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Developing a Model for User Satisfaction Assessment in Energy Efficient Dwellings

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Abstract

Energy efficient dwellings are the buildings, energy consumption of which is minimized throughout their design, construction process and the whole life cycle. They are also defined as buildings which ensure healthy and productive environments for their users. However, the research on energy efficient dwellings in the literature, on the other hand, mainly addresses the topic in the context of environmental and economic sustainability. Residential user satisfaction, which is among the most important factors in the architectural design process, not sufficiently emphasized in the research on energy efficient dwellings. This study aims to determine the user satisfaction in energy efficient dwelling design and application studies comprehensively. Ultimately, it is aimed to develop a model of user satisfaction measurement which can be used throughout the design / construction process and afterwards to this end. Model components were derived from the analysis of various indicators. In this process, characteristics of energy efficient buildings, certification system criteria, housing quality standards and indicators obtained from the academic studies in the literature were taken into consideration. The assessment proposals formed in this way were applied to the pre-determined residential users, and then the indicators were reviewed. In the light of the data obtained through the field survey, the main themes and sub-indicators of the model were finalized. At the end of all the analyses, the explanatory power of the themes of the model were found satisfactory on the phenomenon that is aimed to measure.

Keywords: Energy efficient buildings; user satisfaction; energy efficient housing; satisfaction model

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Desarrollo de un modelo para la evaluación de la satisfacción del usuario en viviendas energéticamente eficientes

Resumen

Las viviendas energéticamente eficientes son los edificios cuyo consumo energético se minimiza a lo largo de su diseño, proceso de construcción y todo el ciclo de vida. También se definen como edificaciones que aseguran ambientes saludables y productivos para sus usuarios. Sin embargo, la investigación sobre viviendas energéticamente eficientes en la literatura aborda principalmente el tema de la sostenibilidad ambiental y económica. La satisfacción del usuario residencial, que se encuentra entre los factores más importantes en el proceso de diseño arquitectónico, no está suficientemente enfatizada en la investigación sobre viviendas energéticamente eficientes. Este estudio tiene como objetivo determinar la satisfacción del usuario en el diseño de viviendas energéticamente eficientes y los estudios de aplicación de manera integral. En última instancia, se pretende desarrollar un modelo de medición de la satisfacción del usuario que pueda ser utilizado durante todo el proceso de diseño/construcción y posteriormente con este fin. Los componentes del modelo se derivaron del análisis de varios indicadores. En este proceso se tomaron en cuenta las características de los edificios energéticamente eficientes, los criterios del sistema de certificación, los estándares de calidad de la vivienda y los indicadores obtenidos de los estudios académicos en la literatura. Las propuestas de evaluación formadas de esta manera se aplicaron a los usuarios residenciales predeterminados y luego se revisaron los indicadores. A la luz de los datos obtenidos a través de la encuesta de campo, se finalizaron los principales temas y subindicadores del modelo. Al final de todos los análisis, se encontró satisfactorio el poder explicativo de los temas del modelo sobre el fenómeno que se pretende medir.

Palabras clave: Edificios energéticamente eficientes; satisfacción del usuario; vivienda energéticamente eficiente; modelo de satisfacción

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1. Introduction

The rapid growth in the world population, industrial and technological advancement increases the energy consumption in the world. As the energy need is met from non-renewable energy sources, it leads to adverse impacts on the world ecosystem. Therefore, the use of renewable energy sources is gaining more importance. In addition, there are many other reasons to save energy. Efficient use of energy brings along positive ecological, economic, and humane outcomes. Efforts to use energy efficiently raise individuals' awareness towards the environment and its impact on humanity (Inter Academy Council, 2007; Lam *et al.*, 2008; Gargiulo *et al.,* 2016).

