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A FRAMEWORK FOR DEVELOPING MASS CUSTOMIZATION HOUSING SYSTEM FOR DWELLING HOUSES IN EGYPT

N. SALAMA[1] N. GHARIB[2] G. MOSSAD [3]

ABSTRACT

The residential housing market in Egypt plays a crucial role in the economy, yet building companies face challenges in meeting diverse customer demands due to the complexity of house designs and components. Effective customization of dwelling houses requires an exact understanding of customer preferences to reduce complexity and avoid post-construction modifications. This study aims to address the gap in mass customization for residential housing design by identifying and prioritizing customer preferences within the Egyptian real estate market. Through a detailed survey conducted on respondents, including architecture experts and prospective buyers, the study employs analytical hierarchy process (AHP) analysis to derive a prioritized list of housing attributes. The research provides insights into customer priorities and preferences, offering a model for developers to enhance customization and align house designs with user needs. The findings are intended to assist construction companies in delivering customized housing solutions and help buyers make informed decisions. The focus is on the Egyptian market, specifically high and upper middle-class categories, with data collection focused on gathering preferences and requirements using the online survey and helping the customer select his dwelling house modules through three streams, the case study stream, the online preference measurement stream, and the design stream.

KEYWORDS: *Mass Customization, Dwelling Houses, Analytic hierarchy process (AHP), Housing attributes.*

1. INTRODUCTION

The residential housebuilding market plays a crucial role in supporting Egypt's economy. One major challenge for building companies is to respond quickly to customer demands[1]. A dwelling house is a complex structure, with numerous dependencies among its various components, sub-components, and attributes. Therefore, it is vital to know exactly what customer requirements are in order to decrease complexity and avoid difficulty or impossible component combinations[2]. However, in order to be able to customize a house, requirements and preferences must be identified. Currently, there is no standardized approach to mass customization in dwelling house design, and builders often lack knowledge about how to prioritize housing attributes effectively[3]. This gap is partly due to evolving customer preferences and emerging technologies.

The importance of developing an appropriate model to determine customer preferences that can be updated to different housebuilding methods and much more to be used in the dwelling housing design.

[1] Nour Salama Assistant lecturer of Faculty of Engineer at Arab Academy for Science and Technology nour_salama@aast.edu

[2] Prof. Dr. Nevine Gharib, Professor of Architecture at Faculty of Fine Arts- Alexandria University nevin.gharib@alexu.edu.eg

[3] Prof. Dr. Gihan Mosaad, Professor of Architecture at Arab Academy for Science and Technology Gihan.mosaad@aast.edu

In order to be able to provide a variety of products at an acceptable cost, it is important to find out how customers assign their priorities to the different elements in a dwelling house that can be customized [4].

The majority of previous studies focus on how to design or redesign an architecture work according to customer preferences, but not much deals with the problem of how to extract these preferences and how to prioritize different aspects and components of the dwelling house [5]. Therefore, the main aim of this study is to find out how to put into consideration customer preferences during the process of designing the dwelling houses and to apply the concept of mass customization during the design of dwelling houses in Egypt. Moreover, this study contributes by applying a requirements and preference measurement survey in order to prioritize and identify what buyers of dwelling houses really focus on when configuring a house. As a result, house elements and attributes can be classified into categories according to variety and preferences. Based on this survey a list of priority housing attributes is derived using Analytical hierarchy process software. This priority listing is of great importance for developers who are willing to offer their customers customized single family houses [6].

The framework developed in this study aims to create a system that allow real estate developers to address customer preferences and needs to proposed houses variations.The data collection process is limited to the Egyptian market and targeting high / upper middle income categories. A questionaire coducted from May to July 2023 and recevied 302 reseponses from stakeholders, potential buyers and experts within the field, with the aim of identifying key decision criteria and understanding the factors influencing their choices.

The research methodology has two primary objectives, first to determine the preferences and priorities of the targeted category to help construction companies to build according to user needs and second to allow the user to select between alternatives to get what is the best for his needs.

2. METHODOLOGY

It is important to develop an appropriate model to determine and evaluate customer requirements and preferences that can be adapted to different housebuilding business plans and create a tool to offer home buyers flexibility with regard to the decision-making process and make it more likely that customers find exactly the options they prefer. The proposed methodology enables stakeholders to contribute their ideas, preferences, and priorities about architectural design at the predesign phase.

