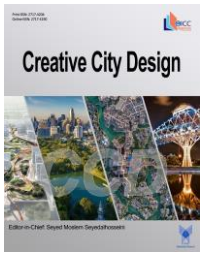

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Research Article

A Comprehensive Evaluation of the Sustainability of Informal Settlements in Qods City Using the Integrated DEMATEL–Interpretive Structural Modeling (ISM) Approach

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Abstract

Aims: This study evaluates the sustainability of informal settlements in Qods City by analyzing causal relationships and the influence intensity among key sustainability indicators. Three informal neighborhoods were selected to assess sustainability across physical, social, economic, and managerial dimensions.

Methodology: Sustainability indicators and sub-indicators were identified through a systematic literature review and expert consultation. Data were collected using field observations and resident questionnaires based on a five-point Likert scale. Statistical analyses including the one-sample T-test and Friedman test were applied to determine sustainability levels, and effect size was calculated to interpret practical significance. Furthermore, the DEMATEL technique was used to construct a total relationship matrix, and DEMATEL was integrated with ISM (Interpretive Structural Modeling).to build a hierarchical network mapping the interdependencies among sub-indicators.

Findings: Findings revealed that although some sub-indicators such as ethnicity, income, and land-use compatibility scored above average, the overall sustainability of the informal settlements was weak or unstable. Economically, the neighborhoods showed favorable conditions, while urban management emerged as the most deficient indicator. Social security, as well as physical aspects including street quality and urban aesthetic quality, were identified as weak. The DEMATEL-ISM analysis clarified the causal and dependent roles of indicators within the sustainability network.

Conclusion: The results underscore significant sustainability challenges in Qods City's informal settlements. By identifying both influential and dependent indicators, the study provides a structured basis for targeted interventions. A comprehensive proposal was formulated to enhance sustainability, combining strategic measures for high-impact causal factors with project-based actions to address dependent and deficient areas.

Keywords: Sustainability, Informal Settlements, DEMATEL, Interpretive Structural Modeling (ISM), Qods City

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1. Introduction

Urbanization has emerged as a dominant trend in recent decades, particularly across developing countries such as Iran. This rapid urban expansion has been accompanied by the centralization of economic opportunities and public services in major cities, which in turn has driven large-scale migration from rural areas and small towns to metropolitan centers. A prominent outcome of this process has been the proliferation of informal settlements on the urban periphery, areas typically inhabited by migrants unable to access formal housing markets due to high costs and the lack of effective housing policies [1]. Although these informal settlements are economically interlinked with central urban areas, they remain spatially, socially, and infrastructurally marginalized [2]. As visible expressions of urban poverty, they are often characterized by substandard living conditions, inadequate infrastructure, and increased exposure to social vulnerabilities, all of which significantly undermine residents' quality of life [3]. One of the most pressing challenges associated with informal settlements is their multidimensional instability, spanning environmental, economic, social, and governance domains [4]. This complexity underscores the urgent need to assess these areas through the lens of urban sustainability [5]. In this context, sustainability refers not only to environmental resilience but also to achieving a balanced and equitable urban development that enhances the overall well-being of marginalized communities [6]. Without a sustainability-driven approach, the continuation of current development trajectories, amid limited natural resources and strained social systems, poses a significant threat to urban viability [7]. The informal expansion of Tehran and its satellite cities exemplifies these dynamics. As Iran's capital city continues to experience soaring land and housing prices alongside the centralization of capital and services, informal settlements have rapidly spread into surrounding urban areas. Qods City, one of Tehran's peripheral municipalities, serves as a notable case. Formerly a rural village, Qods has undergone rapid physical and demographic transformation due to factors such as proximity to Tehran and Karaj, low land prices, uncertain land ownership, and weak land management systems [8].

This study focuses on assessing the sustainability of informal settlements in Qods City. From a social perspective, limited access to essential services such as healthcare, education, transportation, water, and electricity has severely impacted the quality of life [9]. Evaluating social sustainability can inform strategies that improve residents' welfare and strengthen community cohesion, potentially reducing social harms and fostering local stability [10]. From an economic standpoint, these areas are highly susceptible to broader economic fluctuations. Analyzing their economic sustainability can guide the development of inclusive livelihood programs that enhance employment and economic security [1]. Given the interdependence between Qods and the greater Tehran metropolitan region, improving economic conditions in informal areas can generate wider regional benefits. Environmentally, these neighborhoods suffer from severe deficiencies, including pollution, insufficient waste disposal infrastructure, and unsustainable use of natural resources [5]. A comprehensive environmental sustainability assessment is critical to mitigating ecological damage and safeguarding public health. Finally, from a governance and planning perspective, the absence of comprehensive urban management has enabled the unchecked spread of informal settlements in Qods [8]. A multidimensional sustainability evaluation can provide urban planners and decision-makers with targeted insights for improving infrastructure, enhancing service delivery, and curbing the expansion of socio-economic vulnerabilities. By investigating the sustainability of informal settlements in Qods City, this study aims to contribute both theoretically and practically to the discourse on informal urbanization. The findings may help bridge critical research gaps and lead to the development of localized, actionable models for assessing and improving sustainability in similar urban contexts across Iran and the broader region.

In recent years, the growth of urbanization and the decline in the quality of life have made the issues of sustainability and informal settlements a significant and challenging topic among academic communities and urban managers. In this context, numerous studies have been conducted regarding the factors affecting the sustainability of informal settlements and the problems arising from their unsustainability. For example, in the study by [11], titled "Explaining the physical and functional components affecting the physical justice in the Informal settlement of Mashhad metropolis" it was found that physical justice in informal settlements is significantly influenced by physical diversity. Dashtaki et al. [12] studied the effects of the two-way relationship between cities and citizens on sustainability across economic, social, and environmental dimensions, based on the conceptual model of an ideal city. On the other hand, Aras et al. [10], in their study on assessing satisfaction with empowerment indicators in informal settlements in Khalilabad, Tabriz, emphasized that economic and social indicators are crucial in the quality of life in peripheral areas. Khakzad et.al. [13], in their research titled " Assessing the level of socio-cultural sustainability in empowering rural communities (Case study: Mountainous villages of East Azerbaijan province)", showed that social sustainability not only improves the

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quality of life but also positively impacts sustainability in the physical, economic, and environmental dimensions.

As a result, strengthening social aspects leads to the sustainability of the entire settlement system. Arkhazloo et al. [14], in their study on urban planning for sustainable urban development in peripheral areas (case study: KazemAbad neighborhood of Ardabil), concluded that the study area is socially, economically, and culturally unsustainable, characterized by a lack of belonging, insufficient facilities, and poor living conditions, which contribute to its instability. Internationally, researchers such as Rahimi et al. [15], in their study on recognizing the theory of sustainable urban design in suburban areas, stated that land management is an essential factor in the sustainability of informal settlements. Mohamed Elgohary et al. [16], in their research titled "Upgrading informal areas through sustainable urban development principles" emphasized the importance of sustainability in all dimensions, including social, environmental, managerial, economic, and physical. Additionally, a study titled "The jugaad urbanism-sustainable circular cities nexus: Insights from sub-Saharan Africa's informal settlements" conducted by Abagna Azunre et.al. [17], identified the role of local participation and the use of available potentials, along with urban management's strategic approach, in positively influencing the quality of peripheral areas. Hanaee et.al. [18], In their study entitled “Evaluating the Quality of Life in the Suburban Context Based on Environmental Indicators: The Case of the Southwest Elevations of Mashhad City”, critically examined the environmental determinants influencing livability in peripheral urban areas. The authors conclude that adopting conservative planning strategies such as emphasizing risk mitigation, environmental stabilization, and incremental improvement constitutes the most effective approach for enhancing the environmental quality and overall well-being of residents in marginalized suburban neighborhoods. Results of the study by Hataminejad et al. [19] indicate that the environmental quality and spatial configuration of informal settlements primarily shape maladaptive social behaviors, with environmental–cultural factors outweighing socioeconomic ones. Sarakhs exhibits the healthiest social behavior profile, while Mashhad shows the highest dysfunction among the studied settlements.

A review of the research literature reveals that organizing peripheral areas to achieve sustainability has been a key topic in urban planning. Although extensive studies have been conducted on the factors affecting the sustainability of informal settlements in past research, there remains a gap for a comprehensive approach that considers all the dimensions affecting sustainability. Accordingly, this study sought to adopt a comprehensive approach to identifying and evaluating context-specific sustainability indicators in the informal settlements of Qods City, in order to provide a scientific basis for policymaking and planning toward the regularization of these settlements, thereby contributing to the improvement of urban living conditions and the realization of spatial justice. To this end, the first research question, ‘What are the local indicators influencing the sustainability of urban settlements?’, was formulated with the aim of identifying and conceptualizing indigenous indicators relevant to the sustainability of these areas. The second research question, ‘To what extent are informal settlements sustainable, and how can they achieve greater sustainability?’, was aimed at assessing the current sustainability status of these areas and proposing practical strategies for achieving sustainable development.