According to the Global Situation Report of the United Nations Environment Programme, approximately 40% of the energy consumption in the world is consumed during the building use phase in line with the building construction process or user needs; and this data reveals the importance of the role played by the building construction and management in this process (United Nation Environment Programme [UNEP], 2017). In this regard, to minimize the environmental impacts of buildings, such as energy consumption, air pollution, water consumption, heat source effect, negative effects on soil, vegetation and living life, the field of architecture needs to improve sustainability (Lam *et al.*, 2008; Utkutuğ, 2002; Yüksek *et al.*, 2017). In this context, the term of energy efficient dwellings emerges in architecture. To ensure energy efficiency in buildings, especially it is necessary to prevent heat transfer between the indoor and outdoor environment, to optimize heat gain and to meet indoor comfort needs at the same time. Outdoor weather conditions (especially outdoor temperature and available solar radiation during the heating period) have a significant impact on the choice of building layout, single or composite construction materials and application techniques, design, and preparation of system details (Isaksson & Karlsson, 2006). In overall, energy efficient dwellings refer to the buildings, the energy consumption of which is minimized throughout their design, construction process, and the whole life cycle, and which provide healthy and productive environments for their users by adopting sustainable principles. The main approaches in the research on energy efficient dwellings are as follows:

- Assessment of measures on energy efficiency,
- Assessment of systems that generate energy,
- Adopting a holistic approach towards the systems that generate energy and precautions taken for energy efficiency (Gonzalo & Habermann, 2006).

On the other hand, the main aims of them are developing systems to reduce the amount of energy use, CO2 emission, and costs, and investigating the efficiency levels, and evaluating the precautions. Residential user satisfaction, which is among the most important factors in the architectural design process, not sufficiently emphasized in the research on energy efficient dwellings. The present study aims to determine the user satisfaction in energy efficient dwelling design and application comprehensively, and to reveal the need to consider the user satisfaction, energy consumption values, ecological and economic factors. Ultimately, it is aimed to develop a user satisfaction assessment model which can be used throughout the design / construction process and afterward to this end.

2. Residential user satisfaction in the literature

Residential user satisfaction refers to a dependent attitude to the dwelling environment. As suggested by Rosenberg and Hovland (1960), some researchers prefer the definitions of emotional-based components to define user satisfaction in housing, while others prefer perception-based definitions among different attitude components (knowledge, emotional and behavioral), (Amerigo, 2002).

In definitions with a significant emotional component, residential user satisfaction means reflecting the feelings of satisfaction and happiness to the dwelling which creates these feelings (Gold, 1980; Weidemann & Anderson, 1985). In definitions with a significant informative component, on the other hand, residential user satisfaction consists of the factors between the current conditions of the users and the standards expected and demanded by them (Campbell *et al.*, 1976; Marans & Rodgers, 1975; Wiesenfeld, 1992). In the informative approach, Bardo and Hughey (1984), Canter and Rees (1982), Morrissy and Handal (1981) assert that as the residential user satisfaction increases as the difference between the current situation and the demands and needs decreased.

Rapoport suggests that people prefer to be in environments suitable for their psychological and social needs (Rapoport, 1980). In this scope, dwelling selection is also affected by many factors such as household, house type, house size, stage in the life cycle, structure, social class, education and current occupation, household income, neighbourhood / location, and norms regarding dwelling expenditures (Marans, 2003). It is reported that living standards, quality improvement, and social performance should be in line with the demands of the household (Al-Faqih, 2009). User satisfaction as an indicator of individual well-being plays a key role in life quality (Marans & Gocmen, 2005). Satisfaction encourages users to stay while encouraging other individuals to come in. Low satisfaction, on the other hand, pushes users to move away and search for new places (Marans & Rodgers, 1975; Hur & Morrow-Jones, 2008). Satisfaction with neighbourhood characteristics (physical, social, and economic) affects other satisfaction areas as well. Satisfaction with physical characteristics affects both neighbourhood and dwelling satisfaction. Neighbourhood satisfaction plays a role in community satisfaction, and dwelling satisfaction is effective in household satisfaction. Both community satisfaction and household satisfaction are effective on life satisfaction (Marans, 2005; Hur & Morrow-Jones, 2008; Sirgy, 2002).