The methodology in this study includes three streams: (Figure 1)

- A Case study stream.
- An On-line preference measurement stream.
- A design Configuration logic stream.

Our focus is to develop a decision-making framework for housing projects and to help project developers to find out how clients prioritize the different attributes of the dwelling house and how to help them in customizing their future dwelling houses according to their requirements and preferences.

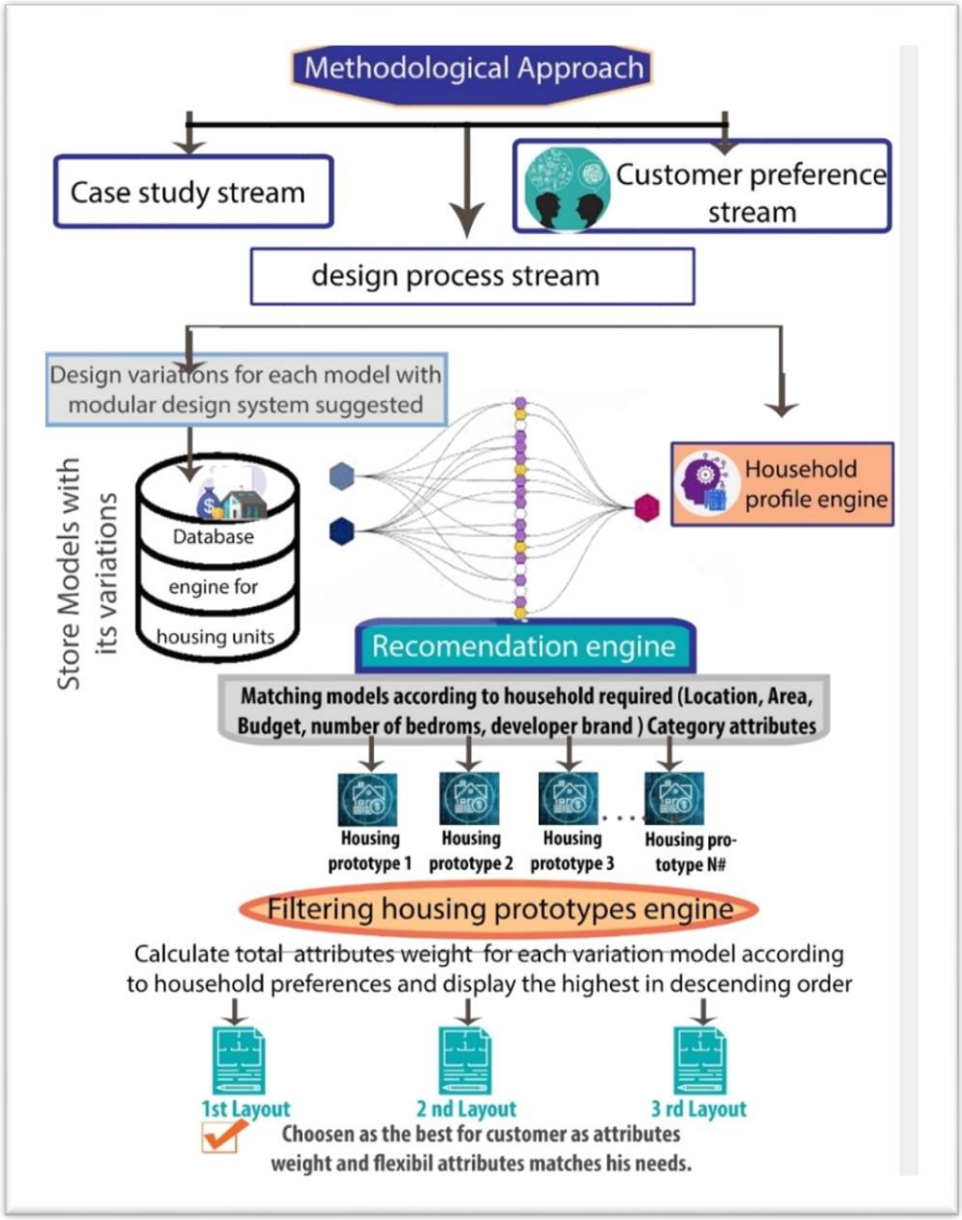

Figure.1 The suggested Framework (source: the author)

2.1 Case Study Stream

The goal of the case study was to categorize all of the components in a house that can be customized. This was done to highlight the customized features that clients value and those that can be standardized, as shown in Table 1 below.