The study is organized as follows: first, the theoretical foundations are discussed; in the third section, the research methodology is explained, which is development-applied and descriptive-analytical in nature. The data collection methods, assessment, and reliability of the methods are outlined, and the study area is introduced. In the fourth section, the findings are presented, and methods for assessing the sustainability of informal settlements in Qods City are outlined, incorporating the DEMATEL method and Structural-Interpretive Modeling (SIM). A scenario for achieving sustainability in the informal settlements of Qods is also provided. Finally, in the fifth section, conclusions and recommendations are presented.

2. Materials and Method

2.1. Sustainability

Sustainability emerged as a solution to address the global challenges of preserving human life on Earth and mitigating human-induced activities. Urban sustainability refers to the absorption, maintenance, and development of natural and human resources within cities [20]. In the definition of urban sustainability, a sustainable city is one that is planned in such a way that its urban community can meet its current needs without threatening the ability of future generations to meet their own needs. Hence, the physical organization of a city becomes essential, as it must enable the urban community to realize a sustainable city. In other terms, sustainable cities can be seen as living communities where all environmental resources are protected from exploitation, and this principle must be upheld at every level of the city [21].

Some key features of urban sustainability include intergenerational justice, which encompasses social justice, geographical justice, and justice in governance [22], protection of the natural environment, minimal use of non-renewable resources, economic vitality and diversity,

an independent and self-reliant community, the well-being of people, and the fulfillment of basic human needs [23]. Political and social instability often obstructs urban planning and sustainable urban projects, leaving many urban residents in substandard living conditions [24]. Consequently, it can be said that specific sustainability indicators cannot be defined for all communities across all geographical contexts without considering local conditions. Achieving sustainability requires incorporating the specific characteristics of each location when determining the sustainability indicators for that place. A sustainable city must possess sustainable features and sustainable development across all dimensions related to urban development. In this context, several key indicators have been examined in urban studies at various scales, which significantly impact sustainability. These include physical, social, economic, and environmental indicators, all of which play a crucial role in ensuring urban sustainability [25] which are shown in Figure 1.

2.2. Informal settlement

Urban informal settlement is one of the most prominent manifestations of urban poverty [26], and it has become one of the most significant challenges for many large cities [2]. With the increase in population and the expansion of urbanization, issues related to Informal settlement have become a core social and security problem in cities [14]. These settlements are known by various names, including: 1) Informal settlement, 2) unplanned settlements, 3) illegal settlements, 4) disorganized settlements, 5) slum housing [27]. Informal settlements are areas that house rural migrants and the urban poor, which have emerged outside of formal and legal urban planning, often without permits, either inside or outside the legal boundaries of cities [28]. The lack of official property documents and deprivation of urban services and infrastructure are key characteristics of these settlements [29].

From a cultural perspective, Informal settlement involves isolation, a sense of foreignness and alienation; from a psychological perspective, it involves distress and fatalism; from an economic perspective, it entails poverty, employment in the informal sector, and job instability; from a health perspective, it involves a lack or inadequacy of healthcare services, drinking water, and sanitation; and from a social perspective, it includes ethnic identity, adherence to traditions and values, extended families, and a lack of specialization, illiteracy, low educational attainment, low income, and particularly the independent culture of Informal settlement. These features are found in the communities of Informal settlement people across different regions [30, 31]. The characteristics of informal settlement areas influence five general indicators, which are summarized in Table 1.

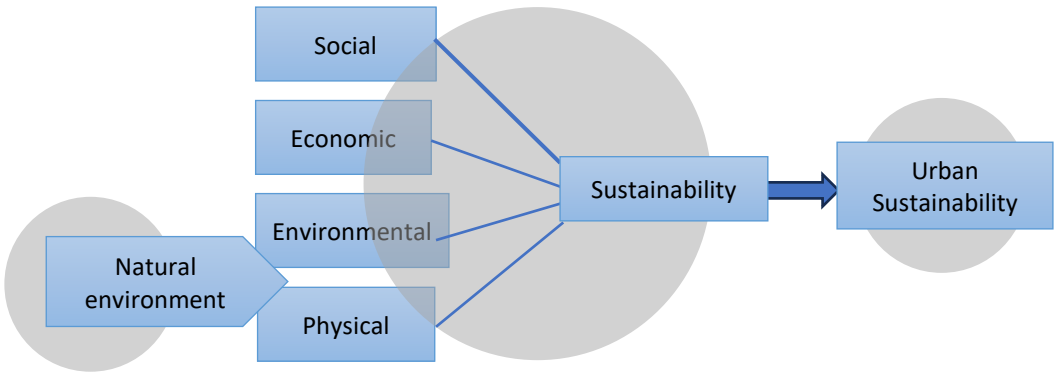

Figure 1. Sustainability indicators

Table 1. Characteristics of informal settlement areas [32]

Indicator	Feature
Physical	Fine-grained texture, Organic fabric, Deficiency in public facilities, Lack of facilities and services, Inefficient access network, Narrow streets, Unstable materials, Lack of proper covering for streets, Unsuitable ecological setting,
Society	Settlement of non-native individuals, Heterogeneous demographic composition, Insecurity, Existence of disorders,
Economic	Lack of property ownership title, Low housing value, Low-income status of residents, Weak employment, Lack of private sector investment,
Environmental	Lack of sewage disposal system, Weak surface water drainage system, Lack of public health services, Presence of incompatible land uses
Management	Lack of service provision, Neglect of urban issues

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Table 2. Key research concepts

Concept	Description	Main Feature
Urban Sustainability	The absorption, preservation, and development of natural and human resources in cities in such a way that the urban community can meet the needs of the current generation without threatening the needs of future generations.	Intergenerational justice (social, geographical, governmental) Protection of the natural environment, Minimal use of non-renewable resources, Economic diversity, Public welfare and fulfillment of basic human needs
Informal settlement	Settlements that have emerged outside of formal and legal urban development planning, primarily without permission, either within or outside the legal boundaries of cities, and host rural migrants and the Informal settlement members of urban society.	Lack of formal property ownership documentation, Deprivation of urban services and infrastructure, Informal settlement, Irregular and spontaneous urban fabric

Since informal settlement individuals often establish their settlements through illegal occupation or unauthorized development in violation of urban planning principles and property ownership laws on land owned by the state, private individuals, or the public, they lead to various issues, such as poor visual appearance, low public health and hygiene standards, lack of formal employment and adequate income, insufficient or absent educational and welfare facilities, low literacy and education levels, unreliable housing in the face of natural disasters, and social, cultural, and psychological consequences [27]. Since the early 20th century, when the emergence of informal settlements became a serious focus of attention, various approaches for addressing informal housing have been put on the agenda. Among the approaches to dealing with these areas, one can refer to ignoring (liberal perspective), forced eviction and clearance, self-help, upgrading, and empowerment [31]. In recent years, the approach of organizing and empowering these areas has been regarded as a suitable and human-centered strategy by specialists. Preventing the formation, controlling the spread, and ultimately stabilizing existing informal settlements are fundamental measures that have attracted the attention of specialists, managers, and researchers. In general, the key concepts of this research, namely urban sustainability and informal settlement, are presented in Table 2.

2.3. Research Methodology

This research is applied-developmental in terms of its objective and descriptive-analytical in terms of its methodology. The research employs a mixed-methods approach, utilizing both quantitative and qualitative methods. For data collection, the theoretical section of the study relied on library research, including the review of books, articles, and interviews with experts. In this section, using the meta-analysis method based on library studies, over 80 credible national and international articles were reviewed. After a thorough examination, 50 articles were selected for the extraction of the indicators and sub-indicators of the study. Subsequently, using the coding method, the indicators and sub-indicators were extracted. To assess the impact and significance of these sub-indicators in the context of the current research, they were presented to a panel of experts consisting of 26 university faculty members, researchers, and professionals in the field of urban studies. The research utilized the fuzzy Delphi method, relying on a five-point Likert scale questionnaire to derive the final indicators and sub-indicators. To examine the research area and gather information, data collection methods included maps, documents, field studies such as interviews, questionnaires, and field observations. The statistical population of the study includes all households residing in informal settlements in Qods city, which, according to the latest available statistics, has a population of approximately 41,058. The sample size was calculated using Cochran's formula with a variance based on a 95% confidence level, resulting in a sample size of 381 individuals. To assess the sustainability of the sample neighborhoods, a qualitative Likert-type questionnaire with a five-point scale was prepared and distributed among the citizens. The respondents were randomly selected from the neighborhoods under study, encompassing a wide range of social groups, including women, men, youth, and adolescents with diverse levels of education, social status, and employment backgrounds. Therefore, it can be stated that the sample reflects a well-considered level of diversity. The reliability of the questionnaire was measured using Cronbach's Alpha, which yielded a value greater than 0.90, indicating high reliability. To analyze the results obtained from the questionnaire and evaluate the sustainability of the case study, the one-sample T-test with a mean of 3 and a 95% confidence interval was employed. Additionally, the Friedman test was used for ranking the indicators with a significance level of 0.05. Subsequently, employing a second-order structural equation model to assess the

