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Research Article

Reimagining facade design using a collaborative gamification approach for enhanced form-based codes: 15 Khordad Street in Tehran

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Abstract
This study presents a novel methodological innovation by integrating the Delphi technique into a gamified evaluation framework, offering a new hybrid approach to collaboratively developing Form-Based Codes (FBCs). The primary goal is to increase the flexibility and participatory nature of the design process. The research focuses on a segment of 15 Khordad Street in Tehran, where facade design was re-envisioned via a collaborative digital platform using the Delphi technique. Based on literature review and a survey, the study provides a deep understanding of the area’s design dynamics. Facade design alternatives were developed and interactively modeled using Unity3D. This interactive environment allowed urban designers exploring various design permutations and selecting their preferred facade elements based on the FBC alternatives. The collective preferences were then synthesized to identify an optimal facade design for the area. Findings revealed that 44% of participants favored a setback pattern, showing a strong preference for a specific urban design approach. By incorporating gamification into the FBC selection process, the study aims to shift urban design from a product-centric approach to a more dynamic, process-oriented, and participatory methodology. This research highlights the potential of gamification in transforming traditional urban design practices into more flexible, inclusive, and cyclical processes.

Keywords: Unity 3D, Gamification, Collaborative design, Form-based codes, Urban facade

Extended Abstract

Introduction: The management of urban aesthetics, particularly in historically and commercially significant zones like Tehran’s 15 Khordad Street, presents a complex challenge that traditional planning methods often fail to address effectively. Conventional approaches to urban design frequently rely on static, product-centric regulations that prioritize physical outcomes over the social and collaborative processes essential for successful implementation. These

conventional, top-down methods often lead to exclusionary design practices, neglecting the crucial dynamics of citizen participation and local knowledge necessary for sustained urban vitality. While Form-Based Codes (FBCs) have emerged as a powerful regulatory tool focused on the physical form and public realm, their formulation is often criticized for being top-down and lacking flexibility. This rigidity stems from a fundamental theoretical weakness: treating the city and its visual context as a fixed entity rather than a living, evolving ecosystem. This research argues that to bridge the gap between rigid design codes and the dynamic nature of urban life, a paradigm shift towards a "process-oriented" approach is necessary, focusing on methods that facilitate collective intelligence and iterative refinement. The current practice's failure to engage effectively with multiple stakeholders necessitates the exploration of innovative platforms. By integrating "Gamification" and "Serious Games" into the urban design process, this study seeks to create a collaborative platform. This approach fundamentally redefines participation, transforming passive feedback into active co-creation and decision-making. This methodology not only facilitates the democratic selection of design criteria but also allows stakeholders to visualize and manipulate design variables in real-time, thereby transforming the drafting of FBCs from a purely technical task into an interactive, consensus-building experience rooted in the specific context of the city.

Purpose and scope: Urban design often suffers from a product-centric focus and superficial participation. This study employs a novel and systematic methodological framework to formulate Form-Based Codes (FBCs) for facade design, moving beyond generic standards to embrace specific socio-cultural contexts. The research is precisely focused on a highly sensitive segment of 15 Khordad Street in Tehran, a historically and commercially vital area adjacent to the Grand Bazaar. This particular context necessitates the establishment of a robust participatory mechanism that is especially vital for preserving the authentic cultural heritage and traditional architectural patterns that define the Bazaar's environment. The central aim is to design and test a structured collaborative process for evaluating and refining urban design choices with expert designers and local stakeholders. This process is engineered to facilitate iterative input and refinement, leading to the collection and synthesis of collective preferences. The ultimate goal is the identification of optimal design patterns that are rooted in consensus and local values, thereby transforming qualitative input into quantifiable FBC recommendations. Ultimately, this research aims to transform urban design from a rigid, static framework into a more dynamic, process-oriented, and genuinely participatory approach. The study seeks to balance the necessity of regulating the built environment with the need to respect the area's rich historical context and respond to contemporary needs. Furthermore, the research intends to propose a flexible, generalizable framework adaptable to other cities and cultural settings, promoting inclusive urban planning practices internationally.

Method: By using the survey method, a deep understanding of the selected area was achieved, and based on the proposed framework, this area was modeled and gamified using the Unity 3D game engine, chosen for its capability to render realistic, navigable environments essential for spatial assessment. For achieving desired form-based codes, the Delphi technique is used with a group of 20 urban design professionals. To ensure validity and reliability, the Delphi results were cross-checked by an additional expert panel. The method presents permutations of alternatives, where a simplified control interface was implemented to minimize the influence of participants' digital literacy. In this virtual environment, users navigate and select the best facade design options considering usage type. Finally, by compiling the selected alternatives, the desired form-based codes are presented.

Findings and conclusion: Based on the results from the choices made by the participants, the optimal alternative for each building and, ultimately, the selected pattern by the target group for the entire test area is presented. With these selected form alternatives, it's now possible to introduce the optimal pattern for the study area. As observed in the above Figure, 44% of the participants have chosen a setback pattern for the entire area. This preference indicates a significant inclination towards a specific urban design approach that could potentially influence the overall aesthetic and functional characteristics of the area. Finally, this research underscores the transformative potential of gamification in urban design, particularly in the formulation and application of Form-Based Codes (FBCs). By integrating gamification, the study demonstrates a paradigm shift from traditional, product-centric urban design approaches to more dynamic, process-oriented, and participatory methodologies. This shift is crucial in addressing the multifaceted and evolving nature of urban design challenges. The findings from this research highlight the importance of incorporating flexibility and adaptability in urban planning processes. The gamified approach allowed for the examination of a multitude of design permutations, offering a more comprehensive understanding of the potential impacts and outcomes. This approach is particularly beneficial in historical and culturally significant contexts like Tehran, where preserving the urban fabric while accommodating modern needs is crucial.