One of the aims of the case study stream is to identify opportunities for introducing a mass customization strategy in Egyptian building companies. The purpose was to gain quantitative insight and knowledge of companies' responses to customer needs and demands and how companies plan to develop their delivery products in a way more satisfactory to customer needs. Data was collected through a set of interviews carried out with the company's staff, including the design, sales, and production managers,

during a period of four months from January to April 2023, to identify the product components and attributes of each component, as well as customizable and non-customizable components.

Developers involved in the interviews are as follows in Table 2.

Components	Attributes
Floor plan	Exploited space
	Bedrooms layout design
	Bathrooms layout design
	Kitchen layout design
	Need of other spaces such as office, gaming room, etc.
Interior design	Wall finishing
	Floor finishing
	Flexible walls for future movement
	Locating electric appliances and switches
	Bathroom layout and finishing
	Kitchen layout and finishing
Exterior design	Roof design
	Front elevation design
	Back elevation design
	Materials used in external finish
	Doors and windows design
	Entrance approach landscaping
Technical systems	Electric system
	Security system
	Heating and cooling system
	Sound system
	Flexibility to add more systems in the future
Environmental	Plot layout
	Parking facilities
	Green areas and playground
	Nearby services
	Nearby transportation facilities
	Community
Reinvestment value	Developer Brand and repetition
	Neighborhood and location
	Property area
	Upgrading possibility of property type
	Neighborhood compared houses
	Structure flexibility for future change

Table.1 Results of stream one (Case Study stream) Classified into categories and attributes.

(source: the author)

	Company (A)	Company (B)	Company (C)
Design Manager	2 times total of 3 hours.	-------	1 time total of 2 hours.
Production Manager	-------	1 time total of 3 hours.	1 time total of 1 hour.
Sales Manager	1 time total of 2 hours.		3 times total of 2 hours.

Table.2 Developers involved in the interviews

(source: the author)

2.2 Online Customer Preference Stream

It is imperative to investigate consumer perceptions on various factors influencing their buying behavior and decision. It seemed that local housing developers have not been making adequate efforts to execute a gap analysis to better understand customer needs, but their business practices are based on builder convenience [7].

It is agreed upon that those factors driving demand preferences of household buyers are difficult to measure, constantly changing, and include complex bundles of attributes [8]. One of the main objectives of this research is to provide insight into the motivation of home buyers during the home purchasing process. It was decided to conduct a customer requirements and preference measurement survey based on Case Study Stream results. This study contributes by applying a multi-criteria decision-making system in order to prioritize and identify what buyers of dwelling houses really focus on when configuring a house. House elements and attributes can be classified into categories according to variety and preferences as shown in Figure 2.

We explored different techniques to build a proper multiple-criteria DMF (decision-making framework) for user selection of the best model dwelling house for his preferences. Criteria were identified through interviews with experts and a potential buyer's survey. The results were synthesized to develop an epistemic context-based Decision-Making Framework (DMF) for house selection equipped with the weighting of each selection criteria. A Decision-Making Tool (DMT) based on the proposed Decision-Making Framework (DMF) was developed using a Decision Support System for practical uses in the real market in Egypt.