sustainability of informal settlements in Qods City, all first-order factors for the observed items were found to exceed 0.70. This indicates that each item made a strong contribution to the measurement of its corresponding sub-indicator. Moreover, all second-order factors for the sub-indicators, as well as the third-order factors for the main sustainability indicators, were also above 0.70. This suggests that all dimensions of sustainability in informal settlements, including social, economic, physical, environmental, and urban governance indicators, and their related sub-indicators played a significant role in measuring their respective constructs. In addition, the results of Cronbach's alpha and composite reliability, both exceeding 0.90, confirm the internal consistency and reliability of the data. The convergent validity of the sustainability constructs, with Composite Reliability values above 0.80, further confirms the appropriateness and strength of the measurement model employed in this study. Finally, for a qualitative assessment of the sustainability of the peripheral areas of the case study, the combination of DEMATEL (Decision-Making Trial and Evaluation Laboratory) method and Structural-Interpretive Modeling (ISM) was applied to rank the sub-indicators of sustainability and determine the influence of each sub-indicator on others. The hybrid DEMATEL–ISM approach is a modeling technique grounded in the interpretive paradigm, well-suited for designing exploratory frameworks. This method draws upon the principles of interpretive methodology and soft operations research, enabling the simultaneous application of the strengths of both DEMATEL and ISM. In this approach, following the identification of the study's sub-indicators, a direct-relation matrix is constructed to identify the relationships between the indicators and sub-indicators, which is then completed by expert judgment. In subsequent steps, a total-relation matrix is formed, allowing for the identification of causal relationships among the variables. Finally, based on the hierarchical structuring provided by ISM, the final model depicting the levels of variables is developed.

2.3.1. *Case study (Qods City)*

Qods City, formerly known as Qal'eh Hassan Khan, is one of the key counties in Tehran Province. As shown in Figure 2, Qods city is located at the western end of Hakim Highway, south of Tehran's District 22 and west of District 21. It borders Shahriar County to the south and Garmdareh County (in Alborz Province) to the west. According to the 2016 national census, Qods City covers an area of approximately 2,700 hectares and has a population of 316,631. Of this, around 124 hectares are occupied by informal settlements, home to an estimated 56,123 residents. In this study, three neighborhoods Shahrak-e-Azizi, Southern Shora, and Mohammadabad identified as key informal settlements within the city (Figure 3), were selected for analysis. The areas of Shahrak-e-Azizi (49.2 hectares), Southern Shora (24 hectares), and Mohammadabad (18 hectares) host populations of approximately 22,130, 10,418, and 8,510 residents, respectively [29].

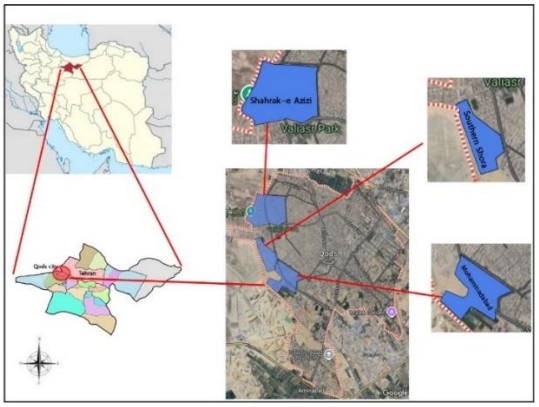

Figure 2. Location map of Qods City

These neighborhoods have experienced uncontrolled expansion, largely due to the presence of vacant land in the western parts of Qods. The absence of effective planning and regulation has contributed to the emergence of new settlements, exacerbating sustainability challenges in both the informal areas and the city as a whole. Overall, the formation and expansion of informal settlements threaten urban sustainability and impose significant financial burdens on the city. However, a systematic assessment of current conditions, along with the development and implementation of appropriate and efficient regeneration strategies, can improve these neighborhoods and help advance urban sustainability in the future.

3. Results and Discussion

In this study, the indicators and sub-indicators of sustainability in informal settlements were identified based on the theoretical framework of sustainability. This was accomplished through an extensive literature review of both domestic and international sources. As a result, five main indicators and twenty-three sub-indicators were extracted and compiled, as presented in Table 3.

3.1. Assessment of the Sustainability Status of Informal Settlements (One-Sample T-Test)

As previously mentioned, a five-point Likert scale questionnaire with a mean reference value of 3 was utilized to descriptively assess the average condition of sustainability indicators and sub-indicators within the informal settlements.

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Figure 3. Pictures of informal settlements in Qods City

Table 3. Sustainability indicators and sub-indicators

Indicator	sub-indicator	Importance in sustainability
Physical	Sense of Belonging, Ethnicity, Security, Migration, Literacy and Education Status	The level of social sustainability has a direct impact on the quality of life of the residents
Society	Housing cost, Income, Employment status, Cost of living	Economic stability for residents contributes to the reduction of informal settlements
Economic	Quality of streets, public facilities and services, Street lighting system, Urban transportation, Urban transportation	An appropriate physical structure serves as a foundation for enhancing quality of life
Environmental	Waste collection and disposal, public health, green space, Land use compatibility, Sewage disposal network, Access to potable water	A healthy environmental condition is essential to ensure the well-being of residents
Management	Urban management practices, Accountability of managers to citizens, Performance in relation to urban programs and regulations.	Good urban governance is a key factor in enhancing the sustainability of informal settlements

After collecting the questionnaire data, a one-sample T-test was conducted using SPSS to assess the sustainability indicators and sub-indicators of informal settlements in Qods city and to examine whether the observed mean values significantly differed from the reference value of 3. The significance level for the test was set at 0.05. However, since the p-value only provides information about the likelihood of observing a difference and does not convey the magnitude or practical importance of that difference, the effect size was also calculated and reported using Cohen's d.

The combined use of the p-value and effect size enabled the interpretation of the results from both statistical and practical perspectives, as discussed in the following sections.

3.1.1. *Economic Indicator*

The results of the one-sample t-test for the economic indicator, as presented in Table 4, indicate that the overall status of the economic indicator does not significantly differ from the average, given that its p-value exceeds 0.05. The positive T-values and mean differences for the sub-indicators of housing costs and income suggest relatively favorable conditions in these areas.

In contrast, the negative T-values and mean differences for the sub-indicators of employment status and cost of living reflect unfavorable conditions. Despite these directional differences, all sub-indicators yielded p-values below 0.05, indicating that their mean scores significantly differ from the reference value of 3. However, the effect sizes for housing costs (Cohen's d = 0.295), employment status (d = 0.407), and cost of living (d = 0.491) fall within the small to moderate range. Notably, the income sub-indicator, with a Cohen's d value of 1.061, demonstrates a very large effect size, signifying high practical significance.

3.1.2. *Social Indicator*

The results of the test for the social indicator in Table 5 indicate that all sub-indicators, except for the sense of belonging sub-indicator, have a significance level of less than 0.05 and a significant difference from the mean threshold of 3. The significance level of 0.06 for the sense of belonging sub-indicator suggests that this sub-indicator is close to the mean threshold. Moreover, the Cohen's d value of 0.098 indicates a small practical significance for this sub-indicator. On the other hand, the t-statistic and the mean difference for the ethnicity sub-indicator are positive,

indicating that the status of this sub-indicator in the informal settlement areas of Qods city is above the average threshold and in a favorable condition. For the other social sub-indicators, the t-statistic and mean difference for each sub-indicator are negative, indicating that their status is below the average threshold and in an undesirable condition. Although the Cohen's d values for the sub-indicators of ethnicity and education indicate only a small to moderate level of practical significance, implying that their impact on the overall perception is limited, the security sub-indicator stands out, with a Cohen's d value exceeding 1. This reflects a very large effect size, underscoring its substantial practical importance and central role in shaping residents' experiences in the study area.

3.1.3. *Physical Indicator*

The results of the one-sample t-test for the physical indicator, presented in Table 6, indicate that the t-statistics and mean differences for most sub-indicators except for the street lighting system are negative. This suggests that the conditions of these sub-indicators in the informal settlements of Qods city are below average and in an unfavorable state..

