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Evaluation of Factors Affecting the Adoption of Smart Buildings Using the Technology Acceptance Model

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ABSTRACT

Objective: This study aimed to find a solution to the acceptance of smart buildings in Iran using the technology acceptance model (TAM). The main research question is the significance of this model relationships, as well as the anticipated adoption of smart buildings in Iran using variables included in the model.

Methods: This descriptive study, is based on survey data collection methods and the way of analyzing data is correlational and casual study. Measurement tool was designed based on the standardized questionnaire presented by Davis. The reliability coefficient was 0.88. Statistical population is unlimited and included citizens of Iran in 1395. The sample consisted of 388 individuals. Given the infinity of society and Cochran formula, 384 individual is sufficient for this research. This study is a random sampling one that was done in the period of 30 days.

Findings and conclusions: The results revealed that all relationships in the model are significant. And among the variables of the model, perceived usefulness, the attitude toward using, and features of smart buildings had the most intense relationship in acceptance this technology. Using regression equations, each of the dependent variables in the model, is predictable by the independent variables.

Innovation of research: The intensity of relationship between variables in technology acceptance model and impact of each variable in explaining the criterion factor was analyzed.

Research limitations: Many people tend not to complete the questionnaire and some ones answer questions unrealistic. Despite all the explanations to justify the respondents, still there are possible directions in responses.

Practical consequences: Using regression equations obtained in this study, we can predict the criterion variables in the model of technology adoption.

Keywords: **Information technology, Perceived ease of use, Perceived usefulness, smart building, TAM, technology acceptance.**

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1. INTRODUCTION

Climate change, caused by the excessive waste of resources, is one of the greatest threats of current time [1]; So that it can be a disaster Mentioned [2]. This situation is largely the result of human fault and the side effects of constructions [3]. In such a way that 65 percent of water consumption and almost 80 percent of greenhouse gas emissions associated with the operation of buildings [4]. In addition more than 50% saving potential in the building sector exist and therefore as a potential sector to deal with the global challenges of energy and climate change is taken into account [1].

According to the statics that defines the role of construction in the management of resources and energy, one of the important issues raised in the construction sector, is smart building [5]. IT has potential advantages in terms of cost savings and reduces the damaging effects of the environment [3]. In a way that smart buildings reduce energy consumption about 50 percent more than conventional buildings. The performance of this type of construction is more than 70% better than conventional buildings [6]. Smart buildings increase productivity and reduce costs consumed [7]. In recent years, investment in smart buildings has increased affectedly in the Asia Pacific region [8]. This construction method has been implemented in Iran as well and for its growth and development, it is necessary that it be accepted in society.

Therefore, in this study determining factors influencing adoption of smart buildings in the Technology Acceptance Model TAM will be identified and evaluated. In this study, the questions focus on the role of model, and the adoption amount of smart buildings in Iran. To identify the impact of each factor on the adoption of smart buildings, we can use the factors and strengthen them, and consequently, facilitated the success of this technology in Iran.

2. LITERATURE

The word "smart" to describe the buildings were first used in the United States in the early 1980s [8]. Analysis of studies has shown that smart building technologies are substantially helped higher stability rating scale to assess LEED [5]. Most recent developments in building energy management systems established due to the advances in computer technology, telecommunications and IT [7]. IT has potential advantages in cost savings and reduces the damaging environmental effects [3]. Many experts predict that IT control and will surround valuable field the building [6]. Michel (1998), Gray (2006), Ehrlich (2007), Ryvz- Moreno et al. (2007), Moore (2009), Liu et al. (2010) and Schultz (2010) found that promote energy efficiency programs requires intelligent system design as one of its main elements. They noted that the integration of systems of communication, computing, control and construction of a unified network that is manageable from a unified operations center, a smart building can optimize its physical infrastructure and result in energy efficiency [5].

Smart buildings and integrated building automation not only increases integration and automation capacity, But can lead to significant energy savings through the ability to automatically reduce the power consumption during peak periods occur[6]. Smart building construction is kind of building that the people, processes and technology are integrated in order to efficient and sustainable manner using high levels of integrated technologies including air conditioning, plumbing, and electricity, systems and renewable energy sources, information technology, control systems and management software are integrated to provide safe, healthy and productivity for the residents of the building [9].

