CRITICAL SUCCESS FACTOR FOR EFFECTIVE UTILIZATION OF MOBILE AR IN THE REAL ESTATE INDUSTRY

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ABSTRACT

Digitalization has become a new normal. The mobile augmented reality technology adds another dimension like visualization of ongoing or unfurnished property, space measurement, exploring multiple design options among the variety of applications in the real estate sector. The success of any technology will depend on the users' acceptance of the technology and their intention to use it for a project. Here the researcher tries to explore those pre-usage critical factors with the help of the technology acceptance model followed by verifying it with post-usage perception by using the expectation confirmation model. These theories are tested for confirmatory factor analysis in which these research models were tested for data reliability and discriminant validity. Later the factors were statistically interpreted using the correlation test to conclude the significance of pre and post-usage behavior in technology continuance.

KEYWORDS

Mobile Augmented Reality (MAR), Real Estate, Technology Acceptance Model (TAM), Expectation Confirmation Model (ECM), Confirmatory Factor Analysis (CFA).

1. INTRODUCTION

The importance of digitalization has been realized by every industry that is exploring ways to make itself future-ready. The role of BIM in achieving it is vital. While shifting from the traditional to the contemporary ways of working, other potential uses of BIM have been discovered. It allows collaborative working of all the stakeholders with added functionality to the AECO sector. But, to enhance its effectiveness, it needs support from other innovative tools and technologies like "augmented reality". Application of AR is not just limited to visualization, it helps in better planning of construction activities, monitoring the site progress, guiding the site workers through the construction process, along with safety hazard identification.

Various factors induce the investment in the mobile augmented reality (MAR) for residential property in the Indian context, which includes 2nd highest number of smartphone users, with 3rd highest data consumption rate, huge investment by technology giants like Apple and Google, and advent of 5G in the market [1]. MAR technology adds another dimension like visualization of ongoing or unfurnished property, space measurement, exploring multiple design options among the variety of applications for the benefit of the Indian real estate sector. Due to its increasing relevance, awareness about MAR technology needs to be established also, its benefits in residential properties need to be outlined. Followed by exploring current market practices. Then,

to utilize MAR with its full potential one must focus on the users who will be applying and using it.

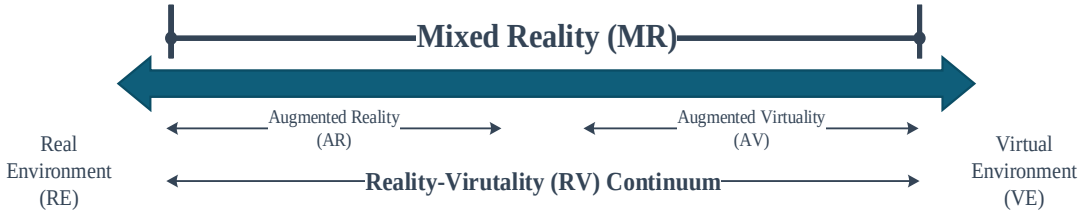
The focus of this research is on the Indian real estate sector. The main objectives of this study are enlisted below.

1) To establish the need for research in the real estate sector by identifying the current market practices adopted by the real estate industry professionals and their awareness about AR technology.
2) To investigate the factors for pre-usage acceptance of the MAR technology in the residential properties. Thereby, verifying it with the post-usage factors related to the user's intent to effectively utilize the MAR technology for the real estate industry.

2. LITERATURE REVIEW

2.1. Understanding Mixed Reality Spectrum

Before understanding the interaction of the virtual and real-world, one shall first understand the terminologies which are defined in-depth by Milgram's in its virtuality continuum.



Source: (Milgram & Kishimo, 1994) [2]

Figure 1. Simplified representation of a "virtuality" continuum

Virtual Reality (VR) – It disconnects human from the real world by taking them into a human-created immersive virtual world (artificial environment) generated using computer-based technology. It replaces the real world. It can be called a hyperconnected (high-tech communications) metaverse (user can collaborate interact in an imaginary world).

Augmented Reality (AR) – It occludes (overlays) the digital information or object or model element which is supplemented by a computer-generated input, to the real-world environment by giving them an experience of the contextual surroundings. It adds (augments) the digital content to the real-world canvas.