Table 4. Results of one-sample T-test of economic indicator

Indicator	T-statistic	Significance level	Average	Mean difference	Confidence interval 95%		Cohen's d
					Upper bound	Lower bound	
Housing Cost	5.76	0.00	3.27	0.27	0.37	0.18	0.295
Income	20.72	0.00	3.64	0.64	0.70	0.58	1.061
Employment Status	-7.94	0.00	2.63	-0.37	-0.28	-0.46	-0.407
Cost of Living	-9.58	0.00	2.43	-0.57	-0.46	-0.69	-0.491
Economic	-2.26	0.40	2.99	-0.01	0.08	-0.10	-0.563

Table 5. Results of one-sample T-test of social indicator

Indicator	T-statistic	Significance level	Average	Mean difference	Confidence interval 95%		Cohen's d
					Upper bound	Lower bound	
Sense of Belonging	-1.92	0.06	2.89	-0.11	0.00	-0.22	-0.098
Ethnicity	6.54	0.00	3.36	0.36	0.47	0.26	0.335
Security	-21.88	0.00	1.81	-1.19	-1.08	-1.29	-1.121
Migration	-15.33	0.00	2.12	-0.88	-0.76	-0.99	-0.786
Education	-7.78	0.00	2.59	-0.41	-0.30	-0.51	-0.399
Social	-8.07	0.00	2.56	-0.44	-0.33	-0.55	-0.547

Table 6. T-test results for the physical indicator

Indicator	T-statistic	Significance level	Average	Mean difference	Confidence interval 95%		Cohen's d
					Upper bound	Lower bound	
Street Quality	-21.07	0.00	1.91	-1.09	-0.99	-1.19	-1.079
Urban Facilities and Services	-8.31	0.00	2.57	-0.43	-0.55	-0.28	-0.607
Street Lighting System	0.05	0.96	3.00	0.00	0.10	-0.10	0.003
Public Transportation	-19.32	0.00	2.05	-0.95	-0.85	-1.05	-0.990
Urban Aesthetic Quality (Building Façade)	-26.25	0.00	1.73	-1.27	-1.18	-1.37	-1.345
Physical Indicator	-14.98	0.00	2.25	-0.75	-0.69	-0.80	-0.804

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Furthermore, simultaneous examination of the significance levels and effect sizes (p-values less than 0.05 and Cohen's d values greater than 0.5) reveals that the mean values of these sub-indicators differ significantly from the reference value of 3, and this difference is of high to very high practical significanceIn contrast, the t-statistic and mean difference for the street lighting system sub-indicator are approximately zero, indicating that its mean is nearly equal to the reference value. Additionally, the p-value for this sub-indicator is 0.96, which confirms the absence of a statistically significant difference. Taken together, the p-value and effect size suggest that this sub-indicator likely has negligible practical significance.

3.1.4. *Environmental Indicator*

The results of the one-sample T-test for the environmental indicator, presented in Table 7, show that all sub-indicators have a significance level of less than 0.05. This indicates that the mean value of all sub-indicators differs significantly from the average threshold value of 3. The sub-indicators of land-use compatibility, public health, and the availability of green spaces, with Cohen's d values greater than 1, exhibit a very high level of practical significance.

In contrast, the sub-indicator of access to safe drinking water shows a small to moderate practical significance, while the sub-indicators related to sewage disposal network and waste collection and disposal, with Cohen's d values below 0.2, indicate a low level of practical significance.

On the other hand, the t-statistic and the mean difference for the two sub-indicators, waste collection and disposal and land use compatibility, are positive, indicating that their conditions in the informal settlements of Qods City are above the average threshold and can be considered favorable. In contrast, the remaining sub-indicators have negative t-statistics and mean differences, suggesting that their conditions are below average and, therefore, in an unfavorable state.

Table 7. T-test results for the environmental indicator

Indicator	T-statistic	Significance level	Average	Mean difference	Confidence interval 95%		Cohen's d
					Upper bound	Lower bound	
Waste Collection and Disposal	2.16	0.03	3.11	0.11	0.22	0.01	0.111
Public Health	20.18	0.00	1.98	-1.02	-0.92	-1.12	-1.034
Availability of Green Spaces	-20.96	0.00	1.98	-1.02	-0.92	-1.11	-1.074
Land Use Compatibility	19.57	0.00	3.99	0.99	1.09	0.89	1.003
Sewage Disposal Network	-3.68	0.00	2.81	-0.19	-0.09	-0.29	-0.188
Access to Safe Drinking Water	-5.67	0.00	2.73	-0.27	-0.17	-0.36	-0.290
Environmental Indicator	-4.80	0.00	2.77	-0.23	-0.13	-0.33	-0.616

Table 8. T-Test results for the urban management indicator

Indicator	T-statistic	Significance level	Average	Mean difference	Confidence interval 95%		Cohen's d
					Upper bound	Lower bound	
Urban Management Approach	-28.50	0.00	1.66	-1.34	-1.25	-1.44	-1.460
Managerial Accountability	-34.52	0.00	1.55	-1.45	-1.36	-1.53	-1.768
Compliance with Urban Plans and Regulations	-28.14	0.00	1.74	-1.26	-1.17	-1.35	-1.442
Urban Management	-30.39	0.00	1.65	-1.35	-1.26	-1.44	-1.556

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3.1.5. *Urban Management Indicator*

The results of the one-sample T-test for the urban management indicator and its sub-indicators show that all sub-indicators have a significance level of less than 0.05, which are shown in Table 8. This indicates that the mean values of all sub-indicators differ significantly from the average threshold of 3. Given the negative t-statistics and mean differences for all sub-indicators, their conditions are considered unfavorable. Moreover, Cohen's d values greater than 1 ($d \geq 1$) across all sub-indicators demonstrate a very high level of practical significance, underscoring the substantial impact of these variables in the context of the study. At the end of this section, a comparison of the sustainability indicators in the informal settlements of Qods City, based on the one-sample T-test, is presented in Chart (Figure 4) and Table 9.

As shown, the mean values for all sustainability indicators, including social, economic, physical, environmental, and urban management dimensions, are below the average threshold (value = 3).

Therefore, it can be concluded that the sustainability status of these areas is unfavorable, in other words, these settlements are unsustainable.

Table 9. Sustainability status of informal settlements in Qods City

Indicator	Overall Status (Mean)	Favorable Sub-Indicators (Mean)	Unfavorable Sub-Indicators (Mean)
Social	Overall Status (Mean)	Ethnicity (Mean: 3.36)	Security (1.81), Migration (2.12), Education (2.59), Sense of Belonging (2.89)
Economic	Average (Mean: 2.99)	Housing Costs (3.27), Income (3.64)	Employment Status (2.63), Cost of Living (2.43)
Physical	Unfavorable (Mean: 2.25)	Street Lighting System (3.00)	Street Quality (1.91), Urban Services (2.57), Public Transport (2.05), Visual Quality (1.73)
Environmental	Unfavorable (Mean: 2.77)	Waste Collection and Disposal (3.11), Land Use Compatibility (3.99)	Public Health (1.98), Green Space (1.98), Sewerage Network (2.81), Access to Drinking Water (2.73)
Urban Management	Highly Unfavorable (Mean: 1.65)	None	Urban Management Approach (1.66), Managerial Accountability (1.55), Compliance with Urban Plans (1.74)

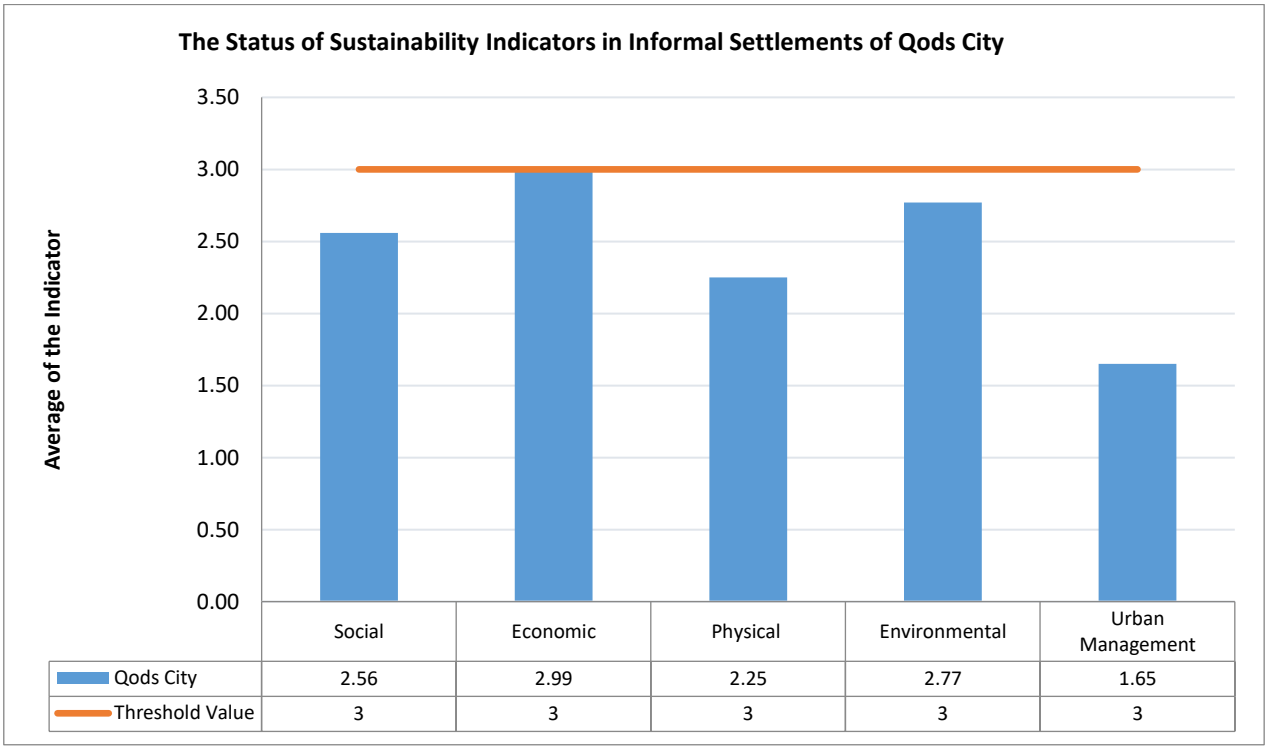

Figure 4. The status of sustainability indicators in informal settlement of Qods City

3.2. Prioritization and Ranking of Sustainability Indicators and Sub-Indicators Based on the Friedman Test

In this section, the Friedman test was used to prioritize and rank the sustainability indicators and sub-indicators of informal settlements in Qods City based on their mean values.