Keywords: Unity 3D, Gamification, Collaborative design, Form-based codes, Urban facade

INTRODUCTION

In contemporary urban design, a critical issue is the prevalent focus on architecture as a standalone element of city design, often characterized by an excessive emphasis on the physical attributes of structures to the detriment of a holistic, interdisciplinary approach. This approach, which tends to overlook the underlying causes of urban challenges, results in a perception of urban design as a finite product rather than an evolving process intertwined with social and political dynamics (Bahraini and Aminzadeh, 2006: 15). In recent years, the process-oriented approach to urban design has gained traction among theorists and practitioners. This approach underscores the importance of comprehensive problem identification, the exploration of diverse and multiple solutions, and the facilitation of implementation processes. It emphasizes logical and transparent decision-making, which is vital for integrating various stakeholder perspectives and fostering public participation in the design process (Hassan & Hamari, 2020). This methodology is instrumental in addressing complex urban challenges, as it facilitates the correction and evaluation of decisions, enhances the efficiency of design processes, and organizes different stages of design in a coherent manner (Behzadfar & Shakibamanesh, 2009: 4; Salimi et al., 2023; Shakibamanesh & Kokabi, 2022). An essential principle in developing urban plans is the maintenance of flexibility, inclusivity, diversity, and the provision of multiple options. Each plan must be adaptable to existing contexts and should be open to continual revisions, steering clear of rigid and unalterable approaches. This necessitates a comprehensive evaluation of all aspects and potential alternatives across various temporal and spatial dimensions (Barati et al., 2019: 16).

Furthermore, it is essential to directly and simultaneously engage designers, stakeholders, and decision-makers in the plan production and decision-making process to promote acceptable solutions (Marcucci et al., 2018: 119). This appropriate and effective connection is emphasized in modern urban design approaches for developing effective, creative, and appropriate solutions for complex problems. In fact, when faced with complex problems, often there is no single correct solution, which makes the participation, interaction, and reaching an accepted outcome by influential groups in the design process especially important (Bakhanova et al., 2020: 3). Therefore, a participatory approach among urban design experts in preparing and developing proposed plans seems necessary; because solving complex and multidimensional urban problems with a static view, relying on the perspective of a single designer, and focusing only on specific aspects and dimensions of a plan is neither possible nor acceptable (Macintosh & Whyte, 2008).

Form-Based Design Codes

Form-based codes are tools for regulating development to achieve a specific urban form. These codes can be applied across all design and planning scales, from a region to a collection of blocks and buildings. They address the relationship between building facades and the public realm, building form and massing, human scale, and various types of streets and blocks through urban regulations (Kan, 2012: 16; Elliott et al., 2012). The primary goal of form-based codes is to systematize the elements and spaces of the city, including buildings, facades, surrounding streets, and open spaces, to produce a predictable outcome in construction and create a more attractive built environment with higher quality, respecting human scale and providing a sense of meaningful place (Khalid Sbri, 2016: 3). Form-based codes typically offer a range of uses that are carefully selected to maximize compatibility between uses and the physical form of the area (City Council of Cincinnati, 2013: 1). Table 1 presents the key features of form-based codes (Adapted from Kan, 2012: 22; Ebrahimi, 2016).

Table 1. Key Features of Form-Based Codes (FBC)

Feature	Description
Vision-Oriented	These codes pursue significant objectives in creating built forms and urban designs at a human scale.
Purposeful	Form-Based Codes are intentional, focusing on transforming and organizing space.
Place-Centric	These codes concentrate on location, adaptable to various geographical, climatic environments, potential developments, and sensitive conservation conditions.
Holistic Approach	FBCs view urban space design from a comprehensive, multi-faceted perspective, formulated based on community needs.
Integration	Form-Based Codes can be aligned with infrastructures, buildings, spaces, and landscapes.
Mandatory	FBCs are obligatory for realizing the comprehensive vision of a community.
Adjustable	Form-Based Codes are adaptable, requiring regular revision in line with the evolving desires of communities.

Form-based codes typically encompass “eight main components”: a regulating plan as a framework for understanding form-based codes, standards for public spaces, block standards, building type standards, building form standards, frontage type standards, architectural standards, and a summary. In addition to these components, other optional elements, such as green building standards, can be included in the code based on community needs (Khalid Sbri, 2016: 16). A vital element to ensure that a form-based code is appropriately and effectively compiled is the “process” by which it is created. The three main stages of form-based code development include: “documentation, visioning, and code summarization” (Parolek et al., 2008: 11). Form-based codes are often presented in the form of diagrams and text, usually tailored to a project by the designer, and after approval, conveyed as regulations. There is often less use of consultative and participatory approaches in the production and final selection of these codes (Kan, 2012: 17).

Collaborative Design: Concept and Levels

Participation involves transparency, openness in the community space, and plurality in the public domain, requiring a space where individuals can influence decisions that affect their fate. This includes people’s involvement in all aspects of policy-making, prioritization, monitoring, implementation, follow-up, and all stages of providing social services (Bazi et al., 2017: 155). Participation can involve engagement at various levels of design, implementation, evaluation of programs, and benefiting from them. Participation can be defined as the conscious, voluntary, collective, and more or less organized action of individuals and groups towards collective goals, needs, and benefits at all macro, meso, and micro levels (Fazeli et al., 2015; Abdullahpur & Barakpur, 2019). Sensitive and competent experts must provide the necessary conditions for participation and expert assistance to allow people to participate more effectively in the development of programs or opposition to them (Sharafi and Barkpour, 2010: 40). The role of experts is not merely to present final and unchangeable solutions but to improve and complete solutions through continuous dialogue with the public. Experts focus all their energy on increasing citizens’ awareness. Therefore, solutions result from the relationship between two groups: first, the opinions of experts who provide technical information, and second, the opinions of citizens (Sharafi, 2010: 26).