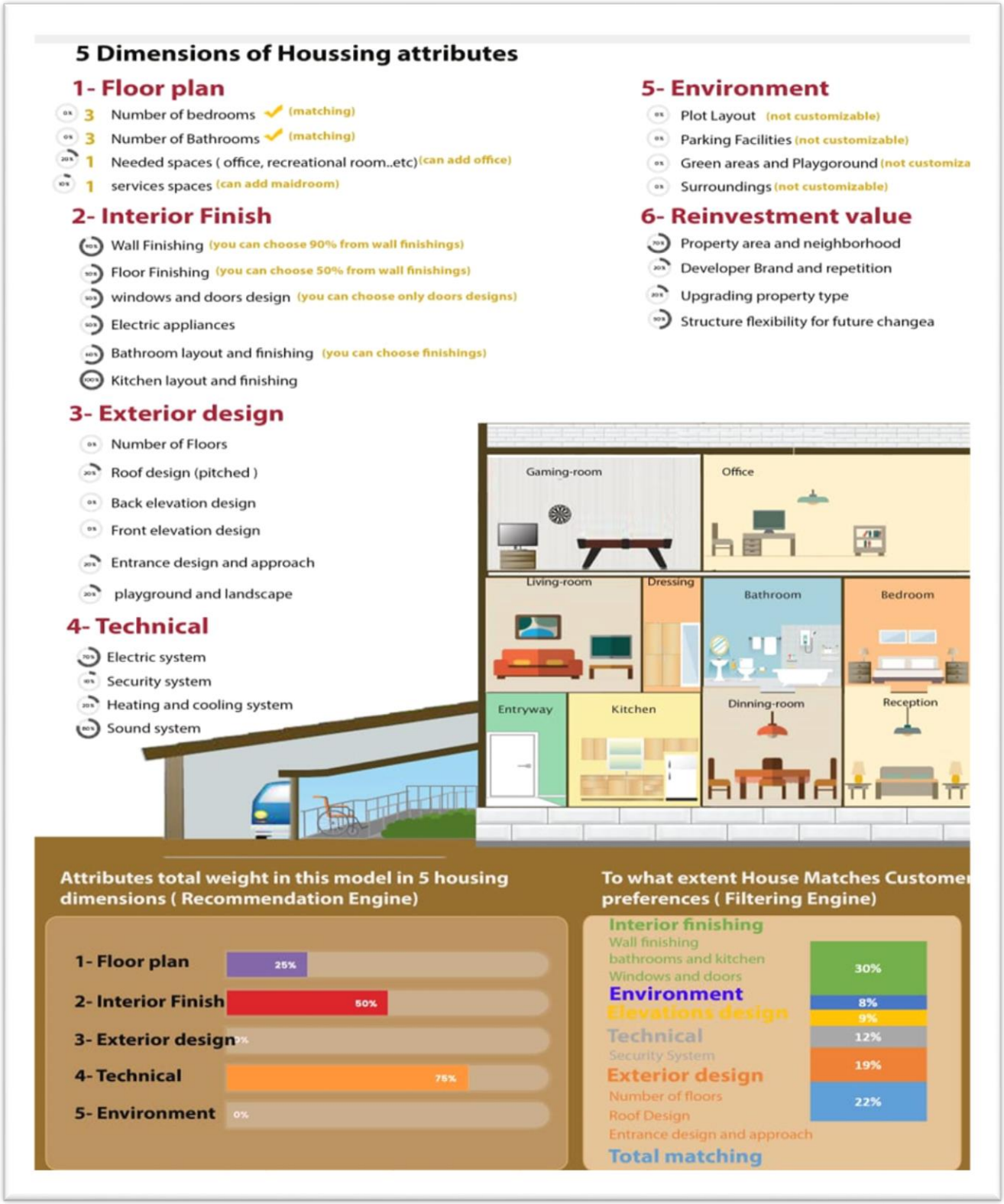

Figure.2: Dimensions of Housing attributes (Source: The Author)

2.3 Design Configuration Logic Stream

After the case study stream and the online customer preferences stream, it was found that we need design logic process software to deal with four functions (Figure 3). First, creating a database of available models with their different variations; second, getting the household profile and preferences; third, a recommendation tool to select from the database matching models with the household requirements; and finally, a filtering module for calculating the total weight of the customer preference attribute and dealing with the customization problem, the variations of different space layouts, and the technical issues for the internal layout designs according to vignette proposals [9].