This test reveals which indicators and sub-indicators are perceived by residents as having the most favorable or unfavorable conditions.

According to the results, the Friedman Chi-Square value is 1524.06 with a significance level of 0.000 ($p<0.05$), indicating a statistically significant difference in the ranking of sustainability indicators across these areas. As shown in Table 10, the economic indicator holds the highest rank with a mean rank of 4.76, while urban management ranks lowest with a mean rank of 1.57.

The results of the Friedman test for the sustainability sub-indicators of informal settlements are presented in Table 11. The Chi-Square statistic for the social sub-indicators is 1118.44, with a significance level of 0.00, indicating a statistically significant difference in the rankings of the social sustainability sub-indicators in these areas.

The sub-indicators, ethnicity and security, ranked highest and lowest, respectively, with mean ranks of 4.45 and 1.60. The Chi-Square statistic for the physical sub-indicators is 1177.66, with a significance level of 0.000, indicating a significant difference among them. Within this group, the sub-indicator street lighting system ranks first with a mean rank of 4.52, while visual quality ranks last with a mean rank of 1.87

Table 10. Friedman test results for sustainability indicators

Indicator	Mean Ranks	Ranks	Chi-Square	df	p-value
Social	3.52	3			
Economic	4.76	1			
Physical	2.58	4	1524.06	4	0.00
Environmental	4.00	2			
Urban Management	1.57	5			

Table 11. Friedman test results for sustainability sub-indicators

Indicator	Sub- Indicator	Mean Ranks	Ranks	Chi-Square	df	p-value
Social	Sense of Belonging	3.70	2			
	Ethnicity	4.45	1			
	Security	1.60	5	1118.44	4	0.00
	Migration	2.11	4			
	Education	3.14	3			
Economic	Housing Cost	3.01	2			
	Income	3.49	1	721.78	3	0.00
	Employment Status	1.85	3			
	Cost of Living	1.65	4			
Physical	Street Quality	2.17	4			
	Urban Facilities and Services	4.08	2			
	Street Lighting System	4.52	1	1177.66	4	0.00
	Public Transportation	2.36	3			
	Urban Aesthetic Quality (Building Façade)	1.87	5			
Environmental	Waste Collection and Disposal	4.27	2			
	Public Health	1.88	5			
	Availability of Green Spaces	1.85	6	1602.86	5	0.00
	Land Use Compatibility	5.89	1			
	Sewage Disposal Network	3.67	3			
	Access to Safe Drinking Water	3.45	4			
Urban Management	Urban Management Approach	1.97	2			
	Managerial Accountability	1.79	3	141.58	2	0.00
	Compliance with Urban Plans and Regulations	2.24	1			

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For the environmental sub-indicators, the Friedman Chi-Square value is 1602.86 and the significance level is also 0.000. In this category, land use compatibility holds the highest rank (mean rank: 5.89), while availability of green space ranks lowest (mean rank: 1.85). Furthermore, the urban management sub-indicators yielded a Chi-Square statistic of 141.58 with a significance level of 0.000. The sub-indicator compliance with urban plans and regulations ranks highest (mean rank: 2.24), whereas managerial accountability to citizens holds the lowest rank (mean rank: 1.79).

3.3. Analyzing Sustainability in Informal Settlements Using a Combined DEMATEL and Interpretive Structural Modeling (ISM) Approach

In this section, sustainability in informal settlements is examined using a combination of the DEMATEL method and Interpretive Structural Modeling (ISM), based on 23 sub-indicators identified through the Fuzzy Delphi technique. A standard DEMATEL questionnaire was designed according to the research objectives and distributed to 26 experts and specialists. Respondents were asked to evaluate the influence of each sub-indicator on the others based on a five-point scale. Accordingly, the influence of each sub-indicator on others was assessed in the rows of the Direct-Relation Matrix using values ranging from 0 to 4. The complete influence matrix (Tc) derived from the DEMATEL method is presented in Table (A.1) in the appendix. Based on the quantitative results extracted from this matrix, the degree of influence of each sub-indicator is reported in Table 12. In this table, sub-indicators with a positive D–R value are considered causal variables, meaning they exert more influence on other sub-indicators than they receive. Conversely, sub-indicators with a negative D–R value are identified as effect variables, indicating they are more influenced by other sub-indicators than they influence others.

According to Table 12, the sub-indicators of urban management approach, compliance with urban plans and regulations, and public facilities and services have the highest degrees of influence, with values of 3.589, 3.361, and 3.199, respectively.

In contrast, the sub-indicators of sense of belonging and ethnicity have the lowest influence values, at 1.932 and 1.970, respectively.In terms of dependence, the sub-indicators of migration and compliance with urban plans and regulations have the highest values, 3.332 and 3.209, respectively, while ethnicity has the lowest dependence value at 1.454. As shown in Table 13, the sub-indicators sense of belonging, security, migration, housing costs, living costs, street quality, visual quality, waste collection and disposal, and public health have negative D–R values, identifying them as effective variables in sustainability. All other sub-indicators, with positive D–R values, are considered causal variables.

Table 12. Influence and dependence of sub-indicators based on the DEMATEL technique

Sub- Indicator	Code	D	R	D+R	D-R	Type
Sense of Belonging	C1	1.970	3.140	5.111	-1.169	Effect
Ethnicity	C2	1.932	1.454	3.386	0.477	Causal
Security	C3	2.246	3.128	5.375	-0.881	Effect
Migration	C4	2.418	3.332	5.750	-0.914	Effect
Education	C5	2.566	2.062	4.628	0.503	Causal
Housing Cost	C6	2.370	2.936	5.306	-0.566	Effect
Income	C7	2.837	2.469	5.307	0.368	Causal
Employment Status	C8	2.499	2.435	4.935	0.063	Causal
Cost of Living	C9	2.599	2.850	5.450	-0.251	Effect
Street Quality	C10	2.772	2.932	5.705	-0.160	Effect
Urban Facilities and Services	C11	3.199	2.848	6.047	0.351	Causal
Street Lighting System	C12	2.444	2.087	4.531	0.357	Causal
Public Transportation	C13	2.474	2.471	4.945	0.003	Causal
Urban Aesthetic Quality (Building Façade)	C14	2.319	3.090	5.409	-0.771	Effect
Waste Collection and Disposal	C15	2.442	2.523	4.966	-0.081	Effect
Public Health	C16	2.784	2.970	5.755	-0.186	Effect
Availability of Green Spaces	C17	2.574	2.203	4.778	0.370	Causal
Land Use Compatibility	C18	2.803	2.293	5.096	0.510	Causal
Sewage Disposal Network	C19	2.666	2.172	4.838	0.493	Causal
Access to Safe Drinking Water	C20	2.560	2.387	4.947	0.173	Causal
Urban Management Approach	C21	3.589	2.869	6.459	0.720	Causal
Managerial Accountability	C22	2.750	2.311	5.062	0.438	Causal
Compliance with Urban Plans and Regulations	C23	3.361	3.209	6.571	0.151	Causal

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Table 13. Results of influence and dependence of sustainability sub-indicators based on the DEMATEL technique

Sub-Indicator Type	Sub-Indicators	Description
Causal Sub-Indicators	Ethnicity, Literacy and Education, Income, Employment Status, Public Facilities and Services, Street Lighting System, Urban Transportation, Green Spaces, Land Use Compatibility, Wastewater Disposal Network, Access to Drinking Water, Urban Management Approach, Managerial Accountability, Compliance with Urban Plans and Regulations	Greater influence on other sub-indicators than dependence on them
Effect Sub-Indicators	Sense of Belonging, Security, Migration, Housing Costs, Living Costs, Street Quality, Visual Quality, Waste Collection and Disposal, Public Health	Greater dependence on other sub-indicators than influence on them