On the other hand the main purpose of this study is to evaluate the factors affecting the adoption of smart buildings by the Iranian people in Technology Acceptance Model. To this end, in this experiment, respectively, theoretical and operational definitions used for each of these variables are presented in Table 1.

Table 1: theoretical and operational definitions of variables

Variable	Definition
Information Technology	The use of digital tools and techniques to manipulate information and social phenomena that surround these systems [3]
Perceived usefulness	Is the degree to which a person believes that using a particular system, or work can enhance performance [10]
Perceived ease of use	The degree to which a person believes that the use of a particular technology, will be effort free [10]
Mindset towards technology	The desire to start using this new technology [11]
The actual use of technology	State if person is already uses the technology or not.

Davis[1] found that people use a technology if only they believe that technology will help them to do things better. He also found that if users believe that a technology is helpful but it is hard to use, then attempts to use the technology, is more important than the perceived benefits of use [10]. The Technology Acceptance Model has evolved to assess the use of the system, acceptance, and user satisfaction [12]. TAM model studies have shown that the effect of perceived ease of use on admission is often less than the effect of perceived usefulness [10].

[1] Fred Davis

D.Choi (1995) study entitled "Do you want to rent an office in a smart building" noted that financial factors and capacity of Smart buildings are the main concern for developer [13]. So[2] and Chan[3] (1999) in the book "Intelligent Building Systems", by considering the characteristics of smart buildings, they assess the different benefits and cost of them. In terms of benefits, rent achieved of smart buildings is higher. Initial construction costs may be higher but other recurrent costs is less, smart buildings have a higher life expectancy [14]. Wong et al (2001) study entitled "financial capabilities of smart buildings: Faustman assessment approach" they find that many investors when making decisions about the value of investing in new technology, costs and benefits are taken into account [15] .

T.Tay et al (2002) study entitled "The impact of IT and communication in building management system", found that the advancement of information technology with reduction cost, results in advantageous acceptance of smart technologies in buildings [16]. Suttle (2002) study entitled "Integrated and intelligent buildings" came to the conclusion that smart building construction can improve productivity and reduce energy consumption [17]. Flax[4] (2002) in a study titled "smart building" arrive at a conclusion that smart building can minimize all current construction costs (including energy, air conditioning, control environment) [18]. Lowry (2002) study entitled "user acceptance model of building management systems" came to the conclusion that factors such as awareness of the system benefits, increases user productivity, adoption and ease of use is an important factors of these technologies [19]. Masyrvn (2005) study entitled "Consent and usage of smart home" found that some of the major obstacles to market development, is including the use perceived, perceived usefulness, perceived reliability, cost, interfaces, controllers Central / computer software and mistrust of Technology [20].

Wong[5] et al (2005) in a study entitled "Intelligent Building Research" reviewed previous studies focused on smart buildings and concluded that the overall cost of smart building projects in general, is about 8% higher than conventional buildings and about 5% of project construction costs for construction services is generally higher and its only because the smart building in compare with conventional building involve more advanced technological materials and components in the building services systems [8]. Walker[6] (2008) in a study about the convergence of green and smart buildings as "bright green buildings" came to the conclusion that a building owner

[2] Albert Ting-pat So
[3] Wai Lok Chan
[4] B. M. Flax
[5] Kwok Wai Johnny Wong
[6] Scott Walker

will usually assume that smart buildings will cost more. However, industry experts agree that smart building eventually cost less. Although capital expenditures or the primary cost of conducting a coherent concept usually is more costly for the owner, implementation and operation costs will drop significantly and economic costs and life cycle cost will be considerably lower. Therefore, smart development and investment in a building has lower costs if the building will be available for owner in a while. Also, high-performance smart buildings reduce overall demand for energy and the needs for new power plants are limited. This reduction also helps to limit emissions [6].

Tomlinson[7] (2010) in "Green by IT: IT environment sustainability" examines the role of information technology and its potential benefits in terms of cost savings and reduce effects of the damaging environmental [3]. Reffat[8] (2010) study entitled "Integrating Intelligent Building Technologies: A Means for Fostering Sustainability" found that smart buildings are improve economic and environmental performance [21]. IBM's software group in 2010 released the report entitled "Improving facilities with smart building solutions IBM", and found that commercial buildings produce 40 percent of the total electricity consumption and about 10 percent of the greenhouse gases and apart from the costs of labor, energy costs alone creates about 30 percent of total operating costs for commercial buildings [22].