Morris and Winter (1978) describe residential user satisfaction as "being satisfied with current dwelling conditions". Francescato suggests that satisfaction reflects people's reactions to the environment in which they live. The term 'environment' relates not only to the physical components of dwelling and neighbourhood but also to social and economic conditions.

Besides, Francescato reports physical, social, and managerial/administrative factors that determine the level of user satisfaction in the dwelling can be measured with if appropriate techniques to be used in data collection and analysis (Francescato, 1997). The model of Francescato *et al.* (1974), one of the earliest examples, showed that residential user satisfaction consists of user expectations as well as physical characteristics. The model contains four main categories: physical characteristics, users, management, and communities. The variables included in four main categories are conceptually clustered in fifteen aspects: density/crowd, security, aesthetics/appearance/ field facilities, access to friends, access to location/community, care, cost, sense of community, management policy, personal freedom/privacy, community perception, neighbor perception, personality traits, demographic features (Francescato *et al.*, 1974).

Sirgy suggests that physical characteristics include crowding and noise level, lighting, environmental quality, and scenery; social characteristics include social interaction with neighbours, places, relationships with people, and home privacy. Economic characteristics are listed as house value in the neighbourhood, cost of living, and socio-economic status in the neighbourhood (Sirgy, 2002). Gur and Dostoğlu (2010) determine satisfaction criteria as social facilities and open spaces, environmental characteristics, physical characteristics of the dwelling, accessibility, and transportation, security, climatic control of dwelling, and neighbourhood relations. In their study, Forte and Russo formed three different groups which determine the factors mainly affecting the quality of life to detect the importance of the factors on residential user satisfaction: Quality of open spaces, quality of internal common fields, and housing unit quality (Forte & Russo, 2017).

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In their study, Al-Homoud and Is-haqat categorize the indicators that affect residential user satisfaction under seven titles: Project location, dwelling design, project design, financial issues, infrastructure issues, environmental issues, social issues (Al-Homoud M. & Is–Haqat, 2019). Barutçular and Dostoğlu (2019) discuss user satisfaction factors under six items being location, scenery, site advantage, garden (green area), neighbourhood, and family unity.

According to Somiah *et al.* (2017), the important indicators of user satisfaction in dwellings are the quality of buildings, social characteristics, the neighbourhood, management features and the residential unit's features. Gündoğdu *et al.* (2019) in their study on user satisfaction in dwellings, they discussed the subject under two main headings: dwelling satisfaction and its environment satisfaction. Dwelling satisfaction was questioned under the headings of location, size, interior layout, functionality, usability, indoor comfort conditions, sunlight, ventilation, insulation, exterior appearance, and landscape. The environment satisfaction was analyzed under the headings of distance between the buildings, street widths, privacy, sun exposure of the buildings, green space, children's playground, presence of car parks, vehicle safety, human and housing security, neighborhood relations, access to the center, education areas, health areas, access to open spaces, entertainment areas, shopping areas and public transport stops. Jiang *et al.*, (2020) in their study conducted in 2020, stated that the main dimensions of user satisfaction in dwellings are housing dimension, living environment dimension and neighborhood dimension. Jiang *et al.*, (2020), stated that the main dimensions of user satisfaction in residences are Housing dimension, living environment dimension and neighborhood dimension. Housing dimension includes floor, size, bedroom no. indicators. Living environment dimension consists of distance of primary school, distance of retail shop, distance of mall, distance of health centre, distance of recreation, distance of metro station, bus stop no. indicators. Neighborhood dimension includes commuting time, store no., frequency of meeting neighbors, known neighbor no., familiar neighbor no., new neighbor no., frequency of community activities, frequency of self-organized activities, frequency of joining management indicators.