Various theories about levels of participation have been presented, where lower levels of participation encompass the “public right to know and be informed” about project subjects and design actions. The intermediate level involves participation in “determining interests and agenda” and “evaluating risks and recommending solutions.” The highest level of participation is achieved when it takes the form of “participation in decision-making” (Münster et al., 2017: 2393). In this type of participation, citizens are involved in decisions about the quality and direction of their lives. This level of participation is based on the following principles (Sharafi and Barkpour, 2010: 39):

- There is no best solution to design problems. Each problem has more than one solution.
- Experts’ decisions are not necessarily better than those of ordinary people. In decision-making, the realities should be stated first so participants can examine and choose from the available options. In such a method, the designer or planner should be considered a participant, determining and discussing the outcomes of possible options and expressing their opinion, rather than choosing from among the options, as other participants do.
- The work of design and planning should be clarified and made understandable. The options considered by experts are frameworks in their minds that need to be brought to the surface for discussion.
- After understanding the details and reviewing the options, participants can present their designs, not just react to ready-made plans.

Serious games and gamification: Enhancing public participation in urban design

Serious games, designed for purposes beyond entertainment, have emerged as significant tools in various fields for enhancing user interaction and facilitating inclusive participation among stakeholders, including vulnerable groups (Bakhanova et al., 2020: 3). These games allow decision-makers to experiment with diverse strategies in a virtual setting, a method that is often less feasible in real-world scenarios due to cost and risk factors. The low-risk environment of serious games provides a secure platform for creativity and experimentation, leading to more profound learning experiences and improved decision-making (Shakeri, 2016: 55; Shakibamanesh, 2014).

Gamification, a relatively new concept, aims to heighten user engagement and address specific issues or behavior patterns within a target community by infusing elements of entertainment (Zarrin Bal Masouleh, 2018: 15). In the context of urban planning, digital games facilitate knowledge transfer, participation, and interaction, thereby enhancing the learning process (Al-Dalou & Abu-Shanab, 2013; Lironi, 2016). These games, often integrated with digital storytelling technologies and mobile media, serve as valuable tools for cultivating social interaction (Shakeri, 2016: 17; Thiel, 2017).

A key benefit of using games in participatory processes is their capacity to present complex spatial concepts in a simplified, game-based environment, thereby making it easier for players to understand and interact with these concepts (Johansen & Pedersen, 2019: 31). While this approach might sacrifice some degree of precision, it significantly enhances user engagement and comprehension. However, the development of accurate, three-dimensional games can be resource-intensive. Hence, the feasibility of such games in participatory processes depends on balancing complexity with simplicity, ensuring that games are either straightforward or intricately designed yet reusable (Johansen & Pedersen, 2019: 23; Vanolo, 2018; Yen et al. 2019).

Gamification should be viewed as a complement to traditional urban design and planning methods rather than a replacement. It offers a way to define potential solutions without altering the fundamental problem-solving approach (Johansen & Pedersen, 2019: 30). For successful gamification, it is crucial to recognize that it is a process-oriented activity, requiring constant adaptation to changing user needs. It is also purpose-driven, necessitating a clear understanding of its objectives and ongoing monitoring of user interactions (Zarrin Bal Masouleh, 2018: 18 and 19).

Analysis of successful and unsuccessful gamification implementations suggests several factors critical for its effectiveness:

- Providing participants with a clearly defined and aspirational goal.
- Stimulating user curiosity.
- Creating a sense of achievement and victory.
- Offering consistent and constructive feedback.
- Delivering meaningful and performance-appropriate rewards.
- Aligning challenges with user capabilities.
- Personalizing user experiences.
- Encouraging social participation and publicizing user progress.
- Fostering a competitive yet collaborative environment.
- Cultivating a sense of progress and achievement among participants.

Serious games, as articulated by Michael & Chen (2006), are defined by their educational or practical objectives, employing typical gaming elements like rules and interactivity to achieve specific outcomes. Zyda (2005) highlights their broad applicability across various sectors such as healthcare, military training, and urban planning, underscoring their versatility. De Freitas & Oliver (2006) discuss how these games create immersive learning environments, offering safe spaces for users to experiment and understand complex systems and processes. Djaouti et al. (2011) emphasize that serious games often incorporate real-life challenges, allowing players to engage with authentic issues, especially pertinent in fields like urban planning.

In summary, serious games and gamification represent a convergence of education, technology, and user engagement. They offer diverse solutions in various fields, including urban design, by creating platforms for experiential learning, problem-solving, and community involvement. Their integration alongside conventional urban planning methods can significantly enhance the effectiveness of participatory processes in urban design (Asghari, 2021).

Given the transformative impact of gamification on urban projects (see Andrade et al., 2017; Opromolla et al., 2015), it is pivotal to delineate the key reasons underpinning its successful integration, as outlined in the table 2.

Table 2. Factors contributing to gamification success in urban projects

Reason for Success	Brief Explanation
Increased Citizen Participation	Gamification allows active citizen engagement in urban processes, enabling firsthand experience and involvement in decision-making.
Facilitation of Complex Conceptual Understanding	This method simplifies complex urban planning concepts, presenting them in a more accessible and game-like manner, enhancing public comprehension.
Enhanced Interaction and Collaboration	Gamification promotes collaboration among individuals and groups, fostering cooperation and coordination in urban projects.
Opportunity for Trial and Error	Providing a safe environment, gamification enables risk-free experimentation, allowing individuals to learn from mistakes without irreversible consequences.
Motivation and Transformation	Gamification boosts motivation and participation, driving positive transformations in urban projects through increased engagement.
Suitable and Elevated User Objectives	Gamification presents appropriate and lofty goals to users.
Instilling Curiosity in Users	Gamification sparks curiosity among users.
Inducing a Sense of Achievement	Gamification instills a sense of victory in users by reaching predetermined goals.
Providing Feedback to Users	Gamification offers feedback to users.
Meaningful and Proportionate Rewards for User Performance	Gamification provides meaningful and proportionate rewards based on user performance.
Balance Between Designed Challenges and User Abilities	Gamification ensures a balance between designed challenges and user capabilities.
Personalization of Experiences for Users	Gamification personalizes experiences for users.
Social Participation and Display of User Progress in Social Groups	Gamification encourages social participation and showcases user progress in social groups.
Creating Competitive Spaces Among Users	Gamification creates competitive environments among users.
Stimulating a Sense of Progress and Competitiveness in Users	Gamification stimulates a sense of progress and fosters competitiveness among users.