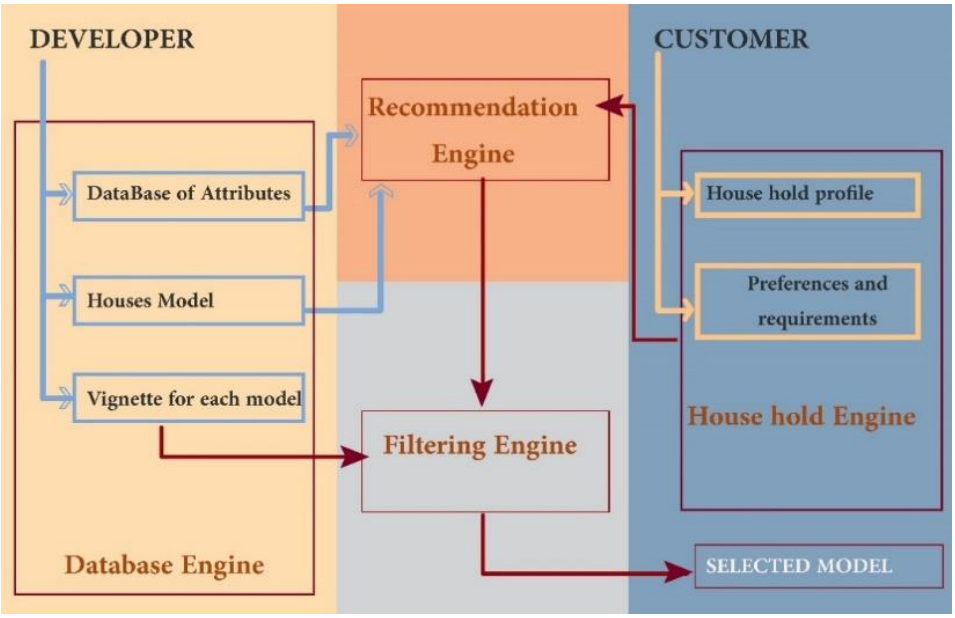

Figure.3 Design Configuration Logic stream (source: the author)

2.3.1 Database engine

Integrating a preparatory home design concept with web technology to create an online interface can become the design platform by which the clients can make more choices and establish better communication with architects and manufacturers. Face-to-face meeting time between architect and client is always limited and time-consuming, while the computational web-based design approach is infinitely patient and always available.

Many pattern book companies now have big websites offering thousands of house plans stored on databases searchable by type, style, square footage, average cost, number of bedrooms, and so on. Some websites also provide the design tool for customizing exterior and interior finishes after the clients select the base model from a house plan catalog [10].

A database of collected models and possible variations from the construction companies was created with the following key attributes:

- Total built area of the constructed model.
- Number of spaces.

- Price category.
- Location code
- Time of installation
- Developer brand.

The key attributes were used to select from the database model variations that fit requirements and preferences entered by the buyer within the household profile engine.

A vignette database was constructed describing each model variations and cost of customizable attributes and the time for the needed work. (Figure 4) shows the vignette content. The more variations in demands the higher the cost in general will become [11].

Vignette number:
Imagine the following house proposition.
I will have a say about the following attributes:

I will have no say about the following attributes:

Figure.4 Vignette proposition (source: the author)

2.3.2 Household profile and preference engine

Based on the theory of customers as innovators, researchers are to develop automated and web-based design tools called "household profile and preference engines" to capture the homebuyers' requirements and preferences [12–13]. Software was developed to engage customers in a dialogue and questionnaire to elicit their demands and preferences.

Total built area required.

Number of spaces required.

Price category.

Location code

Time of installation

Developer brand

The results of the questionnaire were used to select from the database models that fit the buyer requirements and also to modify the weights of the attributes calculated in the On-Line preference stream to take into consideration the home buyers' opinion.

2.3.3 Recommendation engine

The main function of the recommendation engine is a matching algorithm to select a set of housing prototypes from the database models that have already been saved and which match home buyers' profile and requirements as shown in figure 5 (the proposed system framework). This process can be described as the synthesis phase of the problem formulation elements.

2.3.4 Filtering engine

Establishing an architectural logic for a computational system that defines how house layout designs could be structured in a way to facilitate the process to be understood by customers who have no architectural background but are totally aware of what they need in their future house.

Developing the logic which is constructed in the following tasks:

- Creating a standard grid unit that fit with all housing blocks, rooms, and circular housing zones.
- Creating a set of room block zones for different house spaces such as bedrooms, living rooms, kitchen, etc. These are the elements that we use to fit in their place and construct a layout.
- Choosing one of the plot area convenient with customer profiling.
- Select one of the different outlines for the total mass of the housing unit related to percentage of built area.
- Select from displayed layouts constructed with zone cells for functional spaces divided to (guest zone cells, private zone cells, circulation cells vertical and horizontal, and service zone cells). The system displayed different detailed layouts corresponding to the previous selection of zone cells.

