



## Semi-augmented Reality, A Novel Approach to Improve Customer Safety in Pre-sale Process of under Construction Buildings

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### PAPER INFO

#### Paper history:

Received 15 May 2021

Received in revised form 24 June 2021

Accepted 25 June 2021

#### Keywords:

Augmented Reality

Virtual Reality

Building Construction

Safety

Marketing

### ABSTRACT

Effective marketing is quite vital in many building construction projects that depend on the pre-sale cash in-flow. However, the unsafe condition of the under-construction projects postpones in-person customer visits to the completion date and complicates the marketing process. This safety concern is especially critical for the upper floor units. Although virtual tours of the buildings are used to show the project specifications, they do not convey the impression that customers receive in the real ambiance of in-person visits. This research proposes a novel method called semi-augmented reality to address the safety issue of the under-construction projects during the marketing process. In this method, lower floor apartment units are safeguarded for the customer's visits to give an accurate impression of the building's condition. Virtual models of the upper floor apartments are linked to a similar safeguarded unit on the lower floor to augment the existing deviations between lower and upper floor units. The capability of the method was successfully tested in an experimental case. The participating real estate agents in the test found the method beneficial for the customers' safety, attracting their attention, facilitating the decision-making process, and increasing their convenience. This method introduces a new approach to the building pre-sale marketing process. Similar techniques are expected to emerge shortly.

doi: 10.5829/IJE.2021.34.10a.01

### NOMENCLATURE

2D	2-Dimensional	PPE	Personal Protective Equipment
3D	3-Dimensional	QR code	Quick Response code
AR	Augmented Reality	SAR	Semi-Augmented Reality
BIM	Building Information Modeling	VR	Virtual Reality
IFC	Industry Foundation Class		

## 1. INTRODUCTION

Many researchers and practitioners have highlighted the integral impact of adopting an effective marketing approach in the construction industry in different parts of the world [1-5]. Adopting proper communication tools with clients [4, 6] and satisfying the clients' needs [7-9] are fundamental elements of practical marketing approaches in the building construction industry. Since pre-sale customers purchase products that are not entirely built yet, improving these two essential elements can substantially enhance the entire marketing process.

In recent years, advanced technologies, such as augmented reality (AR) and virtual reality (VR) technologies have proven themselves as effective marketing tools [10]. They are likely to change the marketing industry soon [11]. AR and VR are two digital information visualization techniques that rapidly grew in the shadow of the recent advances in information technology [12]. "Virtual reality refers to computer technologies that use software to generate the realistic images, sounds, and other sensations that represent an immersive environment and simulate a user's physical presence in this environment" [13]. Augmented reality is a variation of virtual reality [14], representing a direct or

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indirect view of the real physical world created by adding computer-generated virtual information [15]. Currently, consumer-based AR and VR computer applications form an inseparable part of marketing processes in many organizations [16].

Marketing tools are typically designed to attract potential customer's attention and educate them about the benefits and specifications of the products. AR- and VR-based tools have presented themselves more in favor of various businesses' customers than traditional marketing tools [12]. In a survey conducted by Szymczyk [17], 26% of senior market specialists mentioned AR and VR technologies as the most effective marketing tools in the future. AR and VR have been applied in various forms in marketing processes. Their sample applications include virtual and interactive product preview in public places [18, 19], wearing virtual clothes [20], virtual project tours [21], virtual shopping malls [22], presenting tourist attractions [23], and augmenting items in the museum [24, 25]. AR creates high purchasing pleasure and confidence in the customers [26]. AR and VR technologies are also emerging in building marketing. They are utilized for enhanced sales efficiency through virtual home touring, facilitated sight-unseen purchases, improved fix and flips rehabilitation, enhanced rental marketing, and improved tenant communication [27].

Meanwhile, the construction industry is considered among the most unsafe sectors in the world [28-30]. The construction industry accommodates 7% of the workforce globally; however, 30-40% of work-related casualties happen in this industry [31]. This rate represents five times the global average [32]. The high rates of safety incidents in the construction industry are regardless of various mandatory personal protective equipment (PPE) used and new methods and tools introduced to enhance the safety of the construction sites [33]. However, in recent years, modern technologies and tools have helped many developed economies considerably improve safety in their construction projects [34]. Advanced technologies, such as computer simulation [35, 36], integrated design approaches [37], and AR and VR technologies [38] have enhanced the safety of the construction sites .