These reasons represent key advantages that can significantly contribute to the successful execution of gamification in urban projects.

METHODOLOGY

Definition of the Problem

Traditional approaches to urban facade design are often rigid, expert-driven, and lack mechanisms for iterative collaboration and contextual responsiveness—particularly in historically sensitive environments. This results in urban design outcomes that may not align with user needs, spatial character, or evolving socio-cultural dynamics. The core problem this study addresses is how to develop Form-Based Codes (FBCs) through a participatory, flexible, and context-specific method that integrates expert judgment with interactive design exploration. The challenge lies in combining structured expert consensus (via the Delphi technique) with immersive evaluation (through gamification) to create facade design alternatives that are both contextually appropriate and collectively validated.

Therefore, the study focuses on 15 Khordad Street, selected for its strategic importance as a historical and cultural hub adjacent to Tehran's Grand Bazaar, as well as its unique morphological challenges characterized by a fragmented skyline and inconsistent architectural identities. This research contributes to urban design literature by addressing the methodological gap in participatory planning; specifically, it proposes a hybrid Delphi–gamification approach to overcome the limitations of static, expert-driven Form-Based Codes (FBCs). By using the survey method, a deep understanding of the selected area was achieved. Based on the proposed framework, this area was modeled using the Unity 3D game engine, chosen for its capability to render realistic, navigable environments. For achieving desired codes, the Delphi technique was utilized with a group of 20 urban design professionals, with results cross-checked by an independent panel to ensure validity. In the virtual environment, a simplified interface was implemented to minimize the influence of participants' digital literacy, empowering them to select preferred facade options based on usage type. Finally, by compiling the selected alternatives, the desired form-based codes are presented.

The Delphi Technique

The Delphi technique was implemented during the early design phase to identify, refine, and validate facade design alternatives. It guided the development of code parameters before the gamified environment was built. The technique involved three iterative rounds; each aimed at narrowing the options and achieving expert consensus on the visual and structural components used in the virtual tests. The study participants were 20 urban design professionals and master's graduates, selected for their expertise in urban design and familiarity with Form-Based Codes. All participants voluntarily took part in the gamified testing process. The Delphi technique was employed to gather these expert opinions on the design alternatives. The process was conducted over three rounds: the first round involved a broad range of design ideas, the second focused on narrowing the options, and the third synthesized the collective feedback into final recommendations. Based on the studies conducted in the theoretical foundations section, Table 3 illustrates the emphasis placed on the process of formulating form-based codes within the proposed framework of the study.

Panel Composition

The central research problem—how to collaboratively develop facade design codes through participatory digital tools—was introduced in the first Delphi round. The panel comprised 20 individuals, all either urban design professionals or master's graduates with at least two years of relevant experience. Their expertise ranged across architectural design, urban morphology, and heritage preservation, ensuring interdisciplinary input. These individuals were selected based on academic background and demonstrated familiarity with Form-Based Codes.

Framework Overview and Component Structure

The initial code framework was derived from the literature on Form-Based Codes. This set served as a starting point for the Delphi process. Over three rounds, panelists assessed and modified these codes to meet the study area's contextual and architectural needs. A consensus threshold of 70% agreement was used to accept modifications or additions. These refined codes then formed the basis for the design permutations implemented in the game model. To operationalize the proposed participatory framework, the research outlines a step-by-step process for developing context-specific Form-Based Codes. Figure 1 illustrates the overall workflow of the framework, highlighting the layered structure through which facade elements are analyzed and coded. Complementing this, Table 3 categorizes these layers into distinct components—ranging from spatial configuration to visual and material qualities—forming the basis for systematic evaluation and code development.

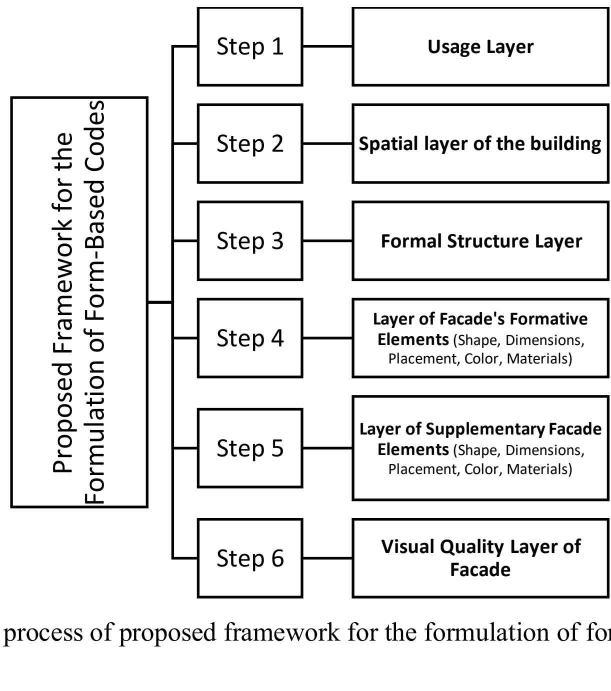


Figure 1. The process of proposed framework for the formulation of form-based codes

