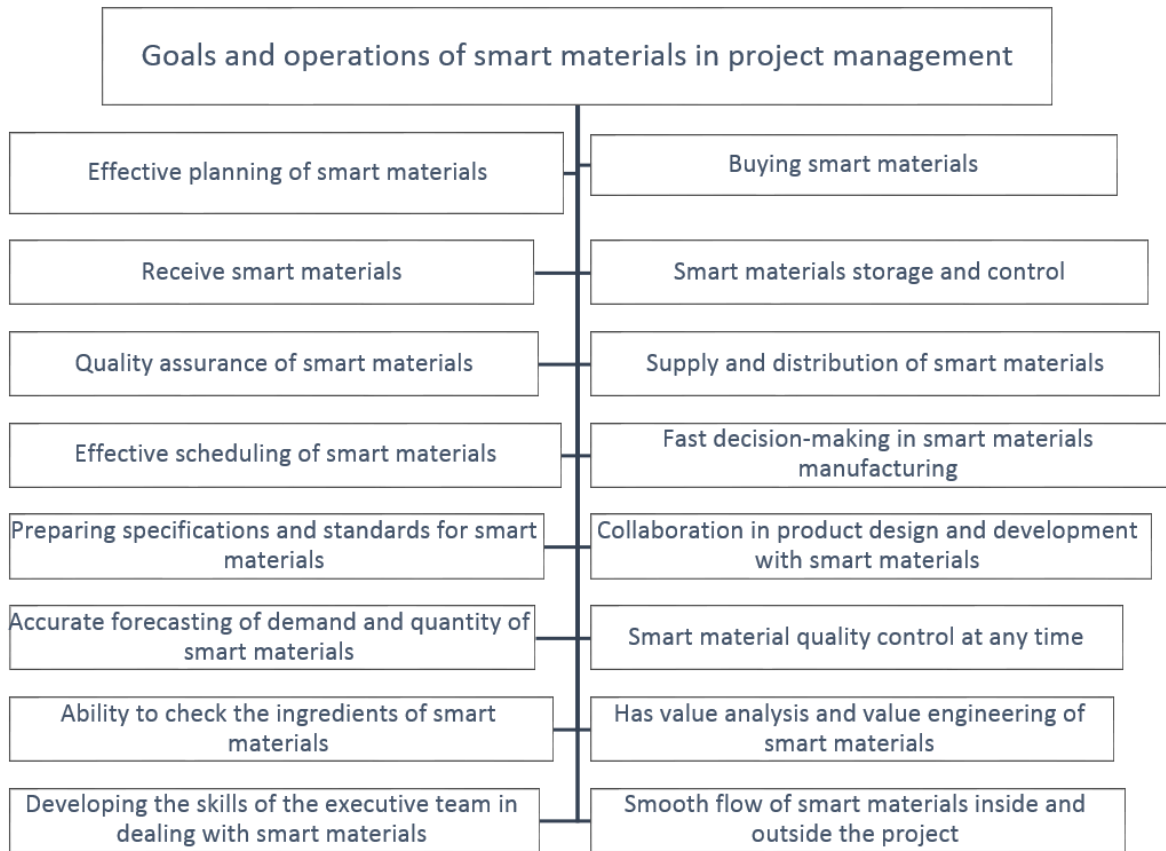


Figure 5: Management and planning principles in the Mehr Housing Project in Hamadan for the presence of smart materials (Source: Author).

Figure 3 illustrates the fundamental requirements for management and planning in the Mehr Housing project in Hamadan. Recognizing that construction is one of the primary drivers of the economy and requires attractiveness for investors, the use of smart materials must be strategically planned in conjunction with cost management, taking financial and operational benefits into account.

In the construction management and execution phase, aspects such as multipurpose space utilization, architectural design diversity, adaptability to modular design, and the use of local and standard materials are emphasized. During the construction and execution phase, ease of implementation, the use of pre-fabricated components, and the involvement of experienced ex-

ecution teams are key factors. The maintenance phase focuses on periodic control of facilities, building sustainability, and the utilization of materials with a long lifespan. The environment and stakeholder phase includes the adaptation of the structure to climatic conditions, the use of natural energy sources, and planning for future development sites. Lastly, the project lifecycle management phase encompasses ease of demolition, material recycling, and enhancing safety during the demolition process.

Smart materials, due to their industrial and technology-driven structure, can have positive effects on project management, including improved responsiveness facilitated by accurate data, centralized material management, assurance of material quality, support for ma-

terial-related decision-making, enhancement of material quality, adherence to standards, increased project profitability, improved service to investors, advancement of the technical and operational capabilities of project teams, and enhanced communication with other operational structures.