Residential user satisfaction is an indicator of environmental and vital quality (Yıldız & Ulusoy, 2014; Salazar & Vázquez, 2021). A housing quality assessment provides information about the current state of the dwelling stock, current wishes, and needs of residential users as input for further projects. Most of the studies analysed on housing quality are based on user satisfaction. Housing quality, which is discussed in the context of user satisfaction, is a broad term that encompasses many aspects and has both an objective and a subjective dimension. Objective size consists of many important aspects such as the dwelling, room numbers, the presence of social facilities, and the dwelling condition. The subjective dimension includes user characteristics that lead to specific needs, desires, and expectations. In summary, housing quality criteria include dwelling conditions such as the characteristics of a physical environment and residential users (Elsinga & Hoekstra, 2005; Brkanić, 2017). In this context, user satisfaction-oriented housing quality standards have been developed in dwellings. The Housing Quality Indicator (HQI) system brings a special emphasis to the association between housing quality and real consumer experience in various traditional and innovative development programs (Harrison, 1999). The Housing Quality Standards (HQS) and Housing Quality Indicator (HQS) systems examined in this study, include both objective and subjective indicators covering many aspects in terms of user satisfaction. In the general framework, dwelling and its environment are handled together in these systems.

Studies in the literature show that several variables of dwelling and its environment, including the socio-demographic characteristics of the residential users, have significant effects on the level of residential user satisfaction/dissatisfaction; they are also related to culture and values. This reveals the importance of evaluating the studies on dwelling satisfaction/dissatisfaction through user experience and feedback.

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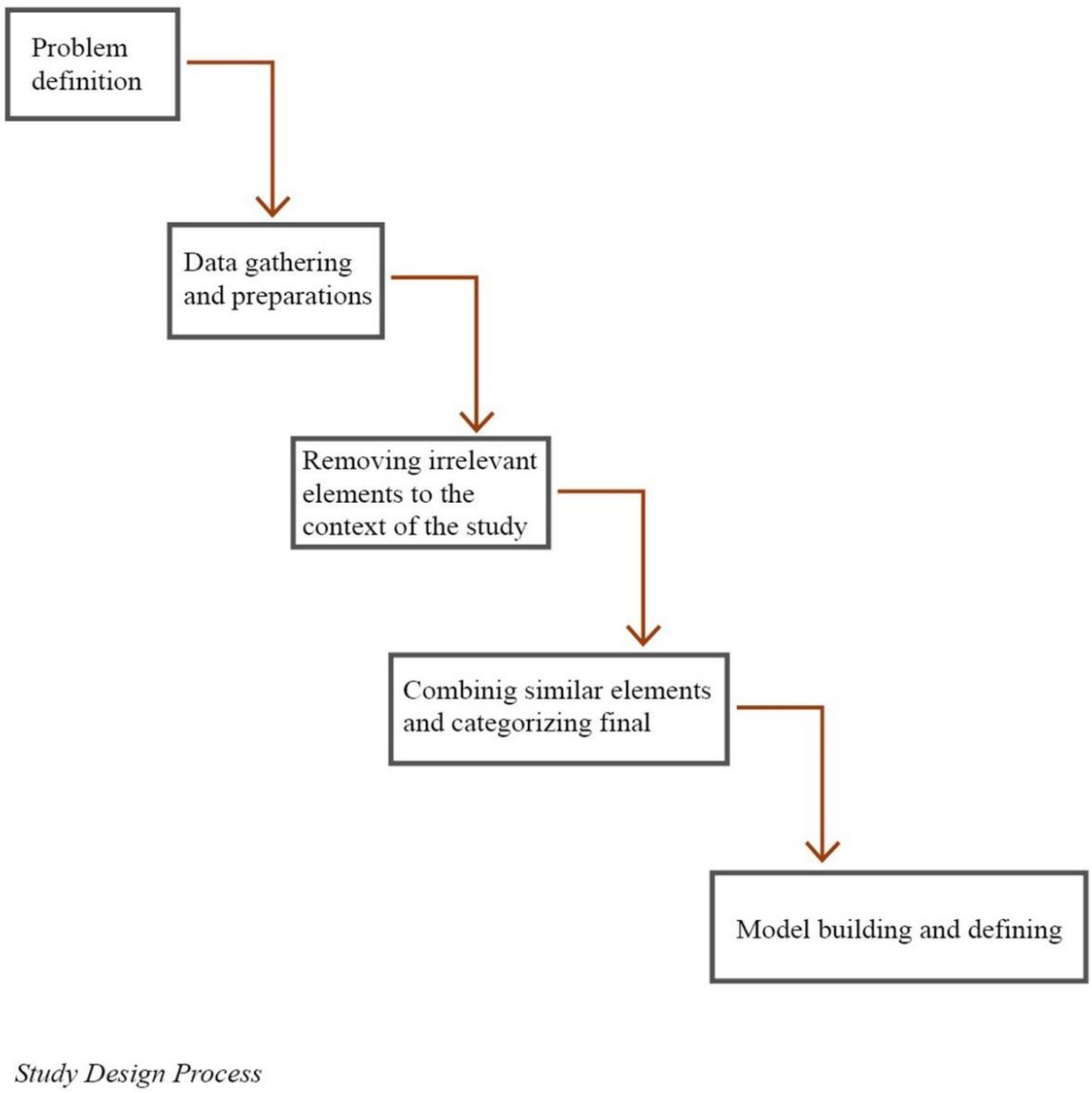
3. Study design and method

