International Journal of Architecture and Urban Development
Vol. 12, No.4, P 53-66. Autumn 2022

E-ISSN 2345-2331
Applied Research Article

DOI: 10.30495/IJAUD.2022.67578.1610

Augmented Reality System Specification for Placemaking

[1]Hossein Amin Pour Pirjel, [2*]Farah Habib, [3]Zahra Sadat Saeideh Zarabadi, [4]Vahdaneh Fooladi

[1]Ph.D. candidate, Department of Architecture, Science and Research Branch, Islamic Azad University, Tehran, Iran.
[2*]Professor, Department of Urban Development, Science and Research Branch, Islamic Azad University, Tehran, Iran.
[3]Associate Professor, Department of Urban Development, Science and Research Branch, Islamic Azad University, Tehran, Iran.
[4]Assistant Professor, Department of Architecture, Science and Research Branch, Islamic Azad University, Tehran, Iran.

Recieved 20.05.2022; Accepted 03.07.2022

ABSTRACT: Augmented reality (AR) builds better participation for placemaking by focusing on real time features, communication, and direct information flow between project stakeholders. This study attempts to access to specification of the Augmented Reality System for Placemaking (ARSP) model and make the research a basis for a profitable e-business model. By investigating AR and placemaking, this research seeks to build an augmented reality system specification of the information flow and communication for project stakeholders' management. This paper explores the potential for using AR technology in interior design by three-dimensional (3D) and two-dimensional (2D) and façade placemaking by 2D textures of brick material. The system consists of a qualitative proof of concept (POC) model, a prototype model, and a minimum vital product (MVP) model to study to compel quantitative research. The ARSP POC model, prototype model, and MVP model are programmed by building an information modeling (BIM) system, Revit and Unity software, and different software development kits (SDKs) as an application for Android devices. Seventy-four experts tested the MVP model in the Delphi method and observed, interviewed, and filled out a questionnaire. The research shows that the contributions of this study to the body of knowledge are twofold. First, this study extends the understanding of AR applications in placemaking. Second, this study identifies possible improvements using AR systems in design, procurement, and construction.

Keywords: *Augmented reality; placemaking; design, construction, procurement, system specification, stakeholders management.*

INTRODUCTION

Information flow, communication, and project stakeholders' participation have changed in the architecture, engineering, and construction (AEC) industry through time: from simple conversation to hand drawings, and most recently, information and communication technology (ICT), such as computer-aided drafting (CAD), building information modeling (BIM), and immersive technologies (ImTechs). However, the implementation and use of ICT are relatively slow in the AEC industry compared to other industries. ImTechs are consists of virtual reality (VR), augmented reality (AR), mixed reality (MR), and extended reality (XR). These visualization systems change the way humans interact with visual information and allow for a different level and quality of discussion between stakeholders, i.e., clients, designers, and builders. The participatory nature of these media, in return, affects placemaking strategies. Regarding placemaking, AR is most connected to human experiences, and the human-computer interface (HCI) is a bridge between them.

The major research problem is the lack of suitable communication and information flow in placemaking stakeholder management. To solve this problem, a system must

*Corresponding Author Email: f.habib@srbiau.ac.ir

improve stakeholders' perceptions. The user is the main pillar of the project, and the needs of the user from the project are evaluated and determined by the client. One of the problems in placemaking is selecting dimensions, color, texture, layout, and material construction. At this stage, the views of the project stakeholders are different, and to reach a common point of view, the client, designer, contractor, and manufacturer or supplier should be in a place such as the construction site or in the manufacturer or supplier place that includes the manufactory or exhibition to check different material samples, decide and buy it. This process is time-consuming and has limitations. These limitations include the level of mental visualization, social considerations, technical and aesthetic issues, stock status, price, delivery conditions of materials, and so on. The final decision and selection of the material may not lead to the desired result because what is desired by the stakeholders is considered mind visualization of the building. This becomes even more complicated when information about building conditions and neighborhoods, materials diversity, and different construction methods must be considered simultaneously. Figure 1 shows the flow of information, communication, and stakeholder participation in placemaking projects.

Various studies have proven the effectiveness of AR technology in improving users' perception, learning, performance, and decision-making. The processes that use augmented reality face opportunities and limitations. AR builds better participation for placemaking by focusing on the real-time feature, communication, and direct information flow between project stakeholders. Despite the extensive capabilities of AR in creating efficient interaction and effective information flow between project stakeholders, this potential has not been sufficiently exploited in the field of architecture and placemaking. Considering the definitions and types of placemaking that consider the building facades as standard placemaking, focusing on the facade is an important part of the placemaking process. Therefore, specifically in the design, procurement, and construction of building facades, AR technology's interactive and real-time advantages have not been used efficiently.

Theoretical Framework

This paper explores the potential for using the AR system for placemaking (ARSP). To achieve the ARSP specification, the research background shall be studied. First of all, this research defines AR and placemaking, provides an overview of the state-of-the-art use of AR in AEC, and discusses its applications in placemaking. These applications study from different views: opportunities and barriers of AR in AEC, the relation of AR to CAD/BIM, AR application cases in business and sale, and determining AR as HCI. For building up the ARSP models and achieving the ARSP production model for e-business in placemaking, the literature review studied different categories presented in figure 2 and described in the literature review section.

Spatial Orientation Research

The system consists of three steps and models, a qualitative proof of concept (POC), a prototype, and a minimum vital product (MVP) to study to compel quantitative research. The ARSP POC, prototype, and MVP models are programmed by BIM families, Revit and Unity software, and different SDKs as an application for Android devices. The proof of concept (POC) model works on interior design with three-dimensional (3D) objects without detecting the floors or walls. The prototype model works on interior design and uses two-dimensional (2D) objects to detect the floor. The authors observed these two steps; meanwhile, stakeholders tested the models and helped make the next step. The MVP model works on interior design and façade design by detecting floors and walls and the ability to draw lines and make surfaces. This model has 2D textures of brick materials because of simplifying and has the potential to test by stakeholders. Seventy-four experts tested the MVP model in the Delphi method and observed, interviewed, and filled out a questionnaire. Figure 3 shows the spatial orientation of the ARSP models' specification in three steps to reach the ARSP production model. The explanation of each step will discuss in the research method and findings.