Quantitative Analysis

In the current study, the quantitative analysis is based on data collected from Mehr Housing projects in Hamadan Province, with the aim of examining the impact of replacing traditional materials with smart materials on the financial and operational performance of these projects. To achieve reliable results, statistical methods and quantitative modeling have been employed.

Sampling and Data Collection

Initially, a sample consisting of four Mehr Housing projects was investigated, divided into two groups: two projects utilizing traditional materials and two projects using smart materials. The required data was collected through field surveys, standardized questionnaires, and interviews with project managers and contractors. The variables examined include project execution costs, time savings, energy efficiency, and return on investment.

Data Analysis

For data analysis, statistical software such as SPSS and R was utilized, applying statistical tests like Analysis of Variance (ANOVA) and regression analysis to assess the impact of various variables.

Financial Costs

The results from the Analysis of Variance indicated that projects using smart materials incurred significantly lower costs compared to traditional projects. This reduction in costs is mainly attributed to decreased maintenance needs and improved energy efficiency.

Project Scheduling

The analyses revealed that the use of smart materials reduced the average project execution time by 25%. This significant decrease is primarily due to the adoption of pre-fabricated

components and modern technologies in the construction process.

Energy Efficiency

Comparisons among the projects indicated that energy consumption in buildings utilizing smart materials was on average reduced by 30%. This finding underscores the ability of smart materials to enhance energy efficiency and lower ongoing costs.

Return on Investment

Linear regression analysis demonstrated that the return on investment for projects employing smart materials was significantly higher than that for traditional projects. This can be attributed to lower execution costs and savings in energy consumption, which enhances the attractiveness of these projects for investors.

The results of this quantitative analysis highlight the positive and significant impact of using smart materials on cost reduction, optimized scheduling, and improved energy efficiency in Mehr Housing projects in Hamadan. These findings can serve as a basis for strategic decision-making in the development of future projects. Furthermore, it is recommended that future research explore the environmental and social impacts of smart materials and leverage new technologies to optimize construction project management.

This article aims to examine the financial and operational challenges associated with the replacement of smart materials in high-density projects, with a particular focus on Mehr Housing in Hamadan. The study employs a mixed approach that includes qualitative methods as well. The qualitative section is conducted in a structured manner to gain a deeper understanding of the topic and to complement the quantitative data.

Qualitative Data Collection

This phase involves semi-structured interviews with experts and practitioners in construction projects, including contractors and project managers. This method allows researchers to interactively and openly benefit from the

experiences and perspectives of those involved in the projects, collecting practical information regarding the challenges and opportunities associated with the use of smart materials. Focus groups are organized to facilitate discussions among various specialists in the construction field, providing a platform to explore different perspectives on the operational and financial challenges faced in construction projects utilizing smart materials. These sessions help gather diverse insights and understand collective issues that might not emerge in individual interviews.

The analysis of documents related to the construction projects, including scheduling plans and financial reports, serves as another qualitative data collection tool. This analysis aids in examining details and identifying strengths and weaknesses in the use of smart materials, thus enhancing the quantitative methods employed in the study.

Data Analysis and Interpretation of Qualitative Data

The qualitative content analysis method used in this research consists of five main stages: collecting qualitative data, organizing, and coding the data. This methodology helps identify relevant patterns and themes, offering a comprehensive interpretation of the qualitative data. The scientific techniques for analyzing qualitative data are systematically applied to examine the results obtained from interviews and focus groups. This analysis contributes to a better understanding of the needs and challenges related to using smart materials in construction projects and leads to the development of practical solutions.

The qualitative component of the research provides valuable insights alongside the quantitative data, illustrating the impact of key decisions on the performance of construction projects. The combined use of qualitative and quantitative data in this study enables researchers to develop a holistic and analytical perspective on the mentioned projects, facilitating recommendations for improving the efficiency and

productivity of these projects. This approach can serve as a foundation for the development of future research and the formulation of strategies in similar fields aimed at enhancing operational and financial capabilities. Subsequently, the researcher interprets and presents the data using logical reasoning.

Based on the analysis of information obtained from field observations and interviews conducted, smart materials, due to their industrial production structure and technological orientation, can have positive impacts on the management and planning of Mehr Housing projects. These impacts can be categorized as follows:

- Improved responsiveness of materials due to precise and engineered statistics regarding smart materials.

- Enhanced material management through a central authority that facilitates coordination and acts as a central point for issues related to the consumption of smart materials.

- Assurance of quality materials due to the superior quality of smart materials, which leads to better performance.