2.2. Need of MAR in Construction Industry

In India, adoption of Building Information Modelling (BIM) in the AECO sector is going close to maturity level in the design phase, by becoming an innate design requirement. Whereas, in the construction and O&M phase it is still evolving (Badrinath, 2019) [3]. Having various barriers for professionals like the cost of the software and hardware still, BIM is getting attention in the AECO sector. And with the realisation of its benefit in terms of having all the data stored at a central hub, there is going to be a pull from the market to apply the techniques that will improve human productivity and construction efficiency.

Some researchers suggest that overloading of information may lead to certain disadvantages as well, viz., important information retrieval, which may cause efficiency reduction (Chu et al., 2018) [4]. Rework due to lack of clarity in the received drawing set or due to human error, is an add-on in terms of cost and stand-by time which could be resolved using AR technology.

The research lies in exploring stakeholder engagement using AR technology, to overcome the limitations of cost, visualisation, and accessibility to a larger population where, Mobile Augmented Reality (MAR) can prove effective to eliminate these issues. As MAR technology helps in visualisation of ongoing or unfurnished property, space measurement, exploring multiple design options among the variety of applications to the buyers. Whereas for the sellers, it helps them to reach the distantly located buyers (via phone) saving time and cost, giving them better experience thus helping in better-informed decision making. This will revolutionise the Indian real estate sector.

But, to utilise MAR with its full potential one must focus on the end users who will be applying and using it. For this, two IT continuance theories were selected viz. Technology Acceptance Model (TAM) to explore pre-usage critical factors and Expectation Confirmation Model (ECM) for checking post-usage perception. These theories have been applied by various researchers which is briefly explained in further sections.

3. METHODOLOGY

To undertake the research systematically, Saunders et al., (2019) [5] developed “Research Onion” to guide the researcher in making precise assumptions to reach the desired goal. The research follows a concurrent mixed-method approach to address the question posed by the researcher. It involves mixed use of both qualitative and quantitative approaches, which yields complete evidence rather than any of the approach alone [6].

A qualitative approach utilises literature for finding the potential of MAR, and an exploratory method to examine the benefits and challenges faced while using it. Whereas the quantitative approach is preferred, to test the theory of technology acceptance and its continuance intention with the help of widely used TAM and ECM theories respectively.

4. DATA COLLECTION

A pilot survey conducted to find out the current market practices deployed by the professionals in the real estate industry followed by a questionnaire survey to triangulate the received inputs. Also, a questionnaire survey conducted for finding out the factors for effective utilization of MAR in the real estate industry using a Technology Acceptance Model (TAM) and Expectation Confirmation Model (ECM) which was aligned with the objective and scope of the study.

A combination of open & close-ended questions was used by the researcher to draw inferences. A greater reach to large sample size was established using an online mode of data collection. A method of convenience and snowball sampling was adopted which was suitable for web-based electronic data collection. It ensures maximum participation by using their contacts to get the responses in cross-sectional research. The ethics of data collection and protocols are ensured before floating the survey.

5. DATA ANALYSIS AND RESULTS

It includes analysis of the received valid responses, i.e., after removing the outliers and generating inferences based on the survey result. Then confirmatory factor analysis method was adopted to test the proposed hypotheses and obtain the essential variables loading to a particular factor based on the threshold value. This helped in checking the reliability and discriminant validity of the collected data.

Then with the retained variables, the proposed/expected model of TAM and ECM was tested for correlation. Which was later used to find out the essential factors based on users' acceptance and their intention to continue using the MAR technology effectively in the real estate domain.

5.1. Pre-usage Survey – 1

The first survey was divided into two tasks viz., to find the current market practices, MAR technology awareness and to investigate the factors for technology acceptance.

Target Audience. The questionnaire survey includes the professionals dealing in the real estate industry either directly or indirectly. This includes a) Developers, b) Builders, c) Real Estate Consultants, d) CREDAI members, and e) Realtors. Total 114 responses were collected in a span of 40 days out of which only 92 valid responses after removing the outliers were further used for analysis.

Table 1. Demographic Information

Characteristics		Frequency	Percentage %
Organisation	Architectural Firm	21	23
	Builders/ Developers	29	32
	Construction + Consultancy	6	7
	Consultancy	7	7
	Others	22	24
	Service Providers	7	7

Current Market Practices and User Awareness. Maximum respondents are currently using traditional methods for showing the property like 2D layout, 3D views and panoramas. There's a shift from conventional to innovative ways, like walkthrough videos, VR 360º view and very few using AR technology.