According to the review article presented by Li, Yib [38], applications of AR and VR techniques in the construction safety methods are divided into three folds, including 1) "safety planning" through hazard identification and assessment before construction begins, 2) "safety training" by visualizing the actual work conditions and providing safety tips to the, and 3) "safety inspection" through easy access to the detailed 3-dimensional (3D) view of the job-site. A review of the past research shows that the focus of different developed safety tools in the construction, including AR- and VR-based tools, is on the construction crew. No research effort was found to address the existing safety concern

for the under-construction building's customers. It should be noted that the untrained and inexperienced job-site visitors, such as pre-sale consumers of the building, bear a higher risk than the safety-educated and experienced construction workers. This safety concern is especially highlighted for the upper floor apartment units. The increased risk of the customers' in-person visits during the construction period is a concern that postpones customers' visits until the project's completion date. Meanwhile, in the final stages of a building project only limited and cosmetic changes can be made to the building and it is challenging to address the clients' particular needs. In this perspective, marketing approaches that consider the safety of customers during the in-person visits of the buildings are required to facilitate the marketing process and enhance the customers' satisfaction.

This research proposes a novel method to address the need for a safe and effective marketing method in pre-sale building marketing. The focus of the proposed method is on multi-story apartment building projects. The research utilizes a novel form of AR and VR technologies, called semi-augmented reality (SAR), to create a safe and effective in-person site visit experience for the customers with augmented reality details for the under-construction building parts. Following, section 2 presents the marketing paradigm of the multi-story apartment buildings. In section 3, the details of the proposed method are explained. Following that, in section 4, specifications of the implemented SAR tablet/smartphone application in the research are outlined. Different steps that were taken to apply and test capabilities of the developed application to a sample seven-story apartment building come in section 5. Finally, section 6 concludes the research results and achievements.

## 2. MARKETING PARADIGM IN MULTI-STORY APARTMENT BUILDINGS

In contrast to typical family house construction projects, the construction of many multi-story residential apartment buildings commences without a sale contract with the clients. An investor invests initial money in the building construction and gradually complements its investment by selling a number of under-construction apartment units to the pre-sale customers. Here, the construction period is essential for the project managers and their real estate agents to accomplish their marketing chores properly, find clients for pre-sale units, and guarantee the required inflow. The unsafe construction environment creates a challenging condition and prevents real estate agents from correctly showing the apartments' specifications to the customers. It is especially the case for the upper floor apartment units where visitors need to

use incomplete and unsafe stairways to reach their desirable units. In recent years, virtual 3D models of the buildings have created a significant enhancement in the marketing process for presenting the building's specifications to the customers. The property owners, customers, real estate agents, and other stakeholders benefit from these virtual 3D models [39]. It should be noted that the 3D models do not replace the experience of the customers to walk through their desirable units, feeling the spaces, and observe the outside views. In-person site visit experience can increase the customers' confidence in the project and increase the chance that the customer steps forward and purchases the apartment. Furthermore, after the apartment purchase and during the construction period, site visits can help the clients proactively contribute to the final specifications of the building, customize it to their needs, and enhance their satisfaction.

In many apartment buildings, apartment units on different floors share similar layout plans. One solution followed by constructors and real estate agents to conquer the unsafe condition of the upper floor units is to prepare safeguarded model units on the ground or the first floor of the building. Pre-sale building customers are directed to visit the safeguarded model units with similar directions and layout plans during their site visits. In this approach, the prepared model units share similar plans and directions with the desired higher-level units; the customers can experience the real space, dimensions, and environment in the unit. However, it should be noted that specific details can drastically change on different floors. Building components such as vertical risers, structural column diameters, finishing details, natural light, building façade, and exterior views can vary from one floor to the other. Existing differences between lower and upper floors can even sometimes mislead the customers. Customers might interest in specific elements of the apartment building in the safe model units that do not exist on the upper floors. It is also possible that specific features in the model units, that do not exist in the upper floor units, discourage the customers from the deal. The proposed SAR method also addresses these concerns.

### 3. PROPOSED METHOD

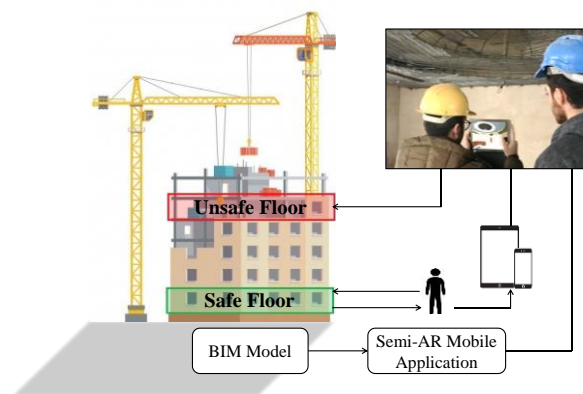
The scope of the proposed method is the projects with similar plans in several floors. In the proposed method, virtual 3D models of the units on the higher floors, with increased safety concerns for the customers' in-person visits, are linked to the real environment of similar units on the lower floors. Therefore, clients can experience the real areas, spaces, and dimensions of their desirable upper floor units while walking in the safeguarded model units. Since the developed virtual model of the desired unit is linked to similar elements in the safeguarded