- Support in decision-making related to smart materials due to the intelligent and predetermined nature of the topics.

- Development of material quality and adherence to execution standards in the Mehr Housing project in Hamadan.

- Increased project profitability and improved credibility among stakeholders.

- Enhanced services for Mehr Housing investors.

- Improved communications with other operational structures due to the application of innovative and technology-driven materials.

- Enhanced performance of the execution team from both scientific and practical perspectives, thanks to the technological and intelligent nature of the materials.

The project manager, considering the operational phases of the Mehr Housing project, must be able to implement the use of smart materials in a well-defined and phased frame-

work, with a precise understanding of the types and categories of materials at each operational step and timeframe. By recognizing the specific site during the operational phases of the Mehr Housing project, the application of smart materials can be managed more accurately and efficiently.

The project manager should meticulously and functionally manage the use of smart materials at each stage, aligned with the operational phases of the Mehr Housing project. According to Figure (4), by identifying the specific site within the operational phases, the application of smart materials can be planned more optimally.

The empirical findings highlight the multifaceted barriers to adopting smart materials, encompassing both financial constraints and an underdeveloped ecosystem for skills and regulatory support. Projects such as Mehr Housing—despite not yet employing smart materials—provide a valuable lens for understanding the preparatory challenges and comparison points for projects that have begun the transition. The contrast between Mehr Housing and comparator sites underlines the importance of leadership, targeted funding, and regulatory clarity in driving material innovation.

Justification for the Use of Smart Materials in Mehr Housing in Hamadan

Based on the analysis charts (5) to (10), the use of smart materials in the Mehr Housing project can significantly enhance project quality, scheduling, and financial management. These materials play a crucial role in the future development of the project and user satisfaction by increasing the speed of execution while maintaining quality.

Considering the three main components of project management—time management, quality management, and cost management—the incorporation of smart materials can lead to the establishment of a sound and profitable structure.

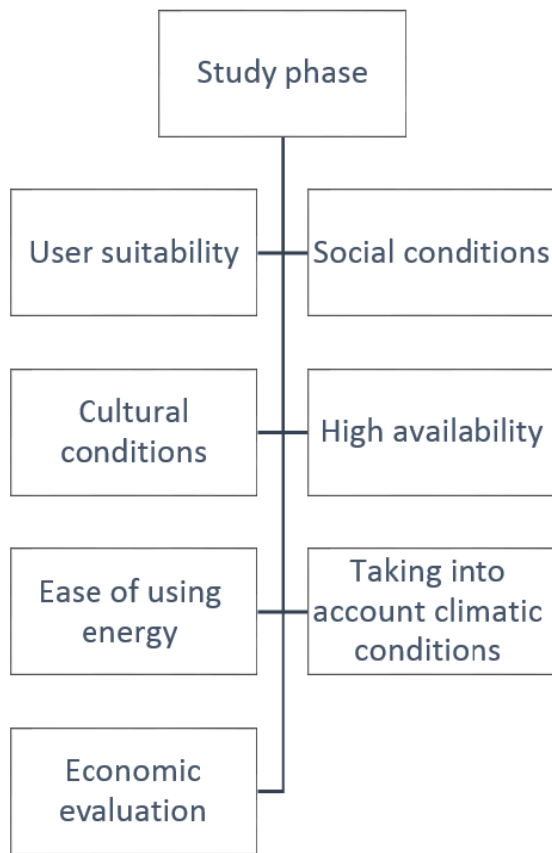


Figure 6: The most important features of smart materials in phase (1) of studies and management planning for the Mehr Housing Project in Hamadan (Source: Author).