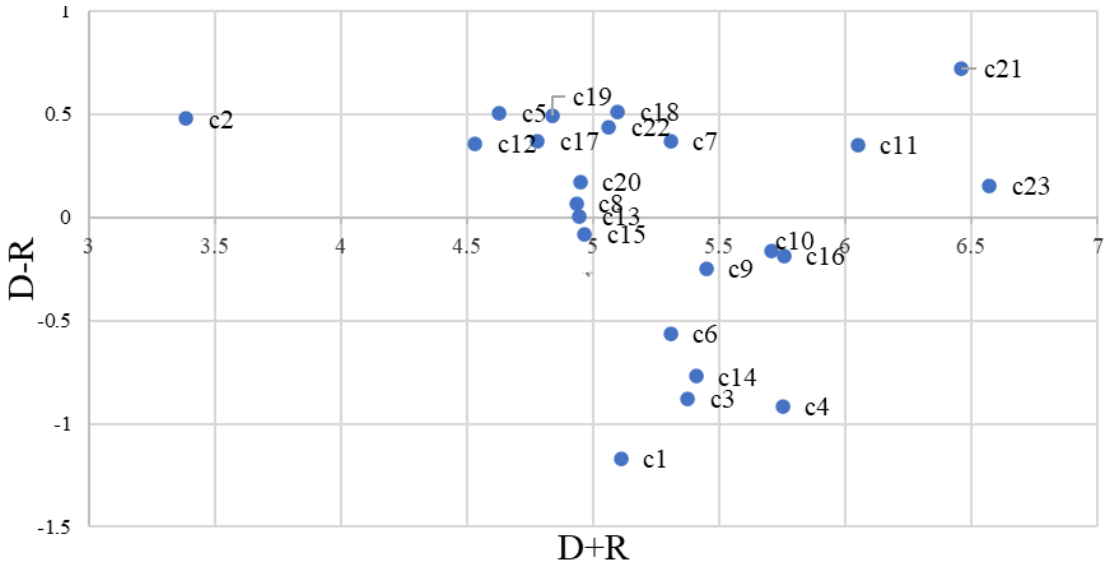

Figure 5. Cartesian coordinate diagram of the DEMATEL technique

Figure 5 presents the Cartesian coordinate diagram of the DEMATEL technique. In this diagram, sub-indicators located above the D–R axis are classified as causal, while those below the D–R axis are considered effect sub-indicators.

3.3.1. *Mapping Significant Relationships and Forming the Structural Self-Interaction Matrix (SSIM)*

To determine the relationship map of the network, the threshold value of the total direct-relation matrix (Tc) must be calculated. In this matrix, all values greater than the threshold (i.e., meaningful relationships) are assigned a value of 1, while those below the threshold (i.e., insignificant relationships) are set to 0. In this study, the threshold value was determined to be 0.1137. By applying this rule, a binary matrix referred to as the Structural Self-Interaction Matrix (SSIM) is generated, where the main diagonal values are all set to 1. Moreover, in order to account for transitive relationships, the SSIM is revised based on the principle that if factor A influences B, and B influences C, then A also influences C. The revised matrix, known as the transitive closure matrix, is presented in Appendix Table A.2. This matrix illustrates both causal and dependent relationships among the sub-indicators, as well as their influence and dependence levels. To identify the relationships and hierarchical levels of the sub-indicators, sets of reachability and antecedents are extracted from the matrix. The reachability set includes the sub-indicator itself and the indicators it influences, while the antecedent set comprises the sub-indicator and those that influence it.

The intersection of these two sets is referred to as the intersection set. The results of these sets are used to determine the hierarchical levels and are presented in Appendix Table A.3. Based on the interpretive structural modeling (ISM) methodology, the first level is identified by finding sub-indicators for which the reachability set and the intersection set are identical. In this study, the sub-indicators "Sense of Belonging (C1)" and "Migration (C4)" met this criterion and were therefore classified as Level One indicators.

Next, these Level One sub-indicators are removed from all rows and columns of the matrix, enabling identification

of the next level. In the second step, the sub-indicators "Security (C3)" and "Housing Cost (C6)" showed matching reachability and intersection sets, and thus were placed in Level Two.

Following this procedure iteratively, the hierarchy was determined as follows: Level Three: Cost of Living (C9), Street Quality (C10), Visual Quality (C14), Public Health (C16), and Urban Management Performance (C23).
Level Four: Ethnicity (C2), Employment Status (C8), Street Lighting System (C12), Urban Transportation (C13), Waste Collection and Disposal (C15), Access to Drinking Water (C20). Level Five: Income (C7), Public Facilities and Services (C11), Land Use Compatibility (C18), Wastewater Disposal Network (C19), Urban Management Approach (C21), Managerial Responsiveness (C22). Level Six: Education Status (C5) and Green Space Availability (C17). According to this classification and ranking, the final model of variable levels is illustrated in Figure 6. In this structure, only the meaningful relationships between indicators at a given level and those at the level immediately below as well as internal meaningful relationships within each level are considered.

3.3.2. Scenario for Achieving Sustainability in Informal Settlements of Qods City

Based on the model presented in Figure 6, which illustrates the influence level and driving power of the identified sub-indicators, a successful scenario for achieving sustainability in the informal settlements of Qods City can be proposed. In this scenario, the sub-indicators Migration and Sense of Belonging positioned at the highest level of influence serve as the most critical driving forces. Therefore, strategies aimed at enhancing residents' sense of belonging and regulating migration flows to and from these areas will form the fundamental and essential foundation of sustainable development efforts. In the next step, the sub-indicators Housing Cost and Security, located at the second level of the model, play a substantial role in promoting sustainability. Housing cost is a key determinant in attracting different social groups. For instance, the availability of low-cost housing in these neighborhoods often attracts low-income populations, eventually contributing to the uncontrolled expansion of informal settlements. Meanwhile, the sub-indicator of security is a vital element in achieving social sustainability.