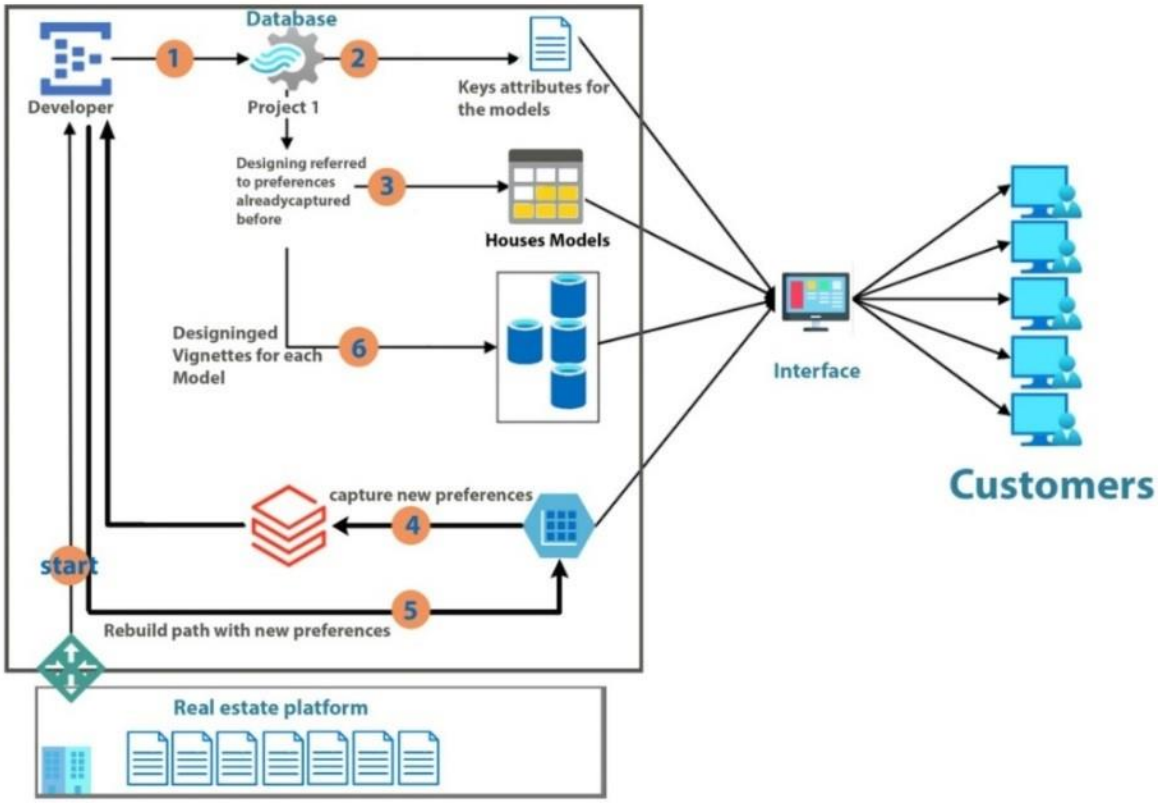

Figure.5 Proposed System Framework (source: the author)

3.RESULTS

A questionnaire was conducted and distributed from May to July 2023 and received 302 responses. It is agreed upon that those factors driving demand preferences of household buyers are difficult to measure, constantly changing, and include a complex bundle of attributes. One of the objectives of this survey is to provide insight into the motivation of home buyers during the home purchasing process and reveal customer preferences in the Egyptian market by specifying the weight of each housing attribute from their point of view.

However, after the preliminary analysis, there were only 274 valid responses to be analyzed using AHP (Analytical Hierarchy Process). AHP was employed to explore the critical project selection criteria. Table.4 presents AHP results later used to develop the DMF (Decision Making Framework). The advantage of this technique is that it allows for the determination of criteria weightings via pairwise comparisons. It compares the relative importance or preference of two attributes. The more criteria there are, the more pairwise comparisons are performed. The selection criteria that were previously identified were grouped based on the nature of their aspects and similarities, such as layout or floor plan, interior design, exterior design, technical systems, environmental factors, and reinvestment factors.