model unit, the customer can simply distinguish the differences. Modified corners, different outside views, and changes in the window sizes are distinguishable in the virtual 3D model of the desired upper floor units. This approach to the virtual model demonstration is called semi-augmented reality (SAR) since the virtual model is linked to similar, not the exact, building elements. This approach also helps customers to get quick SAR tours in different nominated units on multiple floors and compare their features. While the customers' visits are done during the building's construction period, the safeguarded model unit also might still be incomplete. The developed SAR tool can also be used for the augmented visit of the model unit itself. The use of SAR-based tools helps customers to observe the designed completion for different components and, if possible, contribute to the building design according to their needs. Currently, the development of building information modeling (BIM) has become a trend in the construction of many apartment buildings [40].

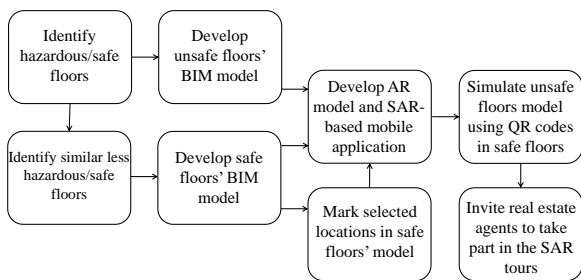
Therefore, the 3D models of buildings are accessible in building projects with no additional cost. With the aid of the existing software packages, BIM-based 3D models of the building can be used for SAR-based model development with minimal cost. The developed SAR models need to be installed on mobile devices such as tablets and smartphones to be used on site. Figure 1 illustrates different parts of the proposed SAR-based marketing method. Figure 1 contains two parts, a and b. Figure 1(a) shows the schematic view of the SAR concept, and Figure 1(b) displays the step-by-step view of the proposed method.

### 4. IMPLEMENTATION OF PROPOSED METHOD

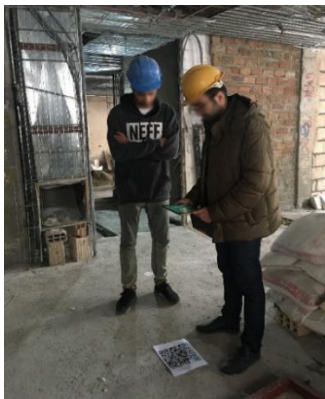
The proposed method was implemented in the form of a mobile application using AR Software in collaboration with a collaborating construction company. The industry foundation class (IFC) [41] files of the buildings were



(a) Schematic view of the SAR concept



(b) Stages to develop SAR-based marketing method

**Figure 1.** Different parts of the proposed SAR-based marketing method**Figure 2.** Scanning QR code to link an upper floor unit to the corresponding elements of the model unit**Figure 3.** Under-construction condition of the building's stairway and elevator**Figure 4.** Real estate agents participated in the SAR application capability test in the real building project case

used for the development of the 3D models of the building in the application. The developed application supported all VR, AR, and SAR views of a building. The VR view was the default view of the developed package. The VR view could be utilized for marketing purposes in on-site or off-site locations. Quick response (QR) codes [42] were used for triggering the AR and SAR views of the building. The QR codes of different apartment locations, such as the center of the living room, center of the master bedroom, corner side of the kitchen, and the front of the main entrance, could be created for different apartment units located on different floors. These QR codes could be scanned for linking the AR or SAR views to the desirable building components regardless of the clients' current floor. Figure 2 represents how a QR code print was scanned by the developed SAR package installed on a tablet to link the virtual models of an upper floor unit to the corresponding elements of the model unit. The customers could then use this mobile application to navigate current and prospective details of the apartment units. The customers could zoom in, zoom out, and calibrate the camera during their SAR experience when required.

## 5. EXPERIMENTAL CASE

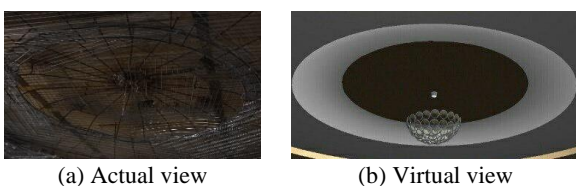
To test the potential capabilities of the proposed method, it was applied to a real under-construction seven-story residential apartment building case in the central part of Tehran (Iran). Following, the case study experiment specification is explained, and the achieved results are presented and discussed.