Table 3. Proposed framework for the formulation of form-based codes

<table>
<tr><th colspan="6">Usage Layer</th></tr>
<tr><th colspan="6">Spatial layer of the building</th></tr>
<tr><td colspan="2">Rooftop</td><td colspan="2">Upper Floors</td><td colspan="2">Ground Floor</td></tr>
<tr><th colspan="6">Formal Structure Layer</th></tr>
<tr><td colspan="4">Building Form (3D Structure)</td><td colspan="2">Building Placement (2D Plan)</td></tr>
<tr><td colspan="2">Horizontal Articulation</td><td colspan="2">Vertical Articulation</td><td colspan="2">Build to Line</td></tr>
<tr><td colspan="2">Minimum/Maximum Building Width</td><td colspan="2">Minimum/Maximum Building Height</td><td colspan="2">Setback/Protrusion</td></tr>
<tr><td colspan="2">Skyline Breaks</td><td colspan="2">-</td><td colspan="2">Min/Max Depth of Plots</td></tr>
<tr><td colspan="2">-</td><td colspan="2">Min/Max Height of Ground Floor</td><td colspan="2">-</td></tr>
<tr><td colspan="2">-</td><td colspan="2">Setback/Protrusion of Upper Floors</td><td colspan="2">Min/Max Width of Plots</td></tr>
<tr><th colspan="6">Layer of Facade’s Formative Elements (Shape, Dimensions, Placement, Color, Materials)</th></tr>
<tr><td>Distinct Architectural Elements</td><td>Display Windows</td><td colspan="2">Windows</td><td>Entrances</td><td>Balconies</td></tr>
<tr><th colspan="6">Layer of Supplementary Facade Elements (Shape, Dimensions, Placement, Color, Materials)</th></tr>
<tr><td colspan="3">Canopies</td><td colspan="3">Signboards</td></tr>
<tr><th colspan="6">Visual Quality Layer of Facade</th></tr>
<tr><td colspan="2">Materials</td><td colspan="2">Light and Dark</td><td colspan="2">Transparency</td></tr>
<tr><td colspan="2">Type</td><td colspan="2">Lighting</td><td colspan="2">Percentage</td></tr>
<tr><td colspan="2">Color Palette</td><td>Position</td><td>Amount of Light</td><td colspan="2">Placement</td></tr>
</table>

By using the survey method and following the Delphi rounds, a deep understanding of the selected area was achieved, and based on the proposed framework, the agreed-upon facade design parameters—such as number of floors, setback type, material palette, and entry articulation—were translated into game logic within the Unity 3D platform. To achieve the desired form-based codes for the area, the Delphi technique is used; each selected parameter is embedded as a selectable design permutation. Participants in the game environment navigated through these alternatives, enabling real-time feedback loops. They are empowered to choose their preferred option for developing form-based codes to organize the facade appearance of the study area. The Delphi-based decisions informed each of the 15 design permutations per building, while the game outcomes helped synthesize the final collective preference.

FINDINGS

Case Study

The study area in this research is 15 Khordad Street in Tehran, between Naser Khosrow Street and Pamnar. This street is one of the important streets in Tehran Province; it is significant because it houses the Grand Bazaar of Tehran, which is the largest economic and functional hub of Tehran and is of great historical and cultural importance. Functionally, as the study area is located within the vicinity of Tehran’s Grand Bazaar, and the land use in this area is predominantly commercial and commercial-administrative. This commercial-centric nature of the area influences various aspects of urban design, including traffic flow, pedestrian dynamics, public spaces and building facades. The focus on commercial and administrative uses also impacts the design and implementation of form-based codes, as these need to accommodate the specific functional requirements of such spaces while ensuring a cohesive urban aesthetic and maintaining the historical integrity of the area (Figure 1a).

Considering the location of the study area within the historical fabric of Tehran, the older parcels in the area often follow the pattern of a central courtyard; however, the newer parcels have adopted a construction pattern with higher density (Figure 1b). The study area demonstrates a lack of coherence in terms of height distribution, as it features predominantly older buildings ranging from 1 to 3 stories, while newer constructions are typically 4 to 5 stories. This disparity in building heights presents a challenge for urban design and planning, particularly in maintaining a balanced streetscape and preserving the historical character of the area while accommodating newer, taller structures. This aspect should be carefully considered in developing form-based codes and urban planning strategies to ensure a harmonious integration of old and new structures (Figure 1c). In terms of materials, the commercial uses in the area predominantly feature brick, while the commercial-administrative buildings utilize a combination of brick, aluminum, and stone. This diversity in material usage adds a layer of complexity to the urban fabric, impacting the aesthetic and functional aspects of building design (Figure 1d).

Figure 2. Primary characteristics of the study area: a) Land use; b) Figure-ground; c) Building height (number of floors); and d) Building facade material

The area's lack of a consistent and uniform skyline, due to the heterogeneous distribution of building heights, further accentuates the challenge of creating a harmonious urban environment. This irregular skyline can impact the visual coherence and overall character of the neighborhood. Addressing these variations in skyline is crucial for developing effective form-based codes that can guide future development while respecting the existing urban landscape (Figure 3).

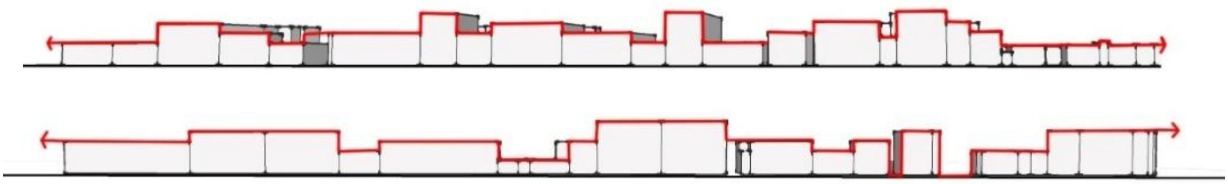
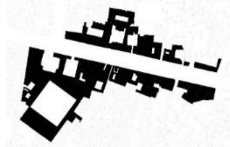
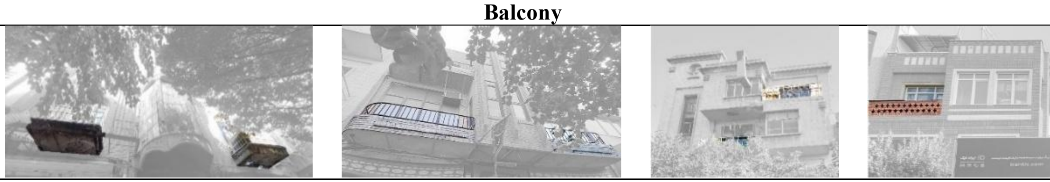