While obtaining the indicators to be used in the model, characteristics of energy efficient buildings, criteria of certification systems, housing quality standards, and academic studies in the literature were used. In the process of developing a model for evaluating user satisfaction in energy efficient dwellings, the problem was defined first. Afterward, necessary data were accessed during the data collection process, different factor groups affecting user satisfaction were determined and these data were classified. Out of the classified parameter set, the assessment proposals/questions were determined to be directed to the users in the field survey. In the light of the data obtained from the field survey, the main themes and sub-indicators of the model were formed, and the assessment proposals were finalized. In the following stage, the model was applicable at the determined residential building. (Figure 1).

Figure 1. Study design process



Source: Prepared by the Authors.

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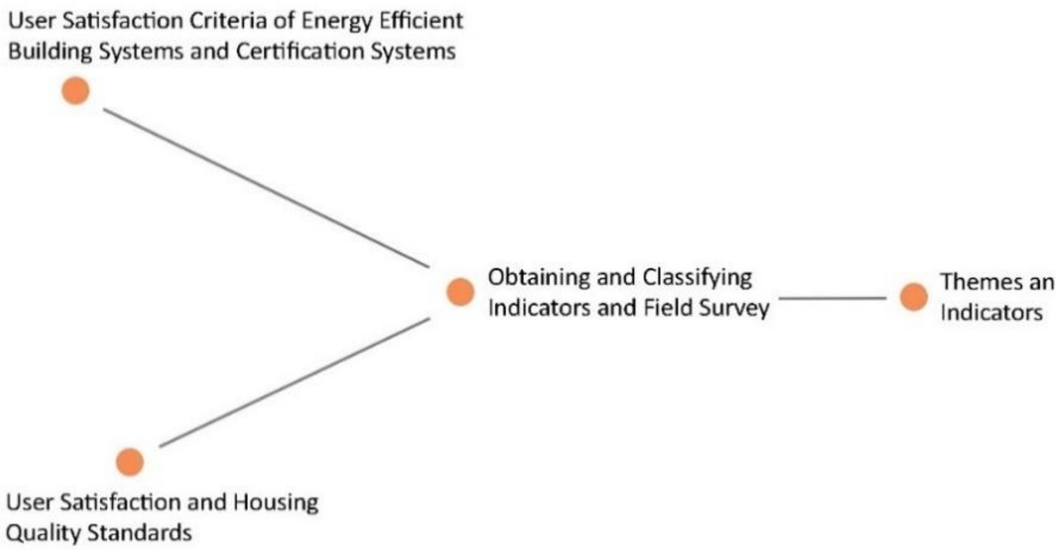
3.1 Process of Obtaining and Grouping Main Themes and Sub-Indicators

It is considered that energy efficient building systems and certification criteria should be considered together with user satisfaction indicators in the literature and housing quality standards during the model development process (Figure 2).

Figure 2. The phase of obtaining the main themes and sub-indicators of the model



Source: Prepared by the Authors.