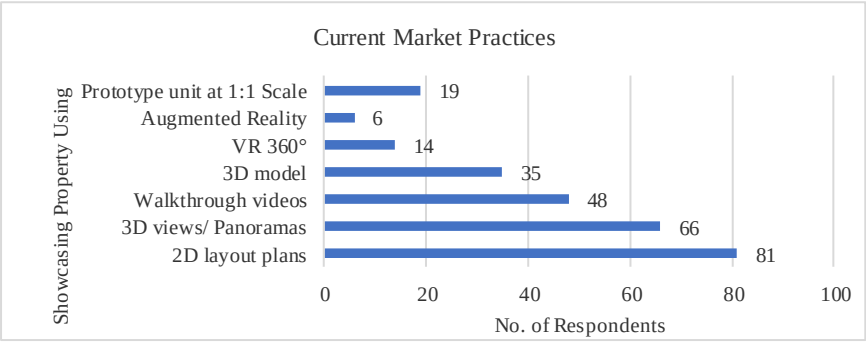


Figure 2. Current market practices

If the MAR was used to give them the add-on experience to the buyers at their hand, then it would help them in better understanding of the property which would be a saving in terms of time and cost spent in constructing a prototype unit.

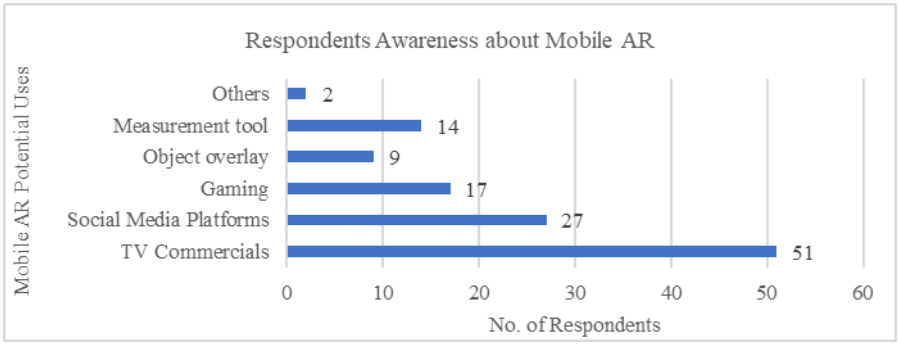


Figure 3. Respondent's awareness about mobile AR

Awareness about MAR technologies has been confirmed by almost all the respondents (either used/ seen). It is a positive sign, as social media and TV commercial marketing and games are playing a vital role in making all the respondents aware of this technology.

Extension of Technology Acceptance Model (TAM). It is generally used in the field of social science for understanding the users' acceptance of information technology. It has been used predominantly since its development by different peer researchers to study the factors related to the acceptance of technology. E.g., augmented reality in urban heritage tourism [7; 8], BIM and AR integration [9], e-shopping [10] etc.

TAM Constructs. Summarized definition of the constructs (factors) and proposed hypothesis are mentioned below.

- *Perceived Ease of Use (PEOU).* It's based on the supposition that it would help them to use technology with very less or no physical or mental effort and is significantly linked to the behavioral intention to use MAR.
    - ***H1:*** *Perception about ease of using technology will have a positive impact on the users' pre-usage perception about the usefulness of mobile augmented reality technology.*
    - ***H2:*** *Perceived ease of use will influence the users' pre-usage attitude towards mobile augmented reality technology acceptance.*
    - ***H3:*** *Perception about ease of using technology by the users' is positively linked to its acceptance by formulating their behavioural intention to use it for the real estate sector.*
- *Perceived Usefulness (PU).* It is based on the supposition that user's pre-usage assessment of any technology that would improve their job performance and efficiency or not is termed as PU. This will positively affect the user attitude toward using the technology and with less significance on behavioral intention.
    - ***H4:*** *Pre-usage perceived usefulness about mobile augmented reality technology will govern their attitude towards technology acceptance.*
    - ***H5:*** *Perception about the usefulness of technology is positively linked to the users' behavioural intention to use it which is a core determinant factor for technology acceptance.*
- *Perceived Enjoyment (PE).* It is based on the supposition that the user's PE refers to the degree to which interactive technology seems enjoyable. This will positively affect the easiness to use of mobile augmented reality.
    - ***H6:*** *If users' will find the technology enjoyable then there is a perception that the mobile augmented reality will be easy to use.*