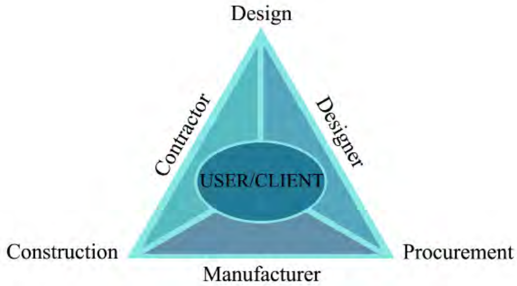

Fig.1: The flow of information, communication, and stakeholder participation in placemaking projects

Fig.2: Literature Review

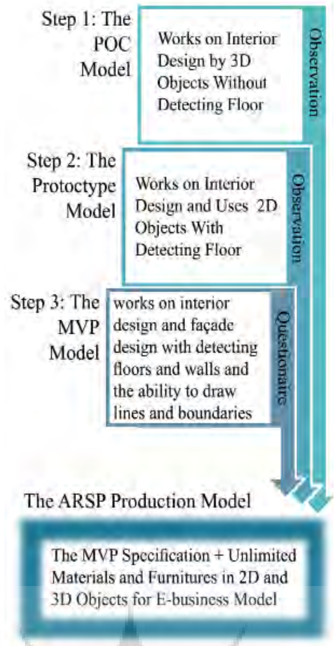

Fig.3: Spatial orientation of the ARSP models specification

Literature Review

The rise of digital technology in the industry is known mostly as I4, the fourth industrial revolution (Newman et al., 2020). I4 represents a combination of advanced technologies, including advanced software such as BIM (Bu et al., 2015) and ImTechs (Govindarajan et al., 2018). ImTechs such as AR and VR have design, construction, and procurement benefits.

Modern construction management, in its broader sense, makes informed decisions according to a wealth of information. Perhaps since the emergence of modern construction management, the serious disconnection between the physical environment and virtual information has become an intrinsic part of managerial problems in construction projects (Chen et al., 2015). The problem has further escalated throughout the 2000-the 2010s and was enlarged by the increasing complexity of construction projects. In response, the industry started embracing advanced digital technologies to make accurate information readily available to managers and workers (Newman et al., 2020).

The placemaking process needs participation between stakeholders and stakeholder management. Information and communication technology are essential for this participation, and computer visualization has potential and limits for this purpose.

According to Pallasmaa's (2012) book, the eyes of the skin: architecture and the senses, computers are typically regarded as a useful invention that opens the field for the human imagination and increases the efficiency of design work. Computer visualization tends to reduce our imagination's enormous, multisensory, simultaneous, and harmonious capabilities. It transforms the design process into passive visual handwork and eye-catching excursion. The computer creates a gap between the place creator and the object, while manual design and the fabrication of a scaled physical model puts the designer in touch with the object or space. The object in our imagination is simultaneously in hand and mind; this tangible image or imaginative object is modeled by our mind-body. We're in and out of the object at the same time. Creative work requires cogeneration, comorbidity, and synesthesia at the mind and body levels.

Augmented Reality

After Milgram et al. (1995) defined AR as augmenting the natural background of the operator with simulated cues, Azuma (1997) determined three aspects of AR, which are, (1). combines real and virtual, (2) interactive in real-time, and (3) registered in three dimensions. Many scholars define AR differently due to the complexity of this technology and hardware and software maturity; the authors have provided some definitions of AR, which are important for this research and are presented separately in table 1. This table proves AR is suitable for information flow and perception; users focus on a virtual object embedded in a real context, decision-making, and better participation. Different studies reviewed the state-of-the-art use of AR in AEC; some demonstrate proof of the usability of AR in the architecture and construction process as a research method presented in Table 2. The table shows different uses that identify AR have been considered by professionals in the last decade.

Table 1: Definitions of AR

Author(s)	AR definitions
Chen & Xue (2020)	Such alignment of digital representations with people's view of the real world enables the simultaneous interpretation of both the virtual and reality. By doing this, AR could improve the information perception process and facilitate decision-making.
Schueffel (2017)	AR is an enhanced version of the physical, real-world reality in which elements are superimposed by computer-generated or extracted real-world sensory input such as sound, video, graphics, or haptics. AR with a focus on direct communication and information flow makes for better participation between the user or the client, the designer or the architect, and the manufacturer or the contractor.
Kalkofen et al. (2009)	AR displays extend the user's perception with additional computer-generated information. This information is usually registered in 3D space and related to objects and places in the real world. Let's consider AR as a visualization technique. The relationship between real and virtual objects is one of focus and context: We want to provide additional virtual context to an important object in the real world, or we want the user to focus on a virtual object embedded in a real context.
Azuma (1997)	AR creates a composite view of the virtual and reality by superimposing objects' digital representations (e.g., image or model) onto the physical environment.