Figure 3. Skyline of the eastern facade (upper) and western facade (bellow)

Based on the impressions formed and the knowledge gained from the scope, the intended framework for providing form-based codes is presented in Table 3 and it is used to analyze the study area for developing Form-Based codes which is presented in Table 4.

Table 4. Analysis of the study area for developing form-based codes (commercial use)

Usage Layer		
Spatial layer of the building		
Upper Floors		Ground Floor
Formal Structure Layer		
Building Form (3D Structure)		Building Placement (2D Plan)
Vertical Articulation		
1-3 Floors	Minimum Building Height	
3-5 Floors	Maximum Building Height	
4.60 meters	Maximum Height of Ground Floor	
4.60 meters	Maximum Protrusion of Upper Floors: 1.20 meters	
Layer of Facade's Formative Elements (Shape, Dimensions, Placement, Color, Materials)		
Balcony		
		
Entrance		
		
Architectural Elements Emphasizing Entrance: Use of Sabat (traditional overhead arches), protrusion, incorporation of traditional Iranian architectural patterns and designs	**Heightened Entrance:** Usage of arch-shaped forms, increased height	**Enhanced Entrance:** Increased height, protrusion, material variation
Windows		
		
Display Windows		
		
Special Architectural Elements		
		
Layer of Supplementary Facade Elements (Shape, Dimensions, Placement, Color, Materials)		
Signboard		
		
Length: Proportional to the width of the plot **Width:** 60 cm **Color and Materials:** Brown, wood		**Length:** Proportional to the width of the plot **Width:** 60 cm **Color and Materials:** Brown, wood | Blue, tile
Visual Quality Layer of Facade		
Materials		
Type: Stone **Color Palette:** White	**Type:** Stone and Brick **Color Palette:** Cream-colored Stone and Red Brick	**Type:** Brick **Color Palette:** Commercial usage predominantly features Cream and Red Brick

Developing the Proposed Model and Research Tests

The study area includes both eastern and western facades. However, to prevent imbalance in the number of designed tests and to maintain consistency in terms of land use types and building forms, the eastern facade is selected as the test area. For conducting the tests, the existing buildings within the named area will be identified and labeled, and then the tests will be applied to them (Figure 4). This focused approach allows for a more controlled and detailed examination of the impact of form-based codes and design interventions.

Figure 3. Coded buildings ma

Based on the form-based codes framework of the study area, the algorithm depicted in Figure 5 has been selected from the identified patterns of the area. It will be used in the gamified model and in the design of research tests.

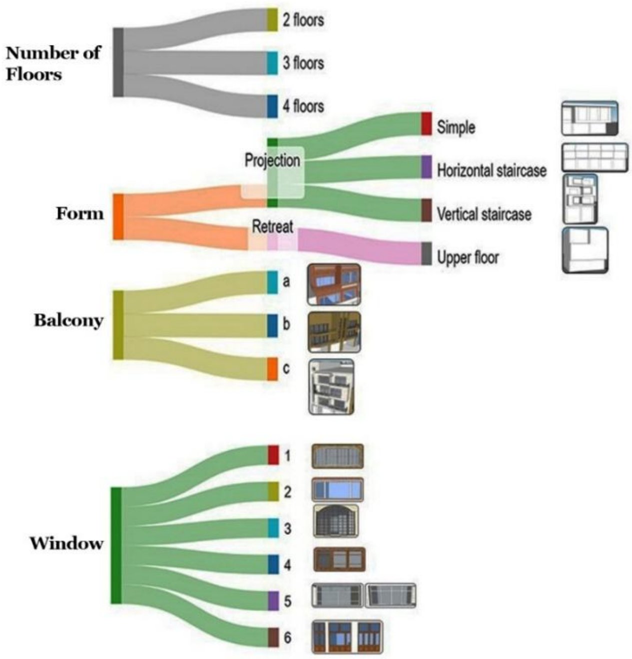


Figure 4. The Selected algorithm for the developed gaming model and design of research experiments

According to this algorithm, each building comprises 15 permutations, with the number of floors, form, window and balcony types, and materials varying across plots. This allows participants to observe changes in the area's structure by altering each building, thereby selecting their preferred option. Plots with suitable existing patterns in the area are considered fixed, so changes to each plot are made in accordance with those patterns. SketchUp software was used to model the area, with every effort made to replicate its existing conditions closely. The modeled environment was then transformed into a game in the Unity 3D engine, designed from a human perspective and at a human scale. To further simulate the environment's reality, real ambient sounds were used in the game space. Additionally, participants can move at different speeds and change their viewing direction within the environment, providing a sense of freedom of movement as if they were in the actual environment (Figure 6).

Figure 5. Designed game environment

In the game environment, buildings that can be modified are marked with their respective designated letters (Figure 7). In front of each, there is a sign indicating the key corresponding to the code of that building. The user observes the building modifications by pressing the respective key on their keyboard.