- *Attitude toward Using (AU).* It is based on the supposition that the user's perception (pre-usage; expected advantage) of any technology is crucial in setting a favorable or unfavorable attitude towards the use of technology. Thus, the affordability and reach to distantly located buyers will be favorable criteria for a positive attitude towards the technology. Hence, it is positively linked to the behavioral intention to use.
    - ***H7:*** *The users' attitude towards using mobile AR technology in the real estate domain will positively influence their behavioural intention to it eventually leading to acceptance of technology.*
- *Behavioral Intention to Use (BIU).* It concludes that the users' acceptance of any technology is directly linked to their behavioral intention to use the technology which is formulated by the following constructs - PEOU, PU, PE and AU.

Confirmatory Factor Analysis (CFA) – TAM Model. It was to test if the variables are loading to their respective constructs/factors as per the expected TAM model. The expected model is tested using the SmartPLS 3 software.

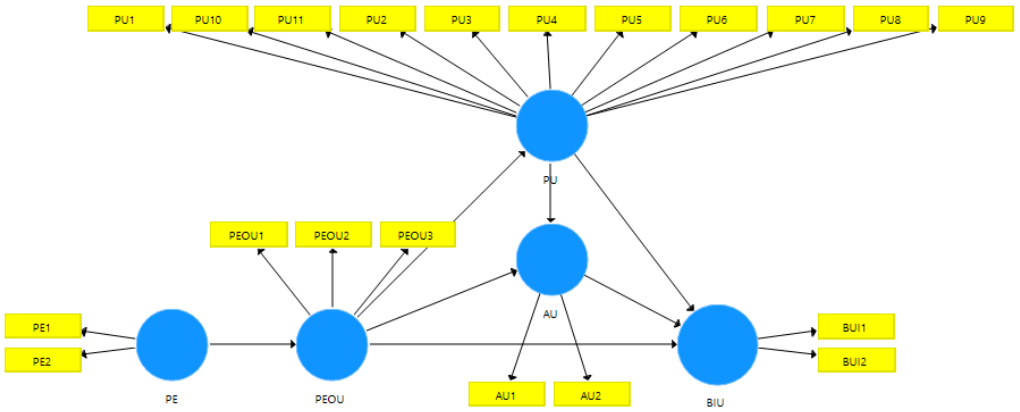


Figure 4. Expected technology acceptance model for CFA

Where, PE= Perceived Enjoyment; PU = Perceived Usefulness; PEOU = Perceived Ease of Use; AU = Attitude towards Using; BIU = Behavioural Intention to Use

A close-ended questionnaire survey using the five-point Likert scale where 1 depicts strongly disagree and 5 depicts strongly agree was used. Operationalization of the constructs is presented in the table.

Table 2. Codes' summary of different variables for TAM model

TAM Constructs	Codes	Variables/ Items
Perceived Ease of Use	PEOU1	Helps placement of AR model along the vertical axis.
	PEOU2	Allows buyers to have a handy layout plan in their device.
	PEOU3	Helps buyers to have a sectional view of the property.
Perceived Usefulness (pre-usage)	PU1	It would help the buyers to visualise the model and its elements.
	PU2	Helps the buyers to explore multiple design options proposed by the designer.
	PU3	Helps the buyers to inspect the on-going/ unfurnished flat.
	PU4	It would allow buyers to interact with the property better.
	PU5	Allows better understanding of model scale and proportions.

	PU6	It would be useful to showcase the model of a double-storeyed flat at same (fixed room surface) level.
	PU7	Helps buyers to cross-check dimensions on-site.
	PU8	Allows the user to get general information about the model elements.
	PU9	Allows the user to get general information about the material.
	PU10	Photo and video capture mode will help the user to save the visuals for later discussion or modification.
	PU11	Virtual collaboration will help the buyers to discuss it with family/ friends.
Perceived Enjoyment	PE1	Will AR application increase buyers' interest in a property by providing an additional experience?
	PE2	Would this help buyers in making a firm decision related to property?
Attitude toward Using	AU1	Would you prefer using mobile AR application for its affordability?
	AU2	Will this help to reach the distantly located prospective buyers?
Behavioural Intention to Use	BIU1	Will you provide an additional AR experience to the buyers?
	BIU2	Are you excited to know more about this technology?