Table 2: State-of-the-art on use of AR in AEC

Author(s)	Descriptions
Ernstsen et al. (2021)	AR mentioned by professionals through interviews as technology in the user-data-driven built vision for the digital transformation of the construction
Cheng et al. (2020)	They reviewed 87 journal papers on MR applications and classified them into four application categories: architecture and engineering, construction, operation, and multiple stages. They summarize the challenges of MR applications as the accuracy of spatial registration, user interface (UI), data storage and transfer, and multiuser collaboration.
Noghabaei et al. (2020)	They identified a significant increase in AR utilization in the architecture, engineering, and construction industry from 2017 to 2018. Furthermore, the research results indicate that the Residential and commercial sectors have adopted these tools the most compared to other sectors.
Yang et al. (2015)	They work on vision-based construction performance monitoring methods, especially visual monitoring of building elements. They found a gap between research and industrial application and proposed future roadmap and directions.
Rankohi & Waugh (2013)	They suggest that AR literature has increasingly focused on visualization and simulation applications, monitoring project progress, and addressing issues faced by field workers.
Bae et al. (2013)	They present a vision-based mobile AR system to access 3D cyber-information on-site by using photographs taken from standard mobile devices, and results show that the underlying 3D reconstruction module of the system generates complete 3D point cloud models of the target scene and is up to 35 times faster than other state-of-the-art Structure-from-Motion algorithms.
Yabuki et al. (2011)	They use AR technology with virtual models displayed in an overlapping manner with the actual landscape from multiple viewpoints to evaluate the height of buildings. They concluded that their experiments showed the feasibility and practicality of the proposed methodology.

Table 3 shows advanced design, engineering, construction, or even manufacturing processes that use AR can face various opportunities and barriers. The table stated that AR opportunities as reduce time, better project delivery, promote design communication, facilitate human integration, improve understanding and barriers as challenges in using AR techniques on the construction site, immature and expensive technology, lack of interoperability between different hardware and software and Risk of information overload. In addition, AR has been integrated with BIM and cloud computing for enhanced functions (Chen & Xue, 2020). Table 4 shows the relation and highly dependent of AR on CAD/BIM in different studies. Different researchers study AR application cases in business and sales. In table 5, related studies to this research are demonstrated. It shows that AR changes consumer behavior and provides systematic experiential benefits and advantages to retailers.

AR as a computational phenomenon depends on human-centered design and HCI when existing in the place. Hewett et al. (1992) define HCI as a discipline concerned with designing, evaluating, and implementing interactive computing systems for human use. Interaction design is a fundamental aspect of HCI and related disciplines connected with researching and designing computer-based systems for humans.

Table 3: Opportunities and barriers of AR in AEC

	Author(s)	Descriptions
Opportunities	Delgado et al. (2020)	They worked with fifty-four experts, built up an online questionnaire, and identified drivers for using AR in construction to enable improvements in project delivery and procurement of services.
	Wu et al. (2019)	They mentioned studies that identify AR provides design and construction professionals with unprecedented opportunities to promote design communication, collaboration, quality control, and safety management.
	Egger & Masood (2019)	They conclude that AR can facilitate human integration in manufacturing systems, providing people with an interface to interact with the digital world of a smart factory.
	Chu et al. (2018)	They stated improved understanding, reduced mistakes, and more efficient access to information.
	Wang et al. (2014)	By comparing visualization before and after AR and reviewing traditional approaches to visualize the architectural design, concentrate on static pictures or three-dimensional scale models, which cause problems. They categorized AR demonstration's advantages in reducing time, easy-to-assess concept design scheme regarding building surrounding environment, low cost to manufacture marketing material for property selling, and high information integration.
Barriers	Sidani et al. (2021)	This review shows that AR implementation is far from its desired state, showing several limitations such as connection and localization problems, lack of non-geometric information, and other challenges in using AR techniques on the construction site (e.g., marker-based AR).
	Delgado et al. (2020)	Limitations such as immature and expensive technology
	Li et al. (2018)	Poorly-designed interfaces and lack of interoperability between different hardware and software
	Chu et al. (2018)	Risk of information overload for the users

Table 4: Relation of AR to CAD/BIM

Author(s)	Descriptions
Sidani et al. (2021)	They analyze AR as such a tool. A systematic review was conducted to examine previous studies in the field of BIM-based AR, shedding light on integrating this technology in the architecture, engineering, construction, and operation (AECO) sector.
Wang et al. (2014)	They studied how the BIM and AR for architectural visualization systems were realized from the perspective of the building process. BIM is changing the building industry from design to the maintenance stage. The synergy of BIM and AR opens up new possibilities in architectural visualization, navigation, and interaction far beyond the traditional static navigation and interaction in front of a computer screen. Feedback from the stakeholders involved in the cases indicated that the system was useful and efficient in visualizing architectural design and communicating with each other. The system supports an innovative performance that allows: designers to put virtual building schemes in a physical environment, owners to gain an immersive and interactive experience, and property sellers to communicate with customers efficiently.
Woodward & Hakkarainen (2011)	They adopted Mobile MR System for Architectural and Construction Site Visualization using 3D CAD/BIM models, timing schedule, and geographical information. They use AR with feature-based tracking to visualize them on site, applying photorealistic rendering, with various mobile user interaction and feedback tools.
Kamat et al. (2011)	They also studied the relationship between CAD and AR by using activity-based construction schedules and 3D CAD models of facilities to describe discretely evolving construction product visualizations.
Roh et al. (2011)	They used visualization and computer vision techniques as an object-based 3D walk-through model for interior construction progress monitoring. The system manager collects, analyzes, and integrates digital photographs of the as-built project and BIM models to monitor construction progress by the owner, construction manager, and subcontractors. Their system represents significant potential improvement over how complicated interior construction works are managed in current practice.

Table 5: AR application cases in business and salefactors

Author(s)	Descriptions
Dacko (2017)	Their findings suggest that take-up is set to go mainstream as user satisfaction is relatively high, and their use provides systematic experiential benefits and advantages to retailers. Despite some drawbacks, their use is positively associated with multiple retail consequences. MAR apps are seen as changing consumer behavior and are associated with increasingly high user valuations of retailers offering them.
Brown & Barros (2011)	They propose applying a combination of virtual worlds and AR to create synthetic environments suitable for remote sales of physical artifacts, right in the purchaser's home.
Pereira et al. (2011)	used AR and artificial intelligence (AI) for body detection and dressed down the neck, which can use in building facades. Their approach is based on introducing computer vision in a hands-free AR setting.
Zhu (et al. (2004	They utilize AR technologies on a hand-held Tablet PC to provide for dynamic modification of the contextual settings of products on store shelves through the use of see-through vision with augmentations.