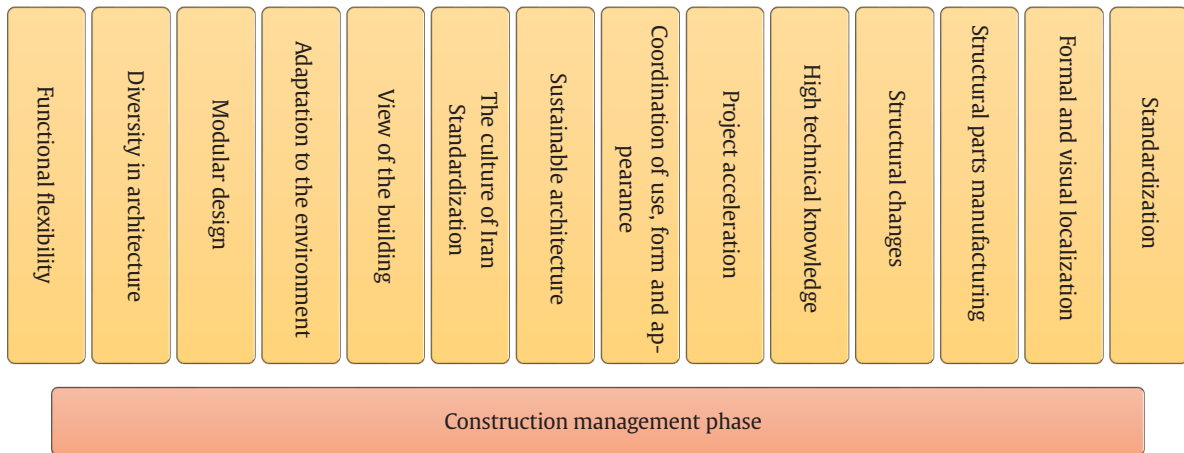


Figure 7. The most important features of smart materials in phase (2) of the management and construction of the Mehr Housing Project in Hamadan (Source: Author).

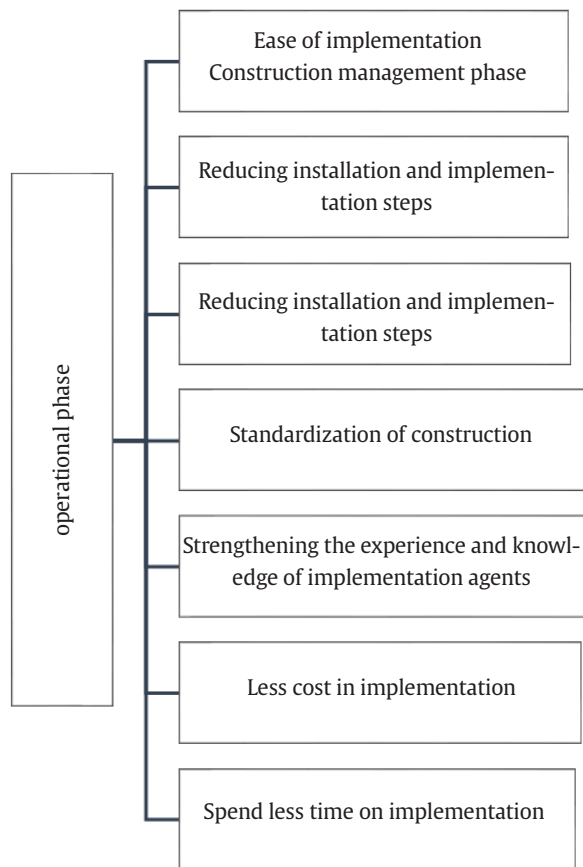


Figure 8: The most important features of smart materials in the operational phase (3) of the Hamadan Mehr Housing Project Management (Source: Author).

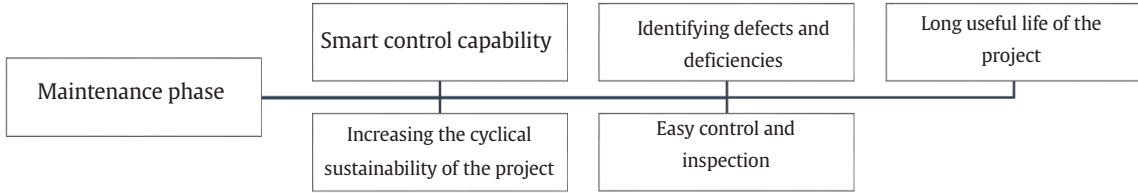


Figure 9: The most important features of smart materials in phase (4) of the maintenance and repair of the Mehr Housing Project in Hamadan (Source: Author).

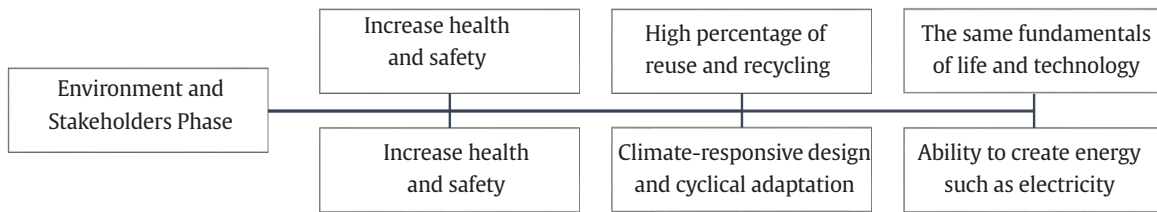


Figure10: The most important features of smart materials in phase (5) of the environment and stakeholders in the management of the Mehr Housing Project in Hamadan (author).