Measurement Model. The factor loadings of 0.6 and above were considered for correlation testing between the constructs. Thus, BIU2 with a considerably low value of 0.223 suggests that the variable does not load into the behavioral intention to use construct thus, eliminated along with PU4 (0.584) and PU6 (0.551) for analysis.

Table 3. Measurement Model - TAM

TAM (Latent) Constructs	**Codes**	**Factor Loadings**		**Composite Reliability (CR)**
		Initial Model	**Updated Model (>0.6)**	
Attitude toward Using	AU1#	0.779	0.770	0.802
	AU2#	0.858	0.865	
Behavioural Intention to Use	BIU1#	0.970	1.000	1
	BIU2	**0.223**	-	
Perceived Enjoyment	PE1#	0.805	0.806	0.858
	PE2#	0.915	0.915	
Perceived Ease of Use	PEOU1#	0.826	0.827	0.852
	PEOU2#	0.783	0.783	
	PEOU3#	0.843	0.842	
Perceived Usefulness (pre-usage)	PU1#	0.712	0.716	0.900
	PU10#	0.746	0.767	
	PU11#	0.637	0.651	
	PU2#	0.754	0.778	
	PU3#	0.700	0.681	
	PU4	**0.584**	-	
	PU5#	0.753	0.742	
	PU6	**0.551**	-	
	PU7#	0.597	0.610	
	PU8#	0.691	0.702	
	PU9#	0.680	0.701	

 # Retained variables after filtering through the above-discussed criteria of factor loading for further analysis.

Construct Reliability. Fornell and Larcker (1981) recommended a CR value of 0.60 or more for establishing reliability.

Discriminant Validity. As per the Fornell-Larcker criterion, the discriminant validity is confirmed if $\sqrt[2]{AVE} > r$. The values obtained satisfy the set criteria thus, confirming the discriminant validity of the constructs.

Table 4. Discriminant validity for updated pre-usage TAM model

	AU	BIU	PEOU	PE	PU
AU	0.819				
BIU	0.048	1.000			
PEOU	0.559	-0.053	0.818		
PE	0.686	0.078	0.497	0.862	
PU	0.552	-0.065	0.647	0.519	0.707

Correlation test of TAM Model. Pearson's r correlation method was used to test interrelationship among the various factors associated after updating the expected technology acceptance model (TAM).

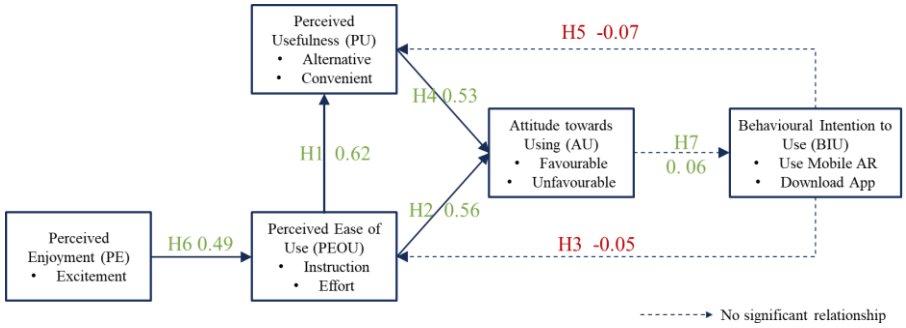


Figure 5. Result of TAM hypotheses model

Interpretation of TAM Model. The users' viewpoint towards technology acceptance is dependent on the following factors which shapes their attitude towards using it. Major factors that would give an edge to launch the MAR application includes, a perception that it would be an easy add-on to their lives. Also, this would be benefitting the users' by giving them a visual experience of the model in their environment along with other useful functions. It would also give a sense of satisfaction before investing in the property thus making a firm decision. Another factor that supports the perception about easy usage technology is a perception of enjoyment, that encourages the **users** to use it for their benefit.

5.2. Post-usage Survey – 2

This section covers the post-usage factors for MAR technology continuance. The details are covered in the following sections.

Target Audience. A total of 30 response was received which consists of 15 responses from the Survey -1 that includes industry professional and remaining 15 was collected by approaching the potential buyers.