Cognitive aspects of interaction design consider what humans are good and bad at, and it shows how this knowledge can inform the design of technologies that extend human capabilities and compensate for human weaknesses (Preece et al., 2019). A well-known way of distinguishing between different modes of cognition is in terms of whether it is experiential or reflective. Experiential cognition is a state of mind where people perceive, act, and react to events around them intuitively and effortlessly. In contrast, reflective cognition involves mental effort, attention, judgment, and decision-making, which can lead to new ideas and creativity (Norman, 1993). AR user experience in primary stages is reflective cognition and experiential cognitive in advance.

Evaluation is integral to the design process. It involves collecting and analyzing data about users' or potential experiences when interacting with a design artifact. A central goal of the evaluation is to improve the artifact's design. The evaluation focuses on both the usability of the system (that is, how easy it is to learn and to use) and on the users' experiences when interacting with it (for example, how satisfying, enjoyable, or motivating the interaction is) (Preece et al., 2019).

Placemaking

The place-making phrase was used for placemaking, and the exchange form shows the change in meaning and content. This evolution indicates the integration of the meaning of this word over time and its acceptance as a basis of a specific theory. Place and placemaking are the subjects of theoretical debate in the built environment disciplines. from Tuan (1977) point of view, "Place is center of meaning, an organized world of meaning, constructed by experience."

Placemaking is a process based on teamwork in which project stakeholders, i.e., employers, designers, manufacturers, and contractors, collaborate on a common goal. Investigating teamwork and identifying key elements and characteristics of an effective team is the most important topic in this section. Tucker and Abbasi (2012) have extensively studied teamwork in architecture and related design disciplines. They believe each person has their own identity in the design process, but it is based on collaboration. Today, specialized teams work interdisciplinary on large and complex projects. These specialties include planning to design in architecture, structure, installations, landscape, and other specialties required by each project, from employer stakeholders to governmental and non-governmental organizations. Different scholars define placemaking with a focus on stakeholder management, and some definitions are mentioned in table 6. This table addresses the importance of participation between stakeholders and the process of creating high-quality places for people to live, work, play and learn. It defines different types of placemaking and focuses on standard placemaking considered in this study.

A practical study done by Arefi (2014) demonstrated that placemaking is inherently a complex, multi-layered, and controversial issue. Placemaking is multi-layered, which includes the physical, social and political dimensions. Places represent physical realities such as large or small, distance and proximity, and access by car or other vehicles. The relationship between people and place is the three possible relationships of need-based, opportunity-based, and asset-based. The asset mapping reflects the foundation of communities' willingness to invest in their capabilities, potential, and capacities.

Asset-based relationship refers to how society's capital and assets are exploited physically and socially. Physical capital refers to the same physical infrastructure as existing housing, roads, parks, buildings, and other urban equipment.

Architects and urban designers generally focus on the physical aspects of a place, while sociologists and cultural geographers

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Table 6: Definitions of placemaking

Author(s)	Placemaking definitions
Wyckoff (2014)	He defines placemaking as creating high-quality places for people to live, work, play and learn and categorizing it into four types: standard, strategic, creative, and tactical. Standard placemaking requires the engagement and empowerment of people to participate in the process, includes a wide range of physical projects and activities, and is pursued by the public, nonprofit and private sectors on an incremental or targeted basis over a long period. Examples include physical projects including street improvements and facades, neighborhood-based projects such as residential renovations, new housing construction, small-scale multi-use projects, park improvements, etc.
Seamon (2012)	This multiplicity of standpoints, as confirmed by him, shows how important the role of stakeholders participate are to improving place creation: "… place creation, it is people, enlightened governmental officials, citizens, and professionals, especially empathetic designers and planners, who draw on their commitment to and knowledge of the place to envision and make changes in the geographical ensemble. Place creation relates to the involvement of dedicated individuals … to strengthen people-in-place and thereby strengthen place ambiance and character".
Schneekloth & Shibley (2000)	They argue, "Placemaking, the act of creating and maintaining places, is active, conflicted cultural work that allows for multiple standpoints and momentary meanings that facilitate or hinder daily life."
Dayaratne (1992)	"Placemaking is the process in which a space in a location is made meaningful to an individual or a group." On the other hand, a major objective of participatory design and engineering is to create a "place."

Table 7: Use of BIM, Revit, Unity, and SDKs in related works

Author(s)	Use of BIM, Revit, Unity, and SDKs
Bourhim & Akhiate (2022)	They compared Vuforia, Wikitude, ARToolKit, and Kudan as AR SDKs. The study focuses on the SDKs in terms of the license, supported platforms, cloud recognition, geolocation, SLAM (Simultaneous Localization and Mapping), and other additional features. Their result shows that none of the discussed AR SDKs can satisfy all the criteria because each framework is suitable for a particular application and its area of implementation.
Balali et al. (2020)	They use BIM models, Revit software, Unity game engine, and C# script to create a VR/AR environment to help stakeholders such as owners, architects, and contractors to exchange material textures while having a sense of cost impacts, which can result in wiser design changes during the preconstruction phase. This can also clarify to the designers and other stakeholders and serve as an effective communication bridge between end-users and designers. Also, contractors can use this tool for better execution of design changes and efficiency improvement. Allowing end-users to contribute during the design phase not only reduces the number of change orders during the construction phase but also creates a better level of trust among the design team and stakeholders.
Amin & Govilkar (2015)	They had a comparative study of various AR SDKs available to create AR apps and found the benefits and limitations of different AR SDKs.
Kim et al. (2014)	They use Unity 3D version to make mobile AR develop a game. Their evaluation of users indicated that interaction with AR content and user interface clarity was improved in the Unity 3D version. They believe platforms like Unity provide the necessary tools for creating interactive 3D content, an effective workspace, and testing and editing features for developers to create interactive applications. In addition, the Vuforia AR extension for Unity enables the necessary marker detection and tracking functionality within Unity, thus allowing developers to create augmented mobile reality (MAR) applications. Also, the Unity interface allows better interaction with MAR contents being developed, user interface clarity, and creation of virtual buttons, along with an enhanced graphical representation due to Unity's built-in shader

are interested in the social and regional aspects. Hence, there is a deep gap between the theoretical and practical features of the place. This gap is technically clear and related to rules, and it is mental or philosophical in another dimension.