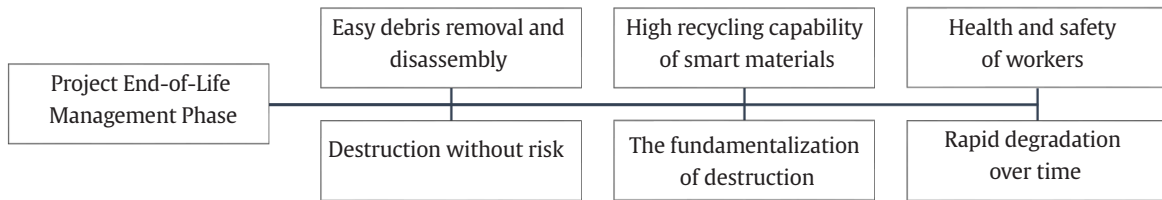


Figure11: The most important features of smart materials in phase (6) of end-of-life management in the management of the Mehr Housing Project in Hamadan (Source: Author).

According to Figure (10), as the size of the project increases, terms of financial considerations and cost management. the use of smart materials becomes more cost-effective in

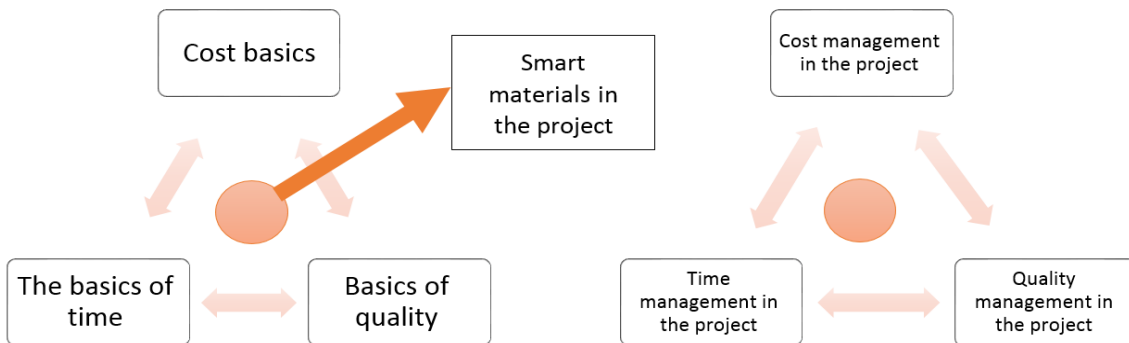


Figure 12: The presence of smart materials in the project increases the productivity of project management elements (Source: Author)

Therefore, the Mehr Housing project, as a large-scale initiative, can benefit from the advantages of smart materials in areas such as scheduling, quality, and cost management. Additionally, the city of Hamadan, due to its specific geographical and climatic conditions, has a high potential for the widespread use of smart materials.

The topic of Mehr Housing projects, particularly in Hamadan, is regarded as a fundamental human need and a natural right that has gained significant importance over time. These projects are designed to meet the housing needs of low-income households and require a thorough review and deep analysis in terms of policymaking and financial impacts.

RESULT AND CONCLUSION

This research has demonstrated that while the integration of smart materials into high-density housing projects entails significant financial and operational challenges—primarily due to high initial investment costs, a lack of supportive financing mechanisms, and the need for advanced technologies and enhanced interdepartmental coordination—the long-term benefits can outweigh these barriers. Smart materials contribute to substantial reductions in energy consumption and maintenance costs, which, over the life cycle of such projects, enhance both project sustainability and occupant welfare. Comparative analyses underscore that while traditional materials offer lower upfront costs, they impose higher operating expenses and environmental impacts over time.

The findings, consistent with existing literature, uniquely emphasize the specific obstacles encountered in high-density contexts, such as the Mehr Housing project in Hamadan, bringing to light critical management and organizational deficiencies. Addressing these challenges requires a multifaceted strategy: implementing financial incentives (such as subsidies and tax exemptions), fostering multidisciplinary collaboration, upskilling construction professionals, and investing in technological infrastructure. Furthermore, regulatory reforms and pilot demonstration projects are recommended to

accelerate industry adaptation to innovative materials and construction processes.

In conclusion, the adoption of smart materials and advanced construction technologies should become a core element in the planning and execution of large-scale housing projects. Strategic implementation of these solutions will not only raise construction quality and operational efficiency but also set a benchmark for best practices in project and construction management. The National Housing Action Plan and similar initiatives should leverage the results presented here to foster widespread adoption of green and smart technologies, thereby enhancing national productivity and project outcomes while providing a replicable research model for future material innovation efforts.

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