**5. 1. Case Study Specification** Each floor of the studied case had two two-bedroom residential apartment units. At the time of the experiment, interior finishing activities of the building construction had just been commenced; the majority parts of the building's finishing works were missing. The stairways were still under construction and unsafe to use. The elevator was not installed as well. Figure 3 presents the condition of the stairway and the elevator shaft at the time of the experiment. The current condition was not appropriate for taking customers to the upper floors. The BIM models of the building, developed by the collaborative construction company, were used for customizing the developed SAR mobile package for the case. Members from the design and construction groups assisted the research team in finalizing the SAR package of the building. Ten active real estate agents in the region with an average work experience of 16 years were contacted to participate in the capability test experiment of the developed SAR package for the case. All participants indicated that they would prefer to set visits for the potential building customers as the primary marketing

practice for under-construction buildings. Eight agents indicated they have past experiences working with AR and VR technologies. However, none of them used AR or VR technologies as a regular practice in their marketing process. Six agents were also using 2D drawings to explain the specifications of the building for the customers as a common practice. Four agents had faced issues during the in-person customers' site visits. Figure 4 illustrates one of the agents using the developed SAR package during the experiment.

The objective of this experiment was to test the potential benefits SAR could bring to the marketing process during the construction period of the building. The test was separately performed for each agent and was divided into two parts. First, participants walked through the model unit on the first floor and observed the AR model of this apartment on the tablet using the developed SAR package. In this part of the experiment, real estate agents could monitor the finishing condition of the incomplete parts of the building. Figure 5 compares the actual view of the ceiling of the model unit on the first floor (Figure 5 (a)) linked to the prospective virtual view of the ceiling (Figure 5 (b)). In the second part of the experiment, the agents were guided to observe the SAR model of the seventh floor's apartment unit in the tablet while standing in the model unit. In this part of the experiment, the participants could observe the prospective virtual views of the seventh-floor unit linked to the corresponding actual components in the model unit on the first floor. The differences between the first and seventh-floor apartments' layouts and outside views were distinguishable through the SAR package. Figure 6 presents the actual view of the living room corner of the first floor (Figure 6 (a)) and a virtual view of the corresponding scene on the seventh floor (Figure 6 (b)). Here, the real estate agents could notice that the under-construction column in the middle of the living room of the model unit does not exist in the finishing condition of the seventh-floor unit. Furthermore, the protruding column on the right-side wall of the model unit fades in the finishing condition of the seventh floor.

**5. 2. Experiment Result** After the experiment, participating real estate agents answered several questions regarding their experience with SAR-based tools. Nine participants identified the SAR-based tool as beneficial for improving customers' safety, attracting



**Figure 5.** Linked views of the actual and virtual models of the ceiling in the model unit on the first floor

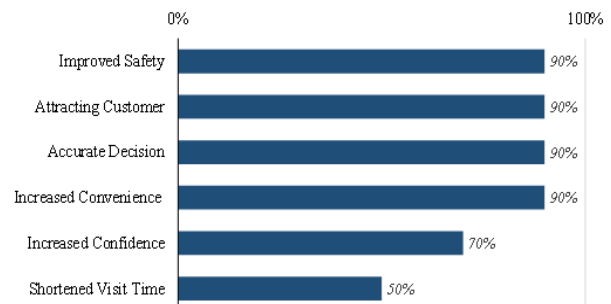


(a) Actual view of the living room on the first floor (b) Virtual view of the living room on the seventh-floor  
**Figure 6.** SAR view of the seventh-floor unit's living room corner was observed in the model unit on the first floor

customers, helping customers to decide accurately, and increasing customers' convenience during their site visits. In addition, seven agents identified the SAR as a beneficial tool for building the customers' confidence in the building's quality. However, only five agents identified SAR as a helpful tool for reducing the in-person site visit duration since they need time to set up the application for each customer. In general, all participants found SAR a helpful tool in their marketing process and indicated that they are interested in using the proposed method in their day-to-day marketing activities. Figure 7 shows the experiment's outcome and the potential benefits of the SAR-based method identified by participants. The achieved result of the investigation revealed the benefits of the proposed SAR method for improving different pre-sale marketing processes of the under-construction apartment buildings. Although the developed SAR application was at the preliminary stage with limited features, all participants indicated their desire to start using it in their marketing activities. Commercial development of the SAR application, with user-friendly and advanced features, can enhance the applicability of the SAR method in the pre-sale marketing practices.