The distinct conceptual divisions of place focus on design aspects of place in the first level and on perceptions and interpretations of place in the second level. The study of the physical features of a place has progressed considerably in recent decades; for instance, the research on how certain physical designs or visual compositions, such as public space, the shape-context relationship, and land use, can play a role in creating vibrant places. An example of this research is Gordon Cullen's (2012) important book, The Urban Landscape Selection, which has been reprinted 15 times, and its effect on urban design is undeniable. Bacon & Walduck's (1967) book, Design of Cities, also teaches planners important lessons about place principles in major cities such as Rome and Philadelphia.

Physical placemaking emphasizes the two categories of place-building and place-marketing. Extensive studies in this area try to adopt design-oriented strategies and initiatives that help the places. This help redefine the mental image and transform areas with a disintegrated urban character into places encouraging cultural consumption.

Related Works: According to this paper's methodology, table 7 shows the use of BIM models, Revit and Unity software, and software development kits (SDKs). According to this table, a mix of software and SDKs is needed for placemaking stakeholders to exchange information such as material textures. In addition, each SDK is suitable for a particular application, and Unity and Vuforia are useful for this study.

MATERIALS AND METHOD

Due to the spatial orientation research and use of information and communication for the ARSP, it is necessary to determine the system characteristics and finalize the specification. According to the research questions, to achieve the desired characteristics of the ARSP, preliminary studies were conducted on the needs of users/clients, designers, contractors, and manufacturers. Understanding the phenomenon of AR for placemaking was examined based on different perspectives. Empirical, rationalist, structural analysis, and hermeneutic views were considered for the research, among which the view of structural analysis based on the process of thesis, antithesis, synthesis, and new thesis is considered in this research. According to the types of scientific research that are fundamental (experimental and theoretical) and applied (developmental and practical), this research focuses on the applied and developmental types.

Despite the AR knowledge, this research emphasizes the application and development of this technology in placemaking. This research is applied and developmental in terms of purpose because the results of this research can be used to achieve strategies for participatory placemaking with the target of the production and e-business model. Also, in terms of nature, this research is mixed, uses advanced interdisciplinary technology, and requires team-based work to achieve research findings to solve the issue. The integration of placemaking strategies input, software and hardware aspects of AR, information systems, e-business solutions, and teamwork notes should be used in the ARSP model and android/IOS application. Placemaking strategies require the creation of information inputs for application content. This information and content, for example, the visualization and simulation of two-dimensional and three-dimensional objects and digital models, has been developed by the field of architecture. ICT, especially AR, has fundamental software and hardware engineering foundations. Computer science colleagues consider the aspects of programming, design, HCI, and interaction design.

The Variables Under Study

The information and knowledge of stakeholders in Placemaking is an independent variable, and the ARSP specification based on the theoretical saturation of stakeholders is a dependent variable. The quality variables mentioned in the questionnaire need to be quantified. They are in two parts: collecting information and knowledge of stakeholders about ICT and AR and their opinions about the ARSP system. Both qualitative variables (nominal or sequential) are measured. According to Joshi et al. (2015), The Likert scale was selected, and for the quantification of qualitative data, 1, 3, 5, 7, and 9 were used respectively for very low, low, medium, high, and very high.

Methods and Tools of Data Collection

In this interdisciplinary research, the relationship between the client, the designer, the manufacturer, and the contractor is facilitated through the AR system. The design team provides information and meta-data for design visualization and collaboration, testing overlay, and superimposition onto real-world context.

Measurement tools are suggested tools that have been reviewed and selected based on the observation and review of written sources in the literature review sector. Observation tools, interviews, and questionnaires were used. For the MVP model, the tools were defined based on similar case studies and have been reviewed twice by experts. The observation, interviews, and questionnaires were done at the 21st Tehran International Building Exhibition in August 2021 and once at the 3rd Tehran Exhibition of facades and interior design in December 2021.

Statistical Population, Sampling Method, and Sample Size

In the section on gathering the information and knowledge of stakeholders in Placemaking (independent variable), the field of activity is divided into five areas: client or user, contractor, manufacturer or supplier, designer or architect, and others. The extent to which experts use smartphones, their most common use other than phone calls, and their familiarity with AR applications such as Snapchat AR, Instagram AR, etc., have been questioned.

Dependent variables include the difficulty of using the system, difficulty detecting floor and wall, and difficulty placing the product texture on the floor and wall. Also, the level of interest in using the system in general, the level of interest in using the product's texture, and the level of difficulty in using the screenshot of the system. To develop the MVP Model, they were asked how much they were interested in reusing it and what experts thought about the future of the MVP Model. If the version is improved and upgraded, what is the level of interest in using and selecting it, and in the end, what is the general level of satisfaction with using the system.

Methods and Tools of Data Analysis

the research method is qualitative and quantitative, in which qualitative data has been converted into quantitative data. The validity of the research is confirmed based on the study of similar case samples taken from the literature review sector. According to the Delphi method, it has been measured in two stages. The reliability of the research is confirmed by the fact that it has been studied in two building exhibitions and has extracted similar results.