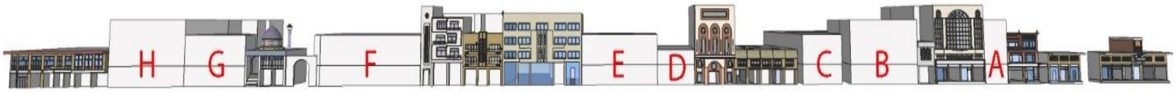


Figure 6. Naming of target buildings in the test

As mentioned, each building in the area has 15 different permutations. An exception is building H, which has a commercial-administrative use and therefore has two unique permutations in addition to the other permutations.

Table 5. Presented permutations for each named building

Specific Code for Each Test		Parcels with Narrow Width	Parcels with Wide Width
A			
B			
C	Two-Story		
D			
E			

F	Three Story		
G			
H			
I			
J			
K			
L	Four Story		
M			
N			
O			

A’	Commercial-Administrative	
B’		
Active*	Entrance Pattern Tests	
Not active		

*The permutations “Activate” and “Not activate” pertain to the presence or absence of a specially designed form for defining the entrance to the courtyard, which can be activated or deactivated using specific letters placed on a sign in front of the courtyard.

Analysis and Evaluation of Virtual Tests

The results obtained from the tests can be examined in two distinct parts; 1) Number of floors, 2) Form:

Floor preferences

This section presents the participants’ preferences regarding the number of floors for each building in the test area. The table below summarizes the percentage of participants who selected each option:

Table 6. Analysis results: Distribution of floor selection preferences per building

Building Code	Percentage of Choice of Number of Floors for Each Building		
	4 Floors	**3 Floors**	**2 Floors**
A	35%	55%	10%
B	40%	35%	25%
C	15%	50%	30%
D	40%	30%	30%
E	50%	25%	20%
F	25%	35%	35%
G	20%	10%	45%
H	25%	20%	45%
Average	41%	43%	40%

Based on the results presented in the table, the most frequently selected alternative for the number of floors in the study area is three stories (Figure 8).

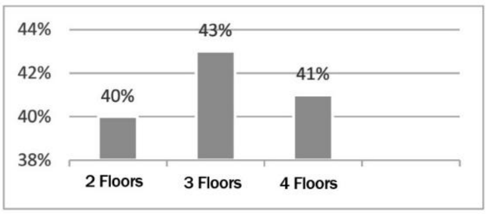


Figure 7. Participants’ selection of floor number alternatives for the entire area

Form selection

This section outlines the distribution of selected facade form alternatives across buildings, highlighting the most favored design elements. In table 7, the selected form alternatives for each of the buildings in the area are presented in Table 7.

Table 7. Analysis results: Distribution of form selection preferences per building

Building Code	Passage-like form	Setback	Horizontal Staircase	Protrusion 1	Vertical Staircase	Protrusion 2	Protrusion 3	Form B'	Form A'
A	10%	60%	-	5%	10%	10%	5%	-	-
B	15%	40%	5%	10%	10%	5%	15%	-	-
C	10%	30%	15%	5%	10%	5%	25%	-	-
D	5%	30%	25%	25%	10%	-	-	-	-
E	-	45%	15%	25%	5%	-	5%	-	-
F	10%	20%	5%	10%	25%	15%	10%	-	-
G	5%	45%	10%	25%	-	5%	5%	-	-
H	-	60%	5%	10%	-	15%	-	10%	-
Total	9%	55%	13%	19%	11%	8%	10%	1%	-

Based on the results from the choices made by the participants, the next step involves presenting the optimal alternative for each building and, ultimately, the selected pattern by the target group for the entire test area (Figure 9).

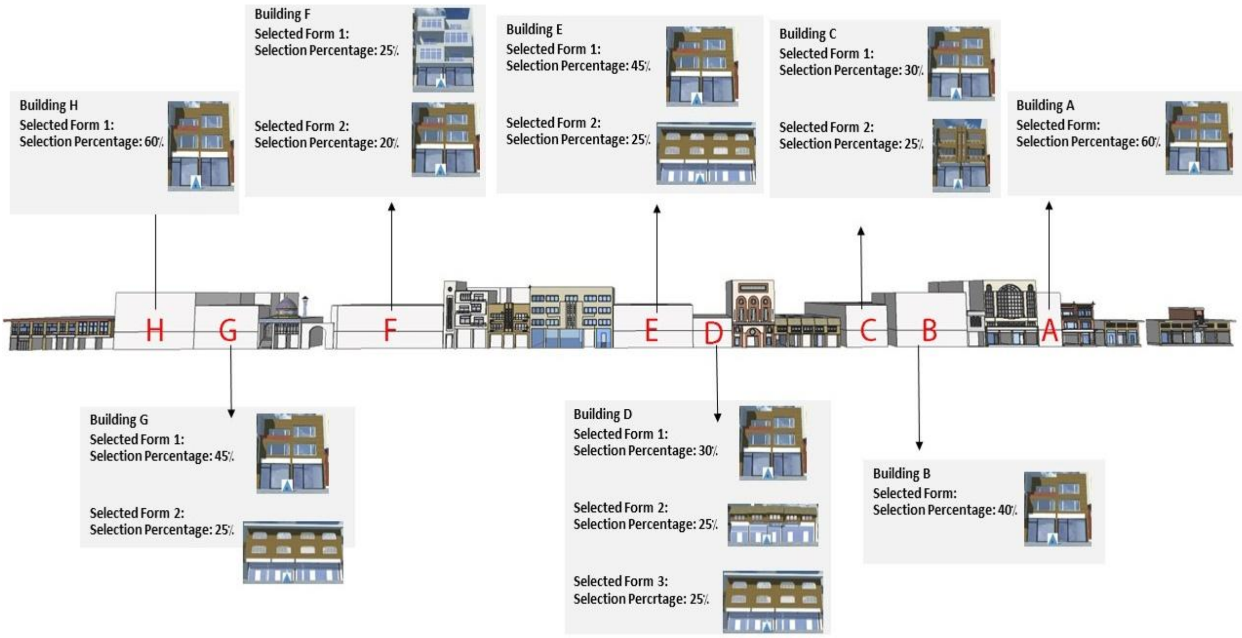


Figure 8. Selected alternatives for each building

Final pattern synthesis

With these selected form alternatives and by synthesizing the results from floor and form selections, the optimal design pattern for the study area can be derived. As observed in the Figure 10, 55% of the participants have chosen a setback pattern for the entire area. This preference indicates a significant inclination towards a specific urban design approach that could potentially influence the overall aesthetic and functional characteristics of the area.