Kaklauskas[9] et al (2010) in study entitled "Comprehensive analysis model for smart built environment", knows the aim of making smart environment, to improve quality of life for residents and increase their satisfaction through daily work with the replacement of smart devices and robots. Smart devices can interpret and respond appropriately to changes in the environment [23]. Gundogan[10] (2012) predicted that as much as information technology and data processing merge more traditional and old project will fail, and electrical and mechanical sectors will be smart systems [24]. Gadakari[11] et al (2013) in study entitled "Intelligent Buildings: Key to Achieving Total Sustainability in the Built Environment" began to explore the various benefits of smart buildings that include reducing water consumption, energy and operating costs as well as increased productivity and investment and flexibility. Smart buildings can also learn about weather conditions from the previous day based on fuzzy logic and understand what is required to do and predict the required energy bars [5].

The literature review found that the smart buildings simplicity and improve the efficiency of building operations and associated benefits; However, the high cost of investment in the construction of this type of construction has always been the main concern of investors in this field; Although the buildings by modifying the pattern of energy consumption, cause in the long run reduce costs.

[7] Bill Tomlinson
[8] Rabee M. Reffat
[9] Arturas Kaklauskas
[10] Handan Gundogan
[11] Tulika Gadakari

3. CONCEPTUAL MODEL

One of the critical success factors in any IT implementation is user acceptance of information technology systems [25]. Technology Acceptance Model has evolved to measure system usage, compliance, and user satisfaction [12]. The advantage of using TAM model is that it designed specifically for use in information systems technology adoption [26]. TAM model is used for technologies that are currently used by customers [27]. Most studies in information technology acceptance used models such as Technology Acceptance Model (TAM). Technology acceptance model focus on explain behavior that affects the decision to use a particular technology [10]. While previous studies around social psychology, general models offer user behavior, the theme focuses specifically on the behavior of computer use [28]. Themes from the social psychology theories view point, use as a basis for determining the cause and effect relationship between the key beliefs: perceived usefulness, perceived ease of use, attitudes and intentions of users, and practical use of the system [12]. In Davis model, an approach that is shaped according to the technology is divided into two separate components: perceived usefulness and perceived ease of use.

Davis defined perceived usefulness as follows: the degree to which a person believes that the use of a particular system will enhance the performance. While the perceived ease of use is the degree to which a person believes that the use of a particular technology, will be effortless. This two will affects technology and plan to use it, and also affects the acceptance of this system [10].

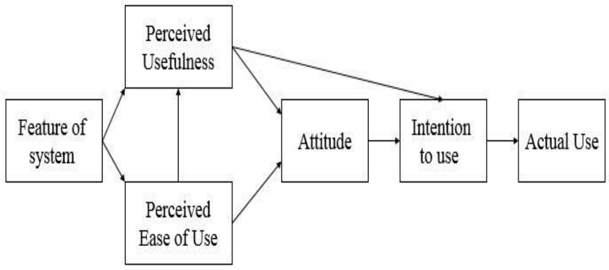

Fig1: Technology Acceptance Model [29]

According to TAM, plans to use the technology, determines the actual usage of, and attitudes toward technology, affect the intention [30]. TAM claims that in determining the intended use, perceived usefulness is more important than attitude. Davis found that attitudes towards the use, at the best case has partial mediating effect of perceived usefulness towards intention to use and has poor strength of causal explanation [10].

The purpose of this modeling is to predict the acceptance of a tool and identifying the necessary changes in order to be acceptable for system users. Technology Acceptance Model (TAM) in fact was developed as a tool to predict the likely adoption of a new technology. Thus, the model assumptions are:

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The main hypothesis: Relationships in the Technology Acceptance Model TAM, for the adoption of smart buildings in Iran are significant.