According to Cohen et al. (2007), a proof of concept or a proof of principle study is a research method in which a certain method or model would be recognized to demonstrate its feasibility or to verify that a certain concept, theory, or prototype has the potential of being used. Questionnaires (as well as surveys and interviews) are research techniques in which quantitative and qualitative data analysis could be conducted based on the information gathered from research participants.

Concept and Implementation of the ARSP POC Model

Initially, the POC model of the system was created according to problem observation between stakeholders. The process involves uploading BIM models to the cloud database in Vuforia, an AR SDK, and receiving a license key for the application. 3D objects modeled as BIM, a Revit family, while material, color, and texture added in rendering engines. Finally, exported as FBX files format are uploaded to the application data cloud and augmented by the ARSP POC model application on the device to the real world. The application is made by the Augment.com website, which can run on phones, tablets, and other devices that have Gyroscope technology. The application has limitations in object quantity and duration of use. The ARSP POC model, which works on the interior design shown in figure 4, is a 3D medical unit that only shows in the real world without detecting the floor. It has the potential to analyze light and make shadows.

Concept and Implementation of the ARSP Prototype Model

The application is made by Unity's AR engine, which can run on phones, tablets, and other devices with Gyroscope technology. In this version, the ability to detect the floor, an important feature of AR, is added to the process. The process involves uploading the Joint Photographic Experts Group (JPEG) format to the cloud database in Vuforia, an AR SDK, and receiving a license key for the application. The license key is uploaded to the application data cloud and augmented by the ARSP prototype model application on the device in the real world. The ARSP prototype model shown in figure 5 is a 2D carpet that works on the interior design shown in the real world with the detection of the floor and the ability to change different types from the 2D objects library.

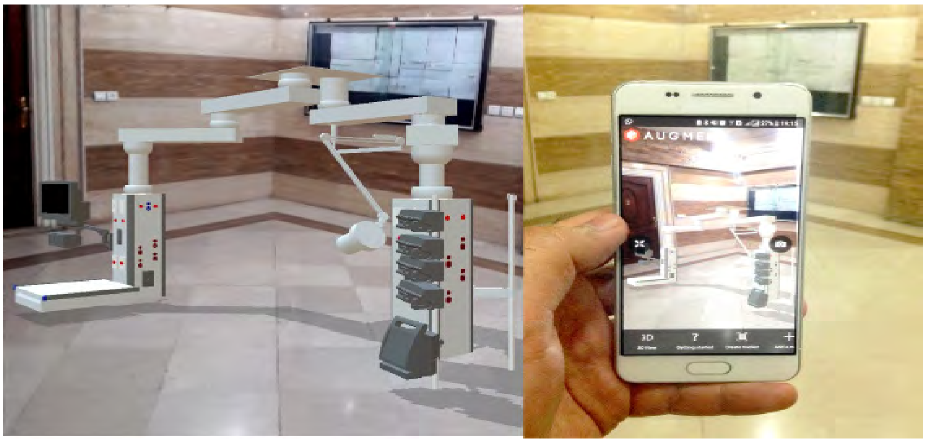

Fig.4: The ARSP POC model

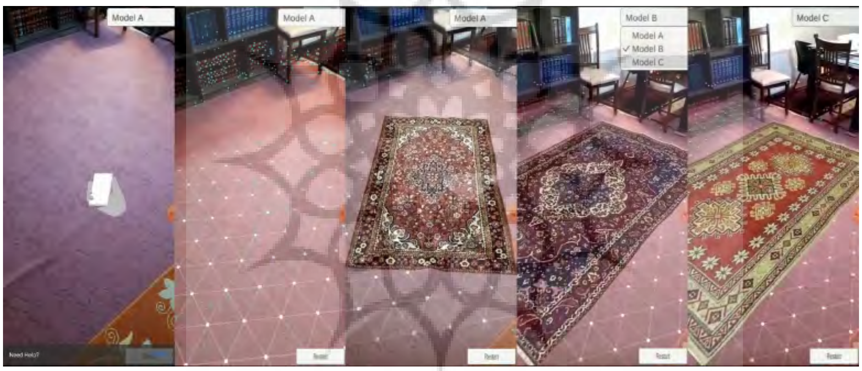

Fig.5: The ARSP prototype model

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Concept and Implementation of the ARSP MVP Model

This version was provided to the project stakeholders to specify the features of the minimum vital version of the product. The initial version has features that experts should review by reviewing and analyzing experts' answers to modify the system and review it to make a minimum vital version of the product. The final results of the questionnaires determine the measurement indicators and effectiveness of placemaking, and the limitations and potentials related to the research topic are identified.

The ARSP MVP model is programmed by Unity software as an application for Android devices. The application is made by Unity's AR engine, which can run on phones, tablets, and other devices with Gyroscope technology. In this version, the ability to detect the floor and wall, an important feature of AR, is added to the process. In addition, the ability to draw lines and boundaries makes the application mature for further steps. The process involves uploading JPEG format to the cloud database in Vuforia, an AR SDK, and receiving a license key for the application. The license key is uploaded to the application data cloud and augmented by the ARSP prototype model application on the device to the real world.

The ARSP MVP model present in figure 6 detects the floor and wall, draws lines and boundaries, and creates the surface with brick material texture, which shows in the real world. The ability to change different types from the library. The ability to change different texture and size were added to this version. This version has the potential to work on interior and façade

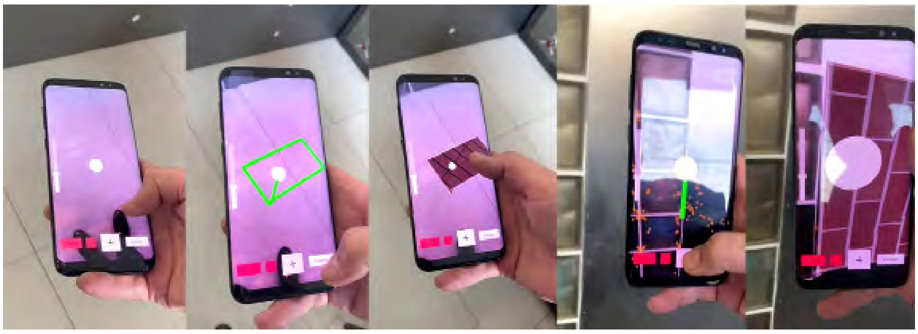

Fig.6: The ARSP MVP model

design.