Extended Expectation Confirmation Model (ECM). It deals with an individual's intention for continuance (continue using) of technology. It explores both post-purchase and continuance behavior with foci of this model lie in post-acceptance variables (perceived usefulness) and satisfaction which gives a holistic idea for the reuse intention [11]. Similar data collection approach has been adopted by the peer researchers, to analyze the adoption of RFID [12], user experience in urban heritage [13], e-learning using AR [14] to analyze perceived usefulness of a particular technology.

ECM constructs. It is summarized below describing definitions for individual constructs (factors).

- *Confirmation (Conf*).* Confirmation of expectation from the technology depends on individuals or sum of beliefs. The user's perception of formulated by prior usage experience and knowledge about the technology caused by hearing, listening or reading that is confirmed based on actual performance (post usage) of the MAR technology.
    - ***H1:*** *Confirmation of expectation of the users' has a significant impact on their post usage perceived usefulness of the mobile augmented reality technology.*
    - ***H2:*** *Confirmation of expectation of the users' significantly affects their attitude towards the easiness to use the mobile augmented reality technology.*
    - ***H3:*** *Confirmation of expectation of the users' is directly linked to their satisfaction level with the mobile augmented reality technology.*
- *Post Usage Perceived Usefulness (Use*).* User's perception about potential or expected benefits after testing the performance of MAR technology in the real estate domain is the measure of post usage perceived usefulness. It is directly linked to the positive outcome of satisfaction.
    - ***H4:*** *The users' post usage perceived usefulness for a mobile augmented reality technology is positively leading to their satisfaction.*
- *Perceived Ease of Use (Ease*).* Post exploration of the technology, the easiness to use it without putting considerable mental effort or without external support will encourage multiple people to use this technology for the real estate domain.
    - ***H5:*** *Perceived ease of use of a mobile augmented reality technology leads to the users' satisfaction from it.*
- *Satisfaction (Sat*).* It is the post usage evaluation of the comprehensive experience with mobile AR technology thus giving a positive affirmation about its benefit. It is a core determinant to the user's continuance intention about this technology in the real estate domain.
    - ***H6:*** *Satisfaction of the users' will significantly affect their perception to continue using the mobile augmented reality technology.*
- *IT Continuance Intention (Cont*).* User's intention to continue using (continuance) the MAR technology for the real estate domain. This decision is based on confirmation of expectations of the technology evaluating it on various factors like post usage usefulness, ease of use leading to optimum satisfaction level for continue using.

Confirmatory Factor Analysis (CFA) – ECM Model. Similar to the TAM model, the collected data was validated by checking the factor loading of the constructs and variables. The survey was analyzed using the statistical software called SmartPLS 3. The expected model was based on the ECM theory, that focus on confirming the users' expectation from the technology after using it for the particular task.

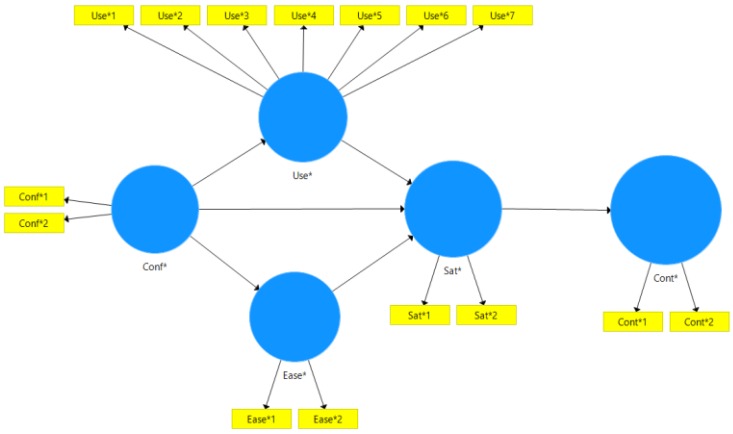


Figure 6. Expected expectation confirmation model for CFA

Where, Conf= Confirmation; Cont* = Continuance Intention; Ease* = Perceived Ease of Use; Use* = Post-usage Perceived Usefulness; Sat* = Satisfaction*

Similarly, the proposed hypotheses were tested using the variables present in the questionnaire survey-2 which is marked against each construct.