Table 3 represents the results of the online survey of the six main category elements of the housing product. Table.4 represents the results for the AHP analysis and the weights of the six main category elements of the housing product.

Categories	1	2	3	4	5	6	7	8	9	Factor
Floor plan						4	6	53	211	8.72
Interior design				8	64	39	55	61	47	6.87
Exterior design				14	73	22	40	69	56	6.89
Technical systems		9	4	45	74	60	39	23	20	5.75
Environmental factors		17	16	38	81	72	14	19	17	5.38
Reinvestment value				21	18	30	21	78	106	7.59

Table.3 Results of the online survey of the main category elements of the housing product (source: the author)

Categories	Floor plan	Interior design	Exterior design	Technical systems	Environmental factors	Reinvestment value	∑x /n
Floor plan	0.211	0.212	0.211	0.212	0.211	0.212	0.212 21.2 %
Interior design	0.167	0.167	0.167	0.168	0.166	0.167	0.167 16.7 %
Exterior design	0.167	0.167	0.168	0.167	0.167	0.167	0.167 16.7 %
Technical systems	0.140	0.140	0.140	0.139	0.139	0.140	0.140 14 %
Environmental factors	0.131	0.130	0.131	0.131	0.131	0.131	0.131 13.1 %
Reinvestment value	0.184	0.183	0.184	0.184	0.184	0.184	0.184 18.4 %

Table.4 Results for the weights of six main category elements of the housing product (source: the author)

3.1. Results of the On-line preference measurement survey (AHP) show that:

- Looking for a home or long-term investment is the highest tenure type, which reflects the interest in real estate investment.
- More than 80% were ready for installation within one to three years.
- 50% of respondents were looking for a home, and almost 70% had an allocated budget between 1 and 3 million Egyptian pound.
- Floor plan (21.2%) and reinvestment factors (18.4%) were the highest of the main category elements of the dwelling house.
- Exploited space is the highest attribute of the floor plan category with a weight of (4.23%), while kitchen layout and sanitary appliances are the highest weight attribute (3.9%), which can be explained as the kitchen in Egyptian society is the most important space of the house.
- Wall finishing is the most important attribute of the interior design (3.2%), followed by the bathroom appliances (3%).
- Doors and windows design are the highest weight attribute (3.4%) in the external design category and front elevation came in the second place with weight of (3.3%).
- Security system (3.7%) is the highest of the technical systems which is logic.

- Although car parking facilities is the highest within the environmental category (2.41%) but it is very low with respect to other attributes such as location (4.7%) which is an unexpected result.
- Developer brand attribute with an unexpected weight of (4%) is the highest reinvestment factor.
- Another unexpected attribute weight value is for transportation facilities (2.16), community level (2.16), availability of green areas (2.24), and parking facilities (2.41).

3.2. Advantages of the Framework:

- Consuming less time to find a unit that matches his dwelling house requirements and preferences as all developers' products were stored on the database and available on-line.
- The database of models will include products of high-rank developers trusted by buyers as well as secondary real estate developers.
- Buyers will be enabled to view different options of the selected models and the cost of customizing different attributes.
- The web-based evaluation of attributes weight is dynamic and change according to customers preferences, requirements and new technology because the database of buyers' preferences is accumulated as well as the database of models.
- Developers will always want to move towards Mass customization being motivated by customers' demands.
- Developers will be able to deliver dwelling houses that matches buyers' preferences and requirements at an acceptable time and quality.

4.CONCLUSIONS

This study highlights the critical need for effective mass customization in Egypt's residential housing market by identifying and prioritizing customer preferences. Using a comprehensive survey and analytical hierarchy process (AHP) analysis, the research generates a prioritized list of housing attributes that reflect the needs and desires of high and upper middle-class buyers. The perspectives gained from this study provide valuable guidance for developers, enabling them to enhance customization and better connect housing designs with user requirements.

By integrating these findings into the design process, construction companies can deliver more tailored housing solutions and help buyers make more informed decisions. This approach not only improves customer satisfaction but also supports the evolution of the residential housing sector in Egypt by addressing its inherent challenges and complexities.