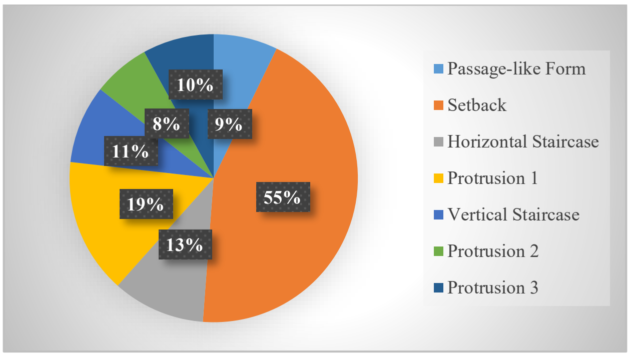


Figure 9. Participants' selection of alternatives for the entire area

Considering the participants' opinions and their selected alternatives, the proposed patterns for the eastern facade of 15 Khordad Street in Tehran, between Naser Khosrow Street and Pamnar, are presented in Figure 11 and 12.

Figure 11. Proposed pattern 1 for the entire area; average selection rate 41.8%

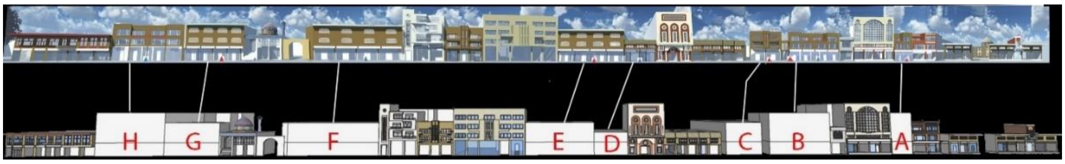


Figure 12. Proposed pattern 2 for the entire area; average selection rate 35%

CONCLUSION

This research underscores the transformative potential of gamification in urban design, particularly in the formulation and application of Form-Based Codes (FBCs). This study introduces a novel methodological integration of the Delphi technique with gamified design evaluation, creating a hybrid approach that has not been previously applied in the context of Form-Based Code development. This fusion enables more responsive and collaborative urban design practices. By integrating gamification, the study demonstrates a paradigm shift from traditional, product-centric urban design approaches to more dynamic, process-oriented, and participatory methodologies. This shift is crucial in addressing the multifaceted and evolving nature of urban design challenges. It is important to note that the codes developed in this study are specific to the socio-spatial and morphological characteristics of the 15 Khordad Street context. The framework may require adaptation when applied to other urban typologies or functional zones. The case study on Tehran's 15 Khordad Street vividly illustrates the effectiveness of gamification in fostering collaborative engagement among urban designers. The use of a gamified digital platform enabled a diverse group of experts to interactively explore and evaluate various facade design alternatives. This process not only enhanced creativity and stakeholder participation but also led to the development of more nuanced and contextually relevant urban solutions.

The findings from this research highlight the importance of incorporating flexibility and adaptability in urban planning processes. The gamified approach allowed for the examination of a multitude of design permutations, offering a more comprehensive understanding of the potential impacts and outcomes. This approach is particularly beneficial in historical and culturally significant contexts like Tehran, where preserving the urban fabric while accommodating modern needs is crucial. This method is especially well-suited for historical urban environments, as it enables preservation-conscious design through participatory input. The case of Tehran's Grand Bazaar vicinity demonstrates how heritage-sensitive facade patterns can be co-developed through structured expert feedback and gamified modeling. Looking forward, the integration of gamification with augmented reality technologies presents an exciting avenue for further enhancing the participatory aspect of urban design. Such technological advancements could revolutionize the way stakeholders interact with and understand the potential transformations in their urban environments.

In conclusion, this study contributes to the emerging discourse on the role of innovative methodologies in urban design. It advocates for a more inclusive, interactive, and flexible approach to urban design, emphasizing the need to move beyond traditional practices. The successful application of gamification in this research paves the way for its broader adoption in urban design processes worldwide.

While this study focuses on the urban context of Tehran, the gamified approach for developing Form-Based Codes can be adapted to other cities facing similar challenges in urban design. For instance, cities with diverse architectural styles and urban forms may benefit from the flexibility of this methodology to integrate various design preferences into a cohesive urban framework. A limitation of this study is the reliance on gamification tools, which may not be readily accessible in all urban contexts. Additionally, digital literacy levels among various user groups may affect the usability and effectiveness of the gamified approach. Future studies could explore alternative methods to ensure inclusivity.

Authors' Contributions

Amir Shakibamanesh contributed significantly to the study by undertaking the following roles: Conceptualization, methodology development, formal analysis, validation of results, investigation, data curation, project administration, and supervision of the overall research process. Maryam Nargeszadeh contributed significantly to the study by undertaking the following roles: Conceptualization, methodology development, formal analysis, validation of results, investigation, data curation, and writing – original draft preparation. Mahshid Ghorbanian contributed significantly to the study by performing the following roles: Conceptualization, methodology development, formal analysis, validation of results, investigation, data curation, project administration, writing – original draft preparation, and writing – review & editing.

Competing Interests

There is no potential conflict of interest.

Ethics Committee Declaration

Ethics committee approval dated November 5, 2024 and numbered IR.AU.REC.1403.567 was obtained by University of Art Ethics Committee for Human Research (Tehran, Iran).

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