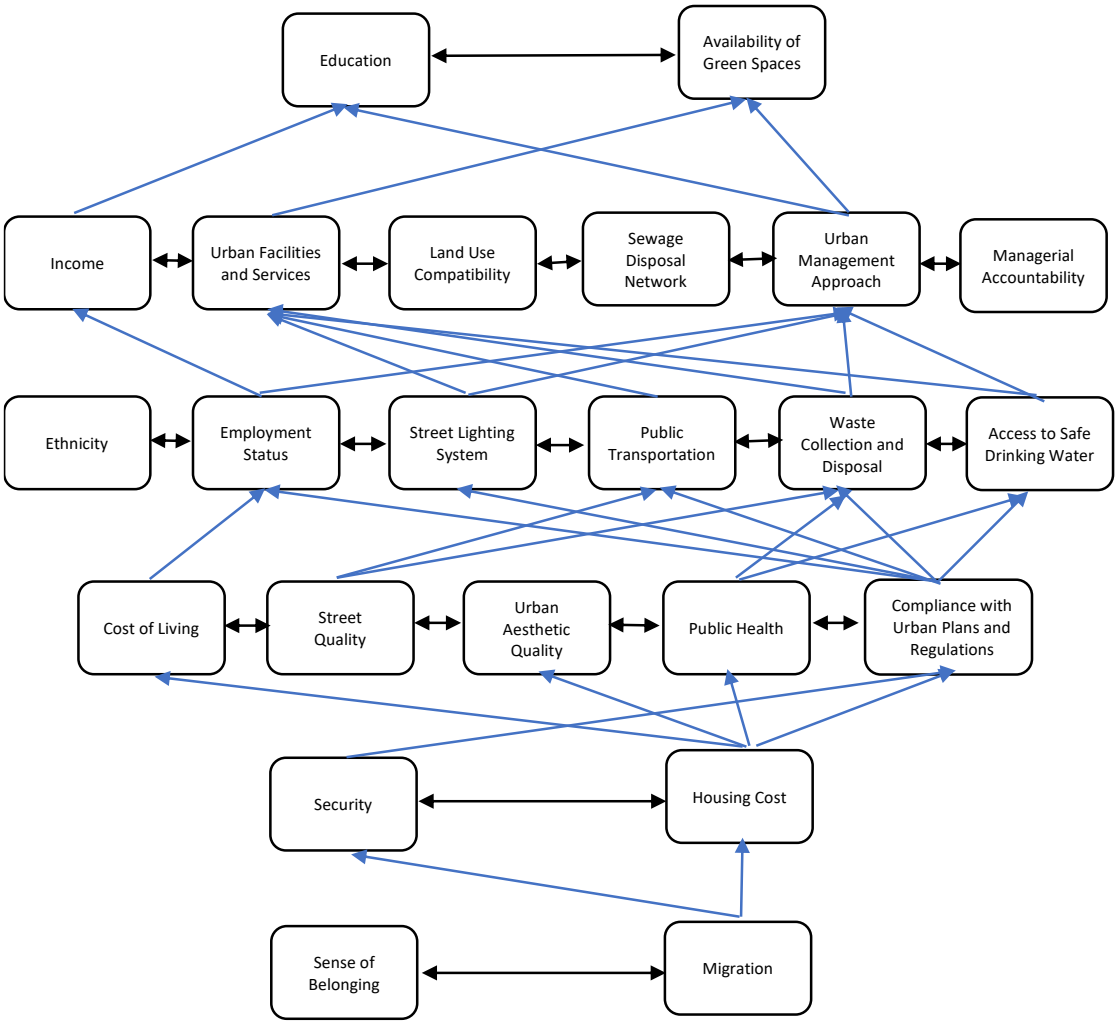

Figure 6. Baseline model developed through DEMATEL and ISM approaches

Table 14. Proposed action plan for achieving sustainability

Sub- Indicator	Level	Timeframe for Implementation	Type of Program	Form	Current Status	Projected Future Status
Sense of Belonging	1	Medium-term	Strategic Planning	Decision-Making	Near Average	Good
Ethnicity	1	Long-term	Strategic Planning	Decision-Making	Weak	Average
Security	2	Short-term	Project-Based	Physical Action	Below Weak	Good
Migration	2	Long-term	Strategic Planning	Decision-Making	Below Average	Average
Education	3	Medium-term	Strategic Planning	Decision-Making	Below Average	Average
Housing Cost	3	Short-term	Project-Based	Physical Action	Below Weak	Good
Income	3	Medium-term	Project-Based	Physical Action	Below Weak	Good
Employment Status	3	Medium-term	Strategic Planning	Decision-Making	Weak	Good
Cost of Living	3	Short-term	Project-Based	Physical Action	Below Weak	Very good
Street Quality	4	Medium-term	Strategic Planning	Decision-Making	Above Average	Average
Urban Facilities and Services	4	Medium-term	Strategic Planning	Decision-Making	Below Average	Average
Street Lighting System	4	Medium-term	Project-Based	Physical Action	Average	Good
Public Transportation	4	Medium-term	Project-Based	Physical Action	Weak	Good
Urban Aesthetic Quality (Building Façade)	4	Medium-term	Project-Based	Physical Action	Average	Good
Waste Collection and Disposal	4	Medium-term	Project-Based	Physical Action	Below Average	Good
Public Health	5	-	-	-	Above Average	-
Availability of Green Spaces	5	Medium-term	Project-Based	Physical Action	Below Average	Average
Land Use Compatibility	5	Medium-term	Project-Based	Physical Action	Good	Very good
Sewage Disposal Network	5	Medium-term	Project-Based	Physical Action	Below Average	Good
Access to Safe Drinking Water	5	Short-term	Strategic Planning	Decision-Making	Below Weak	Very good
Urban Management Approach	5	Short-term	Strategic Planning	Decision-Making	Below Weak	Very good
Managerial Accountability	6	Long-term	Strategic Planning	Decision-Making	Below Average	Average
Compliance with Urban Plans and Regulations	6	Medium-term	Strategic Planning	Physical Action	Weak	Average

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Table 15. Proposed action scenario for achieving sustainability in the informal settlement areas of Qods City

Priority	Key Sub-Indicators	Program Type	Time Frame	Required Actions
First	Sense of Belonging, Migration	Strategic	Medium-term to Long-term	Strengthen local identity, control migration levels, increase public participation
Second	Housing Cost, Security	Combined	Short-term to Long-term	Improve environmental security, control housing and land prices
Third	Road Quality, Landscape Quality, Public Health, Urban Program Performance	Combined	Medium-term	Environmental improvement, enhance visual quality, improve oversight
Fourth	Street Lighting System, Transportation, Waste Management, Access to Water	Project-based	Medium-term	Develop urban infrastructure
Fifth	Urban Management, Manager Accountability	Strategic	Short-term	Reform management structure and communication with citizens

Given its level of impact, fundamental and effective measures aimed at improving neighborhood safety can significantly enhance the overall sustainability of these areas. In the third phase of the scenario, the focus shifts to the sub-indicators Cost of Living, Street Quality, Visual Quality, Public Health, and Urban Management Performance.

Improving the cost of living enhances the residents' economic resilience. Simultaneously, enhancing the quality of streets and the urban landscape contributes to the physical and physical sustainability of the environment. Public health, being the most influential sub-indicator within the environmental dimension, is also addressed at this stage.

Moreover, the performance of urban programs and legal compliance acts as a governance lever across all aspects of sustainability, significantly contributing to the systemic and long-term improvement of informal settlements. Subsequent sub-indicators are addressed according to their respective levels of influence and priority in the proposed scenario.

Finally, in line with the prioritized levels of influence, a comprehensive proposed action plan for achieving sustainability is presented in Table 14. This plan outlines the prioritization of sub-indicators based on timeframe for implementation and type of initiative (strategic plan vs. project-based intervention), and Nature of intervention (policymaking vs. physical action). Furthermore, a comparative analysis is provided, depicting the current status of each sub-indicator prior to the implementation of the plan, alongside the expected outcomes upon full execution of the proposed sustainability initiatives. Therefore, it is necessary to develop and implement a set of corrective actions to achieve the proposed plan in Table 14, based on the type, prioritization, and timeframe of the programs. Accordingly, in Table 15, the scenario of proposed actions is presented.

4. Conclusion

This study aimed to conduct a comprehensive assessment of the sustainability of informal settlements in the Qods City by identifying the causal and structural relationships between key indicators and sub-indicators. Unlike previous studies, the novelty of this research lies in its simultaneous and systematic examination of all five main indicators of sustainability (social, economic, physical, environmental, and managerial) using 23 sub-indicators, grounded in both quantitative field data and dual statistical analysis, including one-sample T-tests with p-values and effect sizes (Cohen's d). Quantitative results revealed that the economic dimension, with an average of 2.99, was the closest to the medium level of sustainability. Sub-indicators such as "income" (mean = 3.64; $p < 0.05$; d = 1.061) and "housing cost" (mean = 3.27; $p < 0.05$; d = -0.291) were relatively favorable, while "employment status" (mean = 2.63; d = -0.407) and "cost of living" (mean = 2.43; d = -0.491) showed fewer desirable conditions. The urban management indicator had the lowest overall mean (1.65), highlighting significant deficiencies in local governance, particularly in "managerial accountability" (mean = 1.55; d = -1.768) and " urban plans and regulations " (mean = 1.74; d = -1.442). Within the social indicator, only the sub-indicator "ethnicity" achieved a satisfactory level (mean = 3.36; d = 0.335), while "security" (1.81; d = -1.121) and "migration" (2.12; d = -0.786) demonstrated major social vulnerabilities. The physical indicator was particularly weak in "urban aesthetic quality" (mean = 1.73; d = -1.345) and "public transportation" (2.05; d = -0.99). The street lighting system was the only physical indicator to meet the average threshold (mean = 3.00). Through DEMATEL analysis, causal sub-indicators such as "urban management" (D – R = +0.720)," urban facilities and services " (+0.351), and "income" (+0.368) were identified as key drivers. Conversely, sub-indicators like

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"sense of belonging" (–1.169), "security" (–0.881), and "public health" (–0.186) were predominantly outcome-based or dependent variables. This classification plays a crucial role in prioritizing targeted planning interventions. The ISM model produced a six-level hierarchical structure of sub-indicators. At the foundational level (Level 1), policy should focus on enhancing sense of belonging and managing migration flows. Level 2 prioritizes security and housing cost, while Level 3 addresses cost of living, street quality, urban aesthetic quality, public health, and compliance with urban plans and regulations. A structured sustainability scenario was developed, defining appropriate timeframes (short-term, medium-term, and long-term) and types of intervention (strategic vs. project-based), facilitating effective policy implementation.Compared with existing literature, the results are consistent with studies by Arkhazloo et.al. (2024) and Khakzad et al. (2023), which emphasized the significance of social and physical sustainability in improving quality of life in informal settlements. However, this study advances beyond prior research by integrating all dimensions of sustainability in a unified, data-driven framework. Rather than focusing solely on current conditions or proposed interventions, it presents a systemic, causality-based understanding of variable interactions, offering a richer explanation of dynamics within these communities. Ultimately, this research demonstrates that achieving sustainability in informal urban areas requires multi-dimensional, phased, and coordinated interventions. The use of detailed metrics, robust statistical methods, and the development of a pragmatic action scenario contribute to the research's utility as a scalable and context-sensitive model for other similar urban contexts in Iran and across the region. In the future, this study could include qualitative studies with the definition of quantitative criteria, such as social and economic per capita, and model them quantitatively, as well as develop and evaluate the sustainability of areas and their corrective programs.