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إطار عمل لتطوير نظام إسكان التخصيص الشامل للمنازل السكنية في مصر

نور سلامة [1] , نيفين غريب [2] ، جيهان مسعد [3]

الملخص

المسكن هو المكان الذي يحصل فيه الانسان على الراحة والأمان طبقا لاحتياجاته وأولوياته. ويتكون المبني السكنى من عدد كبير من المكونات والعناصر المرتبطة ببعضها بطريقة او بأخرى وكلما زاد عدد هذه المكونات والعناصر زاد التعقيد في عمليه تصميم المباني السكنية.

ولقد كان من الجدير بالاهتمام ان شركات المقاولات في مصر تهتم فقط باقتصاديات البناء للحصول على أقل تكلفه للوحدة السكنية ولا تهتم بالأخذ في الاعتبار احتياجات العميل وأولوياته مع عدم تجانس متطلبات العملاء وكذلك التطور الدائم والمستمر في تكنولوجيات البناء.

من خلال الاعمال السابقة كان من الواضح أن وضع أولويات للعناصر والصفات الخاصة بالمباني السكنية غير واضح لدي شركات البناء وغير مأخوذ في عين الاعتبار كما أنه لا يوجد استقرار على منهجية محدده عند تصميم المباني السكنية يأخذ في الاعتبار أولويات الساكن واحتياجاته وأقتصر الامر على ان يقوم البائع بعرض الوحدات المتاحة من خلال الكتالوجات والمواقع الالكترونية لاختيار النموذج المناسب لرغبات العميل وحيث أنه لا توجد الى الان تطبيقات لنظام تخصيصي شامل لتصميم المنازل السكنية في مصر فقد أصبح من المهم التوصل الى تطوير تطبيق قادر علي تحديد أولويات الصفات والعناصر الأساسية للعميل في تصميم المباني السكنية وأخذها في الاعتبار وذلك من خلال استخدام التطبيقات الرقمية المتاحة والتي تمتاز بإمكانية استخدامها بواسطة مستخدم ليس له خلفية معمارية.

أغلب الأبحاث التي قدمت سابقا تعتمد على تعديل تصميم الشكل معماري للمباني السكنية بما يتناسب واحتياجات وأولويات الساكن ولكنها لا تهتم كثيرا في كيفية استخلاص هذه الأولويات والخصائص للمباني السكنية من راغبي شراء هذه الوحدات وتحليلها في ظل التكنولوجيات الحديثة على شبكه الانترنت والنظم الرقمية.

لذلك فأن أحد الأسئلة المطروحة في هذه الدراسة هي عن أمكانية تطوير نظام تخصيصي شامل للمنازل السكنية في الأسواق العقارية في مصر.

يهدف البحث الى تصميم أسلوب للعمل يتكفل بوضع السوق العقارى في مصر على قاعدة بيانات رقمية وتصميم أداة الكترونية تتيح للعميل ذو الخلفية غير المعمارية التعامل مع قاعدة البيانات للحصول على التصميم المناسب للوحدة السكنية.

تعتمد منهجية البحث على الأسلوب الاستنباطي والتحليلي والتطبيقي في نفس الوقت. منهج استنباطي من خلال مراجعه الأبحاث المنشورة ذات الصلة للحصول على فهم شامل للموضوع تحت الدراسة والدراسات السابقة في هذا المجال ووضعها في الاعتبار عند معالجه المشكلة والحصول على البيانات ذات الصلة من خلال شركات المقاولات العاملة في مصر مع تحديد مجالات دراسة الحال وعمل استطلاع للرأي للحصول على تقديرات العملاء للعناصر المختلفة للمبني السكنى.

الكلمات الدالة: المبني السكنى، أولويات الساكن واحتياجاته ،نظام تخصيصي شامل لتصميم المنازل السكنية

[1] مدرس مساعد بكلية الهندسة في الأكاديمية العربية للعلوم والتكنولوجيا.
nour_salama@aast.edu
[2] أستاذة العمارة في كلية الفنون الجميلة - جامعة الإسكندرية.
nevin.gharib@alexu.edu.eg
[3] أستاذة العمارة في الأكاديمية العربية للعلوم والتكنولوجيا.
Gihan.mosaad@aast.edu