The user overlays and superimposes information and meta-data onto the real world by the ARSP MVP application and places context for observation and measurement, revealing hidden conditions and deciding. The construction crew analyses overlay and superimpose information on the project site for layout and quality control. Seventy-four experts tested the ARSP MVP in two steps, and they observed, interviewed, and filled out a questionnaire.

RESULTS AND DISCUSSION

Placemaking consists of three main activities of design, procurement, and construction which vitally need information flow and communication in stakeholder management. BIM and computer visualization technologies such as AR and VR can help placemaking. Besides, computers transform the design process into passive visual handwork; new technologies such as AR need mind and body conciseness and interaction. It improves the perception of the place and makes creative work.

According to background research and research method, the POC model was created to analyze the system, and lessons learned led to creating the prototype for system simulation. The level of user interaction in these two models was low. The MVP model was built up regarding the issue that users shall have more possibility to draw and make boundaries for the targeted area. The MVP model as a draft system for a customer in figure 7 shows the process of three steps as a basis for the ARSP production model, which has the MVP specification plus unlimited materials and furniture in 2D and 3D objects for the e-business model.

Figure 8 depicts the percentage of participants who tested the MVP model, observed, interviewed, and filled out the questionnaire. Results show that a large number of participants are designers and contractors. In comparison, fewer audiences were clients and manufacturers. The main smartphone usage by experts is important, and they answered their most use are calls, social media, taking photos, and expertise apps which demonstrate in figure 9. It concludes that experts are familiar with technical and communication apps and the use of devices. In addition, they asked about their familiarity with AR apps and add-ins like measurement apps, Instagram, and Snapchat AR add-ins by showing photo examples.

As shown in figure 10, surprisingly, 63% of them use it at least once per week. These results present that experts have the knowledge and potential for online and virtual communication and information flow. They are ready to level up to use new technologies like immersive technologies, especially AR.

After gathering information about the knowledge of experts, they were asked about their experience using the ARSP MVP application for android devices. The device used for testing was Samsung Galaxy S8 smartphone with Android 7. The hardness degree of the application used, detecting wall and put material textures and taking screenshots of the result, demonstrated respectively in figures 11, 12, and 13.

These three results show that using the ARSP MVP model was easy for the experts, and some interviewers have useful and technical recommendations for the progress. For instance, add the ability for texture rotation, matching material textures with curved forms, lighting options, brick binding color, and ready-made rectangular shapes to make it easier and enhances the ability to visualize better. Others who felt hard to use explained that they didn't see the help instruction, real textures, texture shadows, and horizontal and vertical texture management. The final questions were about the experts' satisfaction and interest in using the ARSP for their real projects. Figure 14 illustrates the interest level in use and interaction with the ARSP MVP model again, and figure 15 shows the interest level in case of model progress in the future. It shows that experts are following

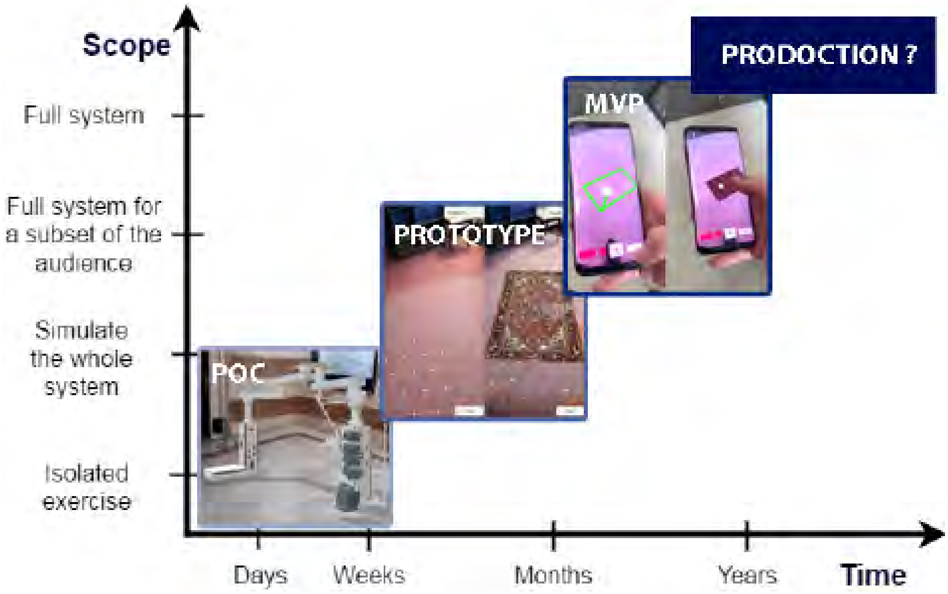

Fig.7: The process of three steps as a basis for the ARSP production model

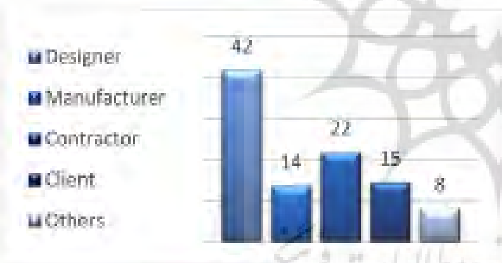

Fig.8: The participants' expertise percentage

Fig.9: The main smartphone usage by experts

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Fig.10: Use of AR apps and add-ins