Authors Contribution

The authors confirm the study conception and design: In this research, Sahar Jamshidi was responsible for collecting data and preparing the manuscript; Hassan Sattari Sarbangholi was responsible for checking the accuracy of the data and evaluating the results, and Karim Hosseinzade Dalir was responsible for selecting and reviewing the research method through written reviews.

Availability of data and materials:

The data supporting the findings of this study are included within the article and its supplementary materials.

Conflict of interests

The authors declare no conflicts of interest.

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Appendices

In this section, Table (A.1) presents the full connection matrix Tc of the DEMATEL method, Table (A.2) presents the secondary self-interaction matrix, and Table (A.3) presents the results of the input, output, and intersection sets of the Structural-Interpretive Modeling method

Table A.1. Full connection matrix Tc of the DEMATEL method

i/j	C1	C2	C3	C4	C5	...	C19	C20	C21	C22	C23
C1	0.076	0.072	0.105	0.124	0.065	...	0.070	0.071	0.095	0.083	0.111
C2	0.124	0.035	0.112	0.110	0.063	...	0.079	0.068	0.092	0.081	0.114
C3	0.130	0.063	0.086	0.136	0.079	...	0.073	0.080	0.112	0.086	0.123
C4	0.135	0.082	0.121	0.099	0.096	...	0.080	0.103	0.118	0.097	0.133
C5	0.130	0.062	0.139	0.150	0.067	...	0.083	0.091	0.130	0.117	0.144
...	...	...	...	...	...	...	...	...	...	...	...
C19	0.132	0.054	0.128	0.139	0.082	...	0.072	0.121	0.138	0.103	0.143
C20	0.142	0.058	0.122	0.148	0.080	...	0.098	0.076	0.131	0.096	0.142
C21	0.179	0.095	0.186	0.192	0.124	...	0.142	0.151	0.126	0.151	0.190
C22	0.143	0.066	0.137	0.147	0.091	...	0.099	0.103	0.143	0.078	0.154
C23	0.169	0.085	0.172	0.186	0.116	...	0.129	0.138	0.167	0.139	0.131

Table A.2. Secondary self-interaction matrix of the structural method

i/j	C1	C2	C3	C4	C5	...	C19	C20	C21	C22	C23
C1	1	0	0	1	0	...	0	0	0	0	0
C2	1	1	0	0	0	...	0	0	0	0	1
C3	1	0	1	1	0	...	0	0	0	0	1
C4	1	0	1	1	0	...	0	0	1	0	1
C5	1	0	1	1	1	...	0	0	1	1	1
...	...	...	...	...	...	...	...	...	...	...	...
C19	1	0	1	1	0	...	1	1	1	0	1
C20	1	0	1	1	0	...	0	1	1	0	1
C21	1	0	1	1	1	...	1	1	1	1	1
C22	1	0	1	1	0	...	0	0	1	1	1
C23	1	0	1	1	1	...	1	1	1	1	1

Table A.3. Input and output sets for level determination

Sub-Indicator	Output	Input	Intersection
c1	c1,c4	c1,c2,c3,c4,c5,c6,c7,c8,c9,c10,c11,c12, c13,c14,c15,c16,c17,c18,c19,c20,c21, c22,c23	c1,c4
c2	c1,c2,c23	c2	c2
c3	c1,c3,c4,c6,c23	c3,c4,c5,c6,c7,c8,c9,c10,c11,c12,c13, c14,c15,c16,c17,c18,c19,c20,c21,c22, c23	c3,c4,c6,c23
c4	c1,c3,c4,c6,c7,c8,c9,c21,c23	c1,c3,c4,c5,c6,c7,c8,c9,c10,c11,c12, c13,c14,c15,c16,c17,c18,c19,c20,c21, c22,c23	c1,c3,c4,c6,cc7,c8,c9, c21,c23
c5	c1,c3,c4,c5,c6,c7,c8,c9,c14,c16,c21,c22,c23	c5,c7,c9,c21,c23	c5,c7,c9,c21,c23
c6	c1,c3,c4,c6,c9,c14,c16,c23	c3,c4,c5,c6,c7,c8,c9,c10,c11,c12,c13,c14,c15,c16,c17,c18,c19,c20,c21,c22,c23	c3,c4,c6,c9,c14,c16,c23
c7	c1,c3,c4,c5,c6,c7,c8,c9,c10,c11,c13,c14,c15, c16,c20,c21,c23	c4,c5,c7,c8,c9,c11,c16,c21,c23	c4,c5,c7,c8,c9,c11,c16, c21,c23
c8	c1,c3,c4,c6,c7,c8,c9,c16,c23	c4,c5,c7,c8,c9,c11,c21,c23	c4,c7,c8,c9,c23
c9	c1,c3,c4,c5,c6,c7,c8,c9,c10,c11,c14,c16,c21, c23	c4,c5,c6,c7,c8,c9,c10,c11,c13,c15, c16,c18,c19,c20,c21,c22,c23	c4,c5,c6,c7,c8,c9,c10, c11,c16,c21,c23
c10	c1,c3,c4,c6,c9,c10,c11,c13,c14,c15,c16,c21, c23	c7,c9,c10,c11,c12,c13,c14,c15,c16, c17,c18,c19,c20,c21,c22,c23	c9,c10,c11,c13,c14, c15, c16, c21,c23

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Sub-Indicator	Output	Input	Intersection
c10	c1,c3,c4,c6,c9,c10,c11,c13,c14,c15,c16, c21,c23	c7,c9,c10,c11,c12,c13,c14,c15,c16, c17,c18,c19,c20,c21,c22,c23	c9,c10,c11,c13,c14, c15,c16, c21,c23
c11	c1,c3,c4,c6,c7,c8,c9,c10,c11,c12,c13,c14,c15,c16,c17,c18,c19,c20,c21,c22,c23	c7,c9,c10,c11,c12,c13,c15,c16,c17, c18,c19,c20,c21,c22,c23	c7,c9,c10,c11,c12, c13,c15,c16,c17, c18,c19,c20,c21,c22,c23
c12	c1,c3,c4,c6,c10,c11,c12,c14,c16,c21,c23	c11,c12,c21,c23	c11,c12,c21,c23
c13	c1,c3,c4,c6,c9,c10,c11,c13,c14,c16, c23	c7,c10,c11,c13,c18,c21,c22,c23	c10,c11,c13,c23
c14	c1,c3,c4,c6,c10,c14,c16,c23	c5,c6,c7,c9,c10,c11,c12,c13,c14,c15, c16, c17,c18,c19,c20,c21,c22,c23	c6,c10,c14,c16,c23
c15	c1,c3,c4,c6,c9,c10,c11,c14,c15,c16,c21 ,c23	c7,c10,c11,c15,c16,c17,c18,c19,c21, c22 ,c23	c10,c11,c15,c16,c21,c23
c16	c1,c3,c4,c6,c7,c9,c10,c11,c14,c15,c16, c18,c19,c20,c21,c23	c5,c6,c7,c8,c9,c10,c11,c12,c13,c14, c15,c16,c17,c18,c19,c20,c21,c22,c23	c6,c7,c9,c10,c11,c14,c15, c16,c18,c19,c20,c21,c23
c17	c1,c3,c4,c6,c10,c11,c14,c15,c16,c17,c18,c21 ,c23	c11,c17,c21,c23	c11,c17,c21,c23
c18	c1,c3,c4,c6,c9,c10,c11,c13,c14,c15,c16, c18,c21,c23	c11,c16,c17,c18,c21,c23	c11,c16,c18,c21,c23
c19	c1,c3,c4,c6,c9,c10,c11,c14,c15,c16,c19 ,c20,c21,c23	c11,c16,c19,c21,c23	c11,c16,c19,c21,c23
c20	c1,c3,c4,c6,c9,c10,c11,c14,c16,c20,c21,c23	c7,c11,c16,c19,c20,c21,c23	c11,c16,c20,c21,c23
c21	c1,c3,c4,c5,c6,c7,c8,c9,c10,c11,c12,c13,c14, c15,c16,c17,c18,c19,c20,c21,c22,c23	c4,c5,c7,c9,c10,c11,c12,c15,c16,c17,c18 ,c19,c20,c21,c22,c23	c4,c5,c7,c9,c10,c11, c12,c15,c16,c17,c18, c19,c20,c21,c22,c23
c22	c1,c3,c4,c6,c9,c10,c11,c13,c14,c15,c16, c21,c22,c23	c5,c11,c21,c22,c23	c11,c21,c22,c23
c23	c1,c3,c4,c5,c6,c7,c8,c9,c10,c11,c12,c13,c14, c15,c16,c17,c18,c19,c20,c21,c22, c23	c2,c3,c4,c5,c6,c7,c8,c9,c10,c11,c12,c13,c14, c15,c16,c17,c18,c19,c20,c21,c22,c23	c3,c4,c5,c6,c7,c8,c9, c10,c11,c12,c13,c14,c15, c16,c17,c18,c19,c20,c21, c22, c23

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