The characteristics of energy efficient dwelling systems (passive houses, green buildings, zero-energy, zero-carbon houses) have been effective in the model development process. Besides, assessment criteria of Passive House (Passivhous) of German origin, Leadership in Energy and Environmental Design (LEED) of American origin, Building Research Establishment Environmental Assessment Method (BREEAM) of UK origin, Australia's GREEN STAR, Germany's German Sustainable Building Council System (DGNB), Japan's Comprehensive Assessment System for Built Environment Efficiency (CASBEE), Canada's Sustainable Building Tool (SBTool), "Excellence in Design for Greater Efficiencies" (EDGE) the certificate system developed by the International Finance Corporation (IFC), Energy Performance Certificate (EPC) that play a central role in the context of the Article 20 (2) of Energy Performance of Buildings Directive 2010/31/EU (EPBD), France's High Quality Environmental Standard (HQE), China's National Evaluation Standard for Green Building (ESGB) and the assessment criteria of the certification system B.E.S.T prepared by the Green Building Council of Turkey were analysed. The criteria of the certification systems developed for the residential buildings were considered to obtain the main themes and indicators of the model. In Table 1, the criteria regarding user satisfaction are highlighted in orange.

As for the assessment criteria of the certification systems, the user-oriented criteria include "Health / Well-Being" criterion in BREEAM, HQE, ESGB and B.E.S.T systems; "Location" criterion in LEED V4, DGNB, SBTool, ESGB and B.E.S.T systems; "Transportation" criterion; in LEED V3, LEED V4, BREEAM, GREEN STAR, DGNB, SBTool, ESGB and B.E.S.T systems; "Indoor Quality / Comfort" criterion in In LEED V3, LEED V4, GREEN STAR, DGNB, CASBEE, SBTool, HQS, ESGB and B.E.S.T systems; "Building Management" criterion in BREEAM, GREEN STAR and ESGB systems; "Socio-cultural Status / Life" criterion in DGNB, SBTool, and B.E.S.T systems; "Technical / Service Quality" criterion in DGNB, HQS, ESGB and SBTool systems.

Table 1. Comparison of the assessment criteria of the certification systems

Assessment Criteria	LEED V[3]	LEED V[4]	BREEAM	Passive House	GREEN STAR	DGNB	CASBEE	SBTool	EDGE	EPC	HQE	ESGB	B.E.S.T.
Country Origin	USA	USA	UK	Germany	Australia	Germany	Japan	Canada	IFC	Europe	France	China	Turkey
Energy	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Water	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Material	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Health / Well-being	-	-	✓	-	-	-	-	-	-	-	✓	✓	✓
Location	-	✓	-	-	-	✓	-	✓	-	-	-	✓	✓
Transportation	✓	✓	✓	✓	✓	✓	-	✓	-	-	-	✓	✓
Integrated Process Management /Pre-planning	-	✓	-	✓	✓	✓	-	-	-	-	-	✓	✓
Sustainable Land / Ecology	✓	✓	✓	-	✓	✓	✓	✓	-	✓	✓	✓	✓
Indoor Quality /Comfort	✓	✓	-	✓	✓	✓	✓	✓	-	-	✓	✓	✓
Environmental pollution / Emissions	✓	✓	✓	-	✓	-	-	✓	-	✓	✓	-	-
Waste in the Construction Process	✓	✓	✓	-	-	-	-	-	-	-	✓	-	✓
Building Management (user oriented)	-	-	✓	-	✓	-	-	-	-	-	-	✓	-
Regional Priority	✓	✓	-	-	-	-	✓	-	-	-	-	-	-
Ecological Innovations	✓	✓	✓	-	✓	-	-	-	-	✓	-	✓	✓
Socio-cultural Status / Life	-	-	-	-	-	✓	-	✓	-	-	-	-	✓
The Economy in the Construction Process	-	-	-	-	-	✓	-	✓	-	-	-	-	-
Technical / Service Quality	-	-	-	-	-	✓	-	✓	-	-	✓	✓	-
Air Filtering	-	-	-	✓	-	-	-	-	-	-	-	-	-
Non-Residential Environment	-	-	-	-	-	-	✓	-	-	-	-	✓	-
Safety and durability	-	-	-	-	-	-	-	-	-	-	-	✓	-

Source: Prepared by the authors.