**6. CONCLUSION**

The emergence of the new AR- and VR-based technologies has evolved the marketing processes of many business sectors from different perspectives. The



**Figure 7.** Potential benefits of the SAR-based method identified by participants

construction industry is a big industry with its specific marketing requirements. The unconfined nature of the construction jobs creates a high risk of incidents and hazards in construction projects and endangers the customers' safety during the marketing process. The complex combination of various building components and the long duration of building projects require proper marketing methods to attract customers' confidence and satisfaction. This research proposed a new AR/VR-based method called semi-augmented reality (SAR) to address the specific needs of pre-sale marketing in multi-story apartment buildings. The proposed method aims to enhance building customers' safety, contribution, and satisfaction. Safety concern of the construction operations has encouraged many researchers to study the new techniques and technologies for safety improvement in the construction industry. The focus of these research efforts, however, has been on the construction crew. In this perspective, this research is among the first research efforts to address the safety of pre-sale customers during the building's construction period. The SAR method can also provide a platform for collecting the customer's particular needs in building projects and consider them in the final product. It is expected that this approach can directly contribute to the customer's satisfaction. The achieved results of the experimental case also demonstrated high potentials for the proposed SAR method. Various applications of AR/VR-based tools have been introduced and used in the construction industry in recent years. However, the proposed SAR method leverages AR/VR technology capabilities in a novel setting to address the current needs of the construction industry.

The proposed method in this research was implemented in an under-construction apartment building in Tehran, and some real estate agents participated in SAR tours. The performed investigation demonstrates the potential benefits of the proposed SAR method.

90% of the participants declared that this method could:

- improve customers' safety;
- attract customers;
- help customers to decide accurately;
- increase customers' convenience during their site visits;
- and only 50% of the participants said that SAR method could:
- be as a beneficial tool for building the customers' confidence in the building's quality.

The implemented SAR-based tool and the results achieved in the experiments might have been affected by the specific regional conditions of the apartment building marketing in Tehran. Further investigations are encouraged in other locations to test the applicability of the proposed SAR method in other regions. Also, the

proposed method is applicable in apartments with similar plans on different floors. As future research, it is suggested to investigate the usefulness and applicability of the SAR method in other kinds of buildings.

## 7. ACKNOWLEDGEMENT

Authors would like to express their appreciation to Mr. Shiri and Ms. Sayanjali, who generously provided their support to the research team during the method implementation and the case study.

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**Persian Abstract**

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**چکیده**

بازاریابی اثربخش در بسیاری از پروژه‌های ساختمانی امری بسیار حیاتی است که می‌تواند جریان نقدی ورودی حاصل از پیش‌فروش آن پروژه را ایجاد کند. با این وجود، شرایط ناامن پروژه‌های در حال ساخت، مراجعه حضوری مشتری را به زمان اتمام پروژه موکول می‌کند و روند بازاریابی را پیچیده می‌کند. این مسئله به ویژه برای واحدهای طبقات فوقانی بسیار پراهمیت است. با آن‌که از تورهای مجازی ساختمان برای نشان دادن مشخصات پروژه استفاده می‌شود، اما احساسی را که مشتریان در محیط واقعی بازدیدهای حضوری دریافت می‌کنند، منتقل نمی‌کند. این پژوهش روشی جدید به نام شبه واقعیت افزوده را برای افزایش ایمنی پروژه‌های در حال ساخت در طی فرآیند بازاریابی پیشنهاد می‌دهد. در این روش، واحدهای آپارتمانی طبقه پایین برای بازدید مشتری کاملاً ایمن می‌شوند تا بازدید مشتری انجام شود و برداشت دقیقی از وضعیت ساختمان داشته باشد. سپس مدل مجازی آپارتمان‌های طبقه فوقانی به واحد ایمن مشابه در طبقه پایین متصل می‌شود تا تفاوت‌های موجود بین واحدهای طبقه پایین و طبقه بالا مشاهده شود. قابلیت این روش در یک مورد تجربی با موفقیت مورد آزمایش قرار گرفته است. نمایندگان آژانس‌های املاک و مستغلات شرکت کننده در این آزمون، روش ارائه‌شده را برای افزایش ایمنی مشتریان، جلب توجه آن‌ها، تسهیل روند تصمیم‌گیری و افزایش راحتی آن‌ها مفید دانستند. این روش رویکرد جدیدی را در روند بازاریابی پیش‌فروش پروژه‌های ساختمانی معرفی می‌کند. انتظار می‌رود که تکنیک‌های مشابه در آینده‌ای نزدیک ظهور کنند.

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