• Secondary hypothesis1: there is a significant relationship, considering the features of smart building and perceived usefulness of its application.
• Secondary hypothesis2: there is a significant relationship, considering the features of smart building and perceived ease of use.
• Secondary hypothesis3: there is a significant relationship among the perceived ease of use and perceived usefulness of smart building application.
• Secondary hypothesis 4: there is a significant relationship between perceived ease of use and attitudes towards this smart building technology.
• Secondary hypothesis 5: there is a significant relationship, among the perceived usefulness and attitude toward using smart building.
• Secondary hypothesis 6: there is a significant relationship considering the perceived usefulness of smart building and intention to use smart building.
• Secondary hypothesis 7: there is a significant relationship among attitude towards the smart buildings and intention to use the smart building.
• Secondary hypothesis 8: there is a significant relationship considering the intention to use smart building and the actual use of smart building.

4. RESEARCH METHOD

The present study is an applied standpoint goal and purpose is to examine the factors affecting the adoption of smart buildings in Iran, thus laying the groundwork for the development of smart buildings in Iran. This research from the consequent perspective is decision-oriented. According to the data collection method is a kind of survey that is descriptive. According to the data analysis, is the correlation type. All Iranian citizens comprised the study population. The study participants were 388 Iranian individuals in 2016. Not to mention according to Cochran formula and considering the unlimited community samples above 384 are sufficient. This is a simple random sampling. A standard questionnaire was developed based TAM Davis instrument. In order to assess the validity and content validity of the questionnaire, relying on the experts and professors necessary reforms has been approved. The study showed Cronbach's alpha coefficient of 0.88, which indicates high reliability and optimal scale used for assessment of the research.

5. RESULTS

5.1. Descriptive research findings

The numbers of participants in this study were 388 Iranian citizens. Due to the gender Prevalence, 55.2% were male and 44.8 percent were women. Also in terms of education, evaluate the frequency of the desired sample shows that the largest number of frequency samples belong to bachelor degree level, in fact 33% of the participants had a bachelor's degree. Frequency distribution and percentages of their level of education it can be seen in Table 2.

Table 2: The frequency distribution and data rate of level of education

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Under Diploma	27	7.0	7.0	7.0
	Diploma	64	16.5	16.5	23.5
	Associate Degree	47	12.1	12.1	35.6
	Bachelor	128	33.0	33.0	68.6
	MA	110	28.4	28.4	96.9
	PhD	12	3.1	3.1	100.0
	Total	388	100.0	100.0	

6. RESULTS OF ANALYTICAL RESEARCH

According to the results of tests Kolmogorov Simonov, turns out that the distribution of data is non-normal. Kolmogorov Simonov test results on all variables shown in the following tables.

Table3: Kolmogorov-Smirnov Test for variables of model

Variable	Kolmogorov-Smirnov Test
Features of Smart Building	Test Statistic = .133 Sig. (2-tailed) = .000
Perceived Usefulness	Test Statistic = .150 Sig. (2-tailed) = .000
Perceived Ease of Use	Test Statistic = .092 Sig. (2-tailed) = .000
Attitude	Test Statistic = .243 Sig. (2-tailed) = .000
Intention to Use	Test Statistic = .219 Sig. (2-tailed) = .000
Actual Use	Test Statistic = .088 Sig. (2-tailed) = .000

Given that the distribution of data is abnormal for all variables in the society model, to analyze the relationship between variables the Spearman correlation coefficient was used. Result of computing the correlation coefficient between the variables shown in Table 4. Given that the Sig is less than the significance level (0.05) significant relationship between the variables in the model has approved.

Table 4: Pearson correlation test for variables of TAM

Predictor Variables	Criteria Variable	Pearson Correlation Test
Features of Smart Building	Perceived Usefulness	R = .626 Sig. (Two-tailed) = .000
Features of Smart Building	Perceived Ease of Use	R = .309 Sig. (Two-tailed) = .000

Perceived Ease of Use	Perceived Usefulness	R = .391 Sig. (Two-tailed) = .000
Perceived Usefulness	Attitude Toward Using	R = .693 Sig. (Two-tailed) = .000
Perceived Ease of Use	Attitude Toward Using	R = .423 Sig. (Two-tailed) = .000
Perceived Usefulness	Intention to Use	R = .580 Sig. (Two-tailed) = .000
Attitude Toward Using	Intention to Use	R = .679 Sig. (Two-tailed) = .000
Intention to Use	Actual Use	R = .350 Sig. (Two-tailed) = .000

To analyze the impact of each independent variable to predict the dependent variable linear regression equation for the relationships outlined in the model is calculated. The results show that the model is statistically significant. According to Figure 5, the results of the regression line indicate that significant regression test were good and in these cases, regression is meaningful.