Table 5. Codes' summary of different variables for ECM model

ECM Constructs	Codes	Variables/ Items
Perceived Ease of Use	Ease*1	MAR application is easy to use and do not require a lot of mental effort
	Ease*2	All the functions of MAR application are clear and understandable
Post Usage Perceived Usefulness	Use*1	It would help the users to visualise the model elements, material texture, explore multiple design options, and inspect it
	Use*2	It would allow users to have a better understanding of model scale and proportions.
	Use*3	It would allow users to view the double-storeyed model at same level by adjusting it in the vertical axis.
	Use*4	It would help users to inspect the size of the furniture, door, window on-site with proposed
	Use*5	It would help to have general info like room dimensions (LxBxH), property price, type of building etc. Material Info like catalogues, material type and cost etc.
	Use*6	It would help to have a sectional view of the property and a handy plan layout in mobile.
	Use*7	Photo and video capture to save the visuals for later and virtual collaboration using the cloud (meeting like google meet, zoom etc.) to discuss it with other people.
Satisfaction	Sat*1	How do you feel about your overall experience of using the MAR applications
	Sat*2	The MAR devices I used to meet my expectations
Confirmation	Conf*1	Using the MAR proved effective in communicating information related to property more than initial expectations
	Conf*2	The functionality of MAR technology for real estate is better than what I expected
Continuance Intention	Cont*1	I intend to continue using the MAR for real estate project
	Cont*2	I am likely to use the MAR on other types of projects as well like a commercial, institutional etc.

Measurement Model. As discussed previously, the factor loading was used as a filter to retain the variables having values greater than the threshold of 0.6. Which leads to the elimination of the Use*4 and Use*6 factors respectively. Also, reliability of the factors have been achieved using the CR values thus confirming the discriminant validity.

Correlation test of ECM Model. Pearson's correlation (r) test was performed using Microsoft Excel. Null hypothesis represents no relationship among the two factors which was accepted if the r value was less than the threshold value of 0.5 (i.e., $r < 0.5$) otherwise rejected. Figure depicts the consolidated summary of all the hypotheses.

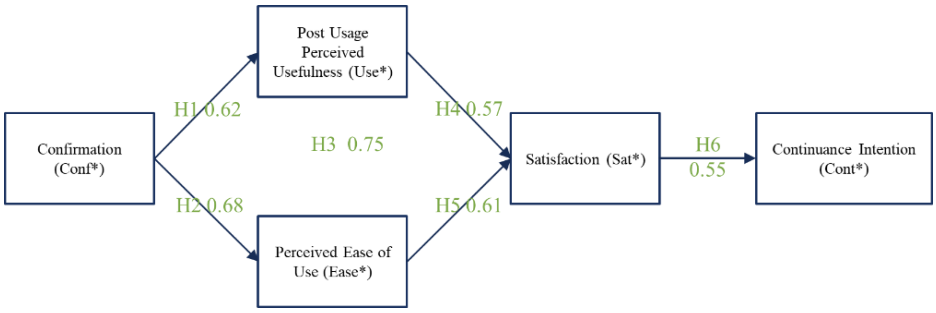


Figure 7. Final result of ECM hypotheses model

Interpretation of ECM Model. The results indicate that efforts should be made in direction of achieving a satisfaction level that is linked to their expectation which is a crucial factor along with the perceived usefulness and perceived ease of use of a particular application. This will encourage the users' to continue using the MAR technology in the real estate sector.

This will be beneficial for developers as they can save their time and cost invested in making a prototype flat and can reach distantly located buyers. Also, this add-on experience will remove the ambiguity created due to the communication gap thereby, helping them in firm decision making.

6. CONCLUSIONS

The study is effective in realizing the factors crucial at pre and post-usage scenario of the MAR technology. Difference between the potential users' vs actual users viewpoint can be inferred through this study. For actual users, consistency between real experience and expectations needs to be established which eventually leads to their satisfaction level. The results are consistent with previous studies that suggest a high level of satisfaction leads to the continuance intention of the technology.

But for the potential users i.e., before launching an application one must check whether it is satisfying their perception concerning the usefulness and enjoyment of the technology along with a strong notion that boost their confidence about easiness to operate it thus confirming its acceptance.

6.1. Future scope of the study –

Exploring other notable user-oriented theories for a better understanding of users pre and post-usage behaviour of the MAR technology. This includes external factors like service system quality, value for money, flow experience of particular app etc. It also includes internal factors like social influence, technological influence, and organisational influence on technology acceptance.

The impact of technology interface on post-usage behaviour by adopting multiple application to assess if it satisfies the users' expectation and motivates continuance intention.

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