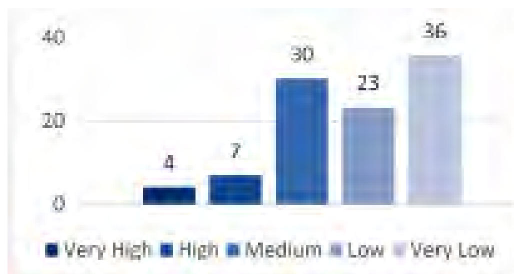

Fig.11: The difficulty degree of using the application

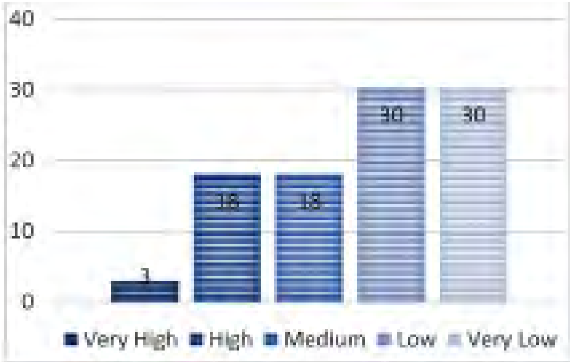

Fig.12: The difficult degree of detecting walls and putting material textures

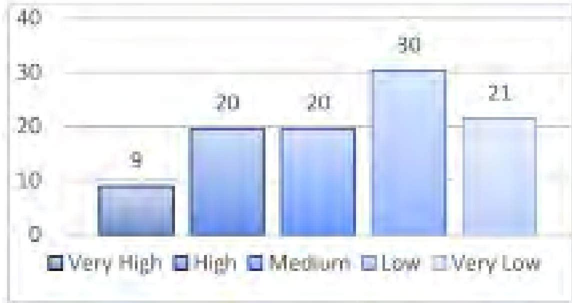

Fig.13: The difficulty degree of taking screenshots of the result

Fig.14: The interest level in use and interaction with the ARSP MVP model again

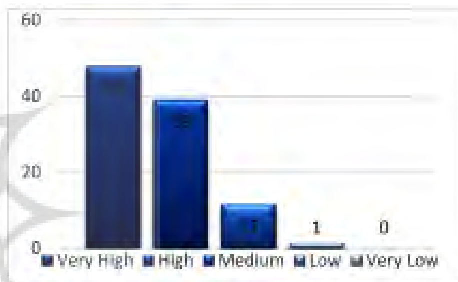

Fig.15: The interest level in case of model progress in the future

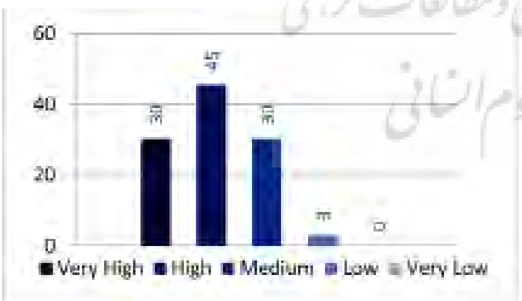

Fig.16: The interest level in choosing and ordering materials for a real project

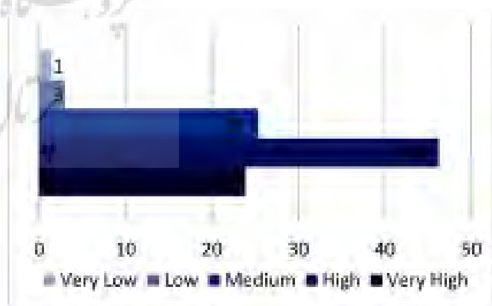

Fig.17: The overall satisfaction level of the system

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the system and will use it in the future. Figure 16 and 17 discuss the interest level in choosing and ordering materials for a real project and the overall satisfaction level of the system. The final result shows that more than 70% of experts are highly satisfied with the system specification, which gives the authors the certainty to build up the ARSP production model.

CONCLUSIONS

Analysis of observation, interviews, and questionnaires with the AR approach suggests that the AR system improves information flow and communication for placemaking stakeholder management.

Views of the stakeholders get closer after using AR. The research shows that the contributions of this study to the body of knowledge are twofold. First, this study extends the understanding of AR applications in placemaking. Second, this study identifies possible improvements using AR systems in design, procurement, and construction. This research showed and enabled stakeholders management to use AR to improve participation in the design, construction, and procurement process to create the place. In this process, stakeholder participants reach their benefits.

The research proposal provides the basis for the ARSP production model, an e-business model for a commercial scale. The e-business model shall be developed with information systems and direct connections with stakeholders to increase productivity and reduce costs. The role of users and their participation in decision-making can be identified by AI and business intelligence (BI) in future studies. The results and recommendations found in this research can be implanted in similar studies.

AUTHOR CONTRIBUTIONS

H. Amin performed the literature review, materials, and method, built up the POC, prototype, and MVP model, the observation, interview, questionnaire, analyzed, interpreted, and compiled the data, and prepared the manuscript text, manuscript edition and results. F. Habib helped with the literature review and professional edition. Z. Zarabadi helped with the variables, methods and tools, and manuscript edition. V. Fooladi helped in the literature review and manuscript edition.

ACKNOWLEDGEMENT

This manuscript is extracted from the Ph.D. thesis in the Department of Architecture, Science and Research Branch, Islamic Azad University, Tehran, Iran. The thesis title is "Placemaking with Augmented Reality for Design, Procurement, and Construction."

We also thank Dr. Vahid Vahdat from Washington State University, Dr. Mojtaba Vahidi Asl from Shahid Beheshti University, and Mr. Hadi Taghiloo, who had great help in the scientific and technical parts of this study. The authors would like to acknowledge the financial support of the Ministry of Science, Research and Technology and Modares Science and Technology Park for this project under grant number 02-00-02-001107.

CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the authors witnessed ethical issues, including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication, submission, and redundancy.

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