Table 5: Linear regression variance analysis of model relationships

Dependent Variable	Model	Sum of Squares	Mean Square	F	Sig.
Perceived Usefulness	Regression	62.878	31.439	42.085	0.000
	Residual	286.858	0.747	-	-
	Total	349.736	-	-	-
Perceived Ease of Use	Regression	19.122	19.122	35.671	0.000
	Residual	206.917	0.536	-	-
	Total	226.039	-	-	-
Attitude Toward Using	Regression	100.718	50.359	34.277	0.000
	Residual	559.762	1.469	-	-
	Total	660.480	-	-	-
Intention to Use	Regression	100.197	50.098	86.191	0.000
	Residual	220.294	0.581	-	-
	Total	320.491	-	-	-
Actual Use	Regression	37.814	37.814	24.037	0.000
	Residual	602.525	1.573	-	-
	Total	640.339	-	-	-

The final result is given in Table 6.

Table 6: Regression analysis Criteria variable and predictor variables

Criteria variable	Predictor variable	Unstandardized Coefficients (B)	Standardized Coefficients (Beta)	t	P
Perceived usefulness	Constant	1.882	-	7.642	0.000
	Features of Smart Building	0.304	0.309	6.396	0.000
	perceived Ease of Use	0.267	0.215	4.446	0.000
perceived Ease of Use	Constant	2.712	-	17.373	0.000
	Features of Smart Building	0.230	0.291	5.973	0.000
Attitude Toward Using	Constant	1.308	-	3.728	0.000
	perceived Ease of Use	0.348	0.203	4.108	0.000
	perceived Usefulness	0.383	0.278	5.618	0.000
Intention to Use	Constant	1.547	-	8.373	0.000
	Attitude Toward Using	0.229	0.328	7.245	0.000
	perceived usefulness	0.343	0.356	7.878	0.000
Actual Use	Constant	1.954	-	10.071	0.000
	Intention to Use	0.227	0.243	4.903	0.000

Since the amount of Sig for all independent variables is less than 0.05, thus the results of the test variables in the inequality of the coefficients to zero are significant. Consequently, the regression model can be calculated as follows:

Perceived Usefulness =1.882+0.304(Features of smart building) + 0.267(Perceived ease of use)
Perceived ease of use=2.712+0.230(Features of smart building)

Attitude Toward Using =1.308+0.348(Perceived ease of use) + 0.383(Perceived usefulness)

Intention to Use =1.547+0.229(Attitude toward using) + 0.343(Perceived usefulness)
Actual use=1.954+0.227(Intention to use)

Based on the information obtained from significant numbers and the relationships between the components in the conceptual model presented approve or reject primary and secondary research hypotheses are as follows:

Table 7: Simple linear regression analysis of Criteria variable and predictor variables

Hypothesis	P	r	Result
Significant relationship among the features of smart building and perceived usefulness	0.000	0.626	Confirms hypothesis 1
Significant relationship among the features of smart building and perceived ease of use	0.000	0.309	Confirms hypothesis 2
Significant relationship among the perceived ease of use and perceived usefulness	0.000	0.391	Confirms hypothesis 3
Significant relationship among the perceived usefulness and attitude toward using	0.000	0.693	Confirms hypothesis 4
Significant relationship between perceived ease of use and attitudes toward using	0.000	0.423	Confirms hypothesis 5
Significant relationship considering the perceived usefulness of smart building and intention to use it	0.000	0.580	Confirms hypothesis 6
Significant relationship among attitude towards the smart buildings and intention to use it	0.000	0.679	Confirms hypothesis 7
Significant relationship among the intention to use smart building and the actual use from it	0.000	0.350	Confirms hypothesis 8

According to the above table, relations in the Technology Acceptance Model TAM to accept smart buildings in Iran are significant and the main hypothesis is confirmed.

7. CONCLUSION

According to the results of the first and second hypotheses can be said smart building features more than perceived ease of use, causing the people to perceive that such structures are useful. On the one hand, ease-of-use features of smart buildings should be strengthened to increase. Lack of promoting smart buildings at the community level, and the lack of publicity and necessary trainings, is the reasons for the weakness of the intensity of perceived usefulness, for this type of buildings. This result is consistent with the findings of Lowry (2002) along with factors such as awareness of the benefits of increased user productivity, using this technology, and adoption and ease of use is an important factor in the acceptance of these technologies.

The result of the third hypothesis can be interpreted that as much as people find this technology easy to use then they find it more useful. In smart buildings, to the extent possible, attempt to remove the human element in the use of construction equipment, which means that all activities are smart and automated and require no user effort. According to the regression equation to perceive the usefulness of the application of the criterion variable, we can see that features smart building application has a greater impact in compare with perceived usefulness. Although many people perceive the ease of use of smart buildings, but due to the high initial cost to build smart buildings or smart the available buildings, applying this technology to not consider useful for them. This result confirmed the findings of Wang et al (2001).

The results of the fourth hypothesis suggests that the relations in the Technology Acceptance Model TAM that were examined in this study, solidarity and strength of the relationship between perceived usefulness and attitude towards the use of smart buildings, is more than other relationships examined. Also perceive the ease of use is significantly correlated with the attitude to these buildings; this relationship is positive and average. The linear equation attitudes, more influenced by the perceived usefulness and after that, the perceived ease of use are directly affected. This result is consistent with results from Davies studies that have shown effect on the acceptance of perceived ease of use, is often less than the effect of perceived usefulness.

According to the sixth and seventh hypothesis, the relationship between attitudes to smart buildings and tend to use this type of buildings was established. This type of communication is direct and relatively strong. The positive relationship between perceived usefulness of smart building and the willingness to use it among people is confirmed. The intensity of this relationship is relatively high. According to the regression equation, we can see that the prediction of the desire to use variable, more than any other factor, perceived usefulness effect on the criterion variable. The impact of attitude to this type of construction is less effective than perceived usefulness of the prediction of willing to use it. These results are consistent with the Davis findings which by using TAM model claimed that in determining the intended use, perceived usefulness is more important than attitude toward using, and attitude to use, is at best case is a mediating effect of perceived usefulness on intention to use and has poor strength of causal explanation.

According to the eighth hypothesis, significant correlation between the tendency to use smart building and the actual

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use of the building has proved. This communication is direct and medium. According to the regression equation, variables that used for smart building, directly affect by a desire to use this technology. It could be interpreted that as much as people's willingness to use this technology getting more, the use of this technology will be more, but one of the reasons that make this relationship less strong may be due to the high cost of buying, renting and living in this type of construction. Smart buildings embody high initial costs for their owners. Although Flex (2002) found that smart buildings can minimize all running costs of buildings (including energy, air conditioning, and control environment). But pay the initial cost for this type of construction is difficult for many individuals and families. The result, in line with the findings of Choi (1995), which noted that financial capability and smart buildings, is the main concern for developer. It can be inferred that other factors can affect actual use of smart buildings, including the geographic area where the building is located, promote the use of smart buildings in the area is and not established the necessary infrastructure for integration and smart buildings in Iran are the other reasons. For example, if power is interrupted for a short time, then the water management system, pumping water to the floors of buildings, access control, CCTV, air conditioning and lighting system will be impaired and disabled.

So in this study, all the relationships in the Technology Acceptance Model TAM were evaluated on the basis of the original hypothesis and it was found that all of these relationships are significant. According to the average relationship between the tendency to use smart building and the actual use of the technology, besides the tendency to use smart building, other factors that affect this technology must be noted, such as economic conditions and the high cost required to settle find in this building, the lack of national infrastructure needed to integrate technical equipment and... In this study, the Davis Technology Acceptance Model TAM is used to discuss the research. Researchers can use the developed TAM3 model review this issue. In addition since the TAM model is not enough to predict the acceptance of the technology; we suggest that this study also be performed as UTAUT[12] models and TTF[13] and TRA[14] and TPB[15] .

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