In the following phase of forming the main theme and indicators of the model, the studies on housing quality assessment systems conducted in the scope of user satisfaction were examined, the internationally recognized House Quality Indicator (HQI) and The Housing Quality Standards (HQS) systems were evaluated during the model development process and their indicators were compared.

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Criteria regarding user satisfaction are highlighted in orange in Table 2. Comparison of the housing quality standards reveals that health, location, open spaces, spatial quality, waste management, lighting, accessibility, and auditory comfort indicators stand out.

Table 2. Comparison of the assessment criteria of the housing quality

Assessment Criteria	HQI	HQS
Location	✓	✓
Open Spaces	✓	✓
Health	-	✓
Spatial Layout	✓	✓
Routes and Movement Areas	✓	-
Security	-	✓
Food Preparation and Waste Disposal	-	✓
Sanitary Units	-	✓
Sustainability	✓	-
Indoor Air Quality	-	✓
Lighting	✓	✓
Electricity	-	✓
Thermal Environment	-	✓
Smoke Detectors	-	✓
Dimensions	✓	-
Building and Materials	-	✓
Accessibility	✓	✓
Auditory Comfort	✓	✓
Air Pollution of the Region	-	✓
Water Supply	-	✓
Lead-Based Paint	-	✓
Visual Impact / Landscape Layout	✓	-
Technical Quality / Service Quality	✓	-
Inclusive Environment	✓	-

Source: Prepared by the Authors.

The indicators collected and reported in the related research in the literature were added to those obtained from the assessment tools (energy efficient building systems, certification criteria, and housing quality standards) and a total of 252 indicators were obtained.

In the studies, the abovementioned indicators on user satisfaction were considered and the indicator set was mitigated to user satisfaction-related 194 indicators. In Figure 3, these 194 indicators are highlighted in black. Indicators extracted from the scale are highlighted in red.

After detecting the user satisfaction-related indicators, those having the same meaning and/or can be grouped under one heading were named with a common name and the number of indicators was reduced to 33.

These indicators were classified under 4 main themes: "Health", "Comfort Conditions", "Dwelling-Environment Relationship" and "Systemic Characteristics and Service Features" (Table 3).

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Figure 3. The phase of obtaining the main themes and sub-indicators of the model

~~Ecological Innovations~~
Auditory comfort
Unidentified allergic reactions
Air quality
Transportation
~~Water~~
Dimensions
Relationships within the community
Eye dryness
~~Waste in the Construction Process~~
Operating costs
Social and Cultural Status
Environmental quality
Spatial Layout
Fatigue
Routes and Movement Areas
~~Building and Materials~~
Familiarity with the systems
~~Material~~
Sanitary Units
~~Water supply~~
Access to Management
~~Environment-Friendly Contractor~~
Facilities
Visual Impact
Shared Open Space
Shared Internal Areas
Car Parking Area for Visitors
~~Unit Type by Areas~~
Living Area
~~Additional Features~~
~~Energy Efficient White Goods~~
Elevators
Wheelchair Design Products
~~Ecological Innovation~~
External environment
Roads, Parking Areas and Pedestrianisation
~~Material~~
Neighbourhood
Physical Characteristics
Density / Crowded
Access to Friends
~~Management Policy~~
Personal Freedom / Privacy
Personality / Demographic Characteristics
Size
Internal View
Nearby Dwellings
Space
Neighbours
Crowding and Noise Level
Scenery
~~House Value in the Neighbourhood~~
~~Construction Process - Economic Characteristics~~
Social Relations with Neighbours
Environmental Qualities
Climate Control of the House
Protection Against Theft
~~Reducing the Heat Island Effect~~
Quality of Common Internal Areas
~~Flat Roof Equipment and Suitability~~
Sound Insulation
Community Areas within the Building
Bathroom Ventilation
Project Density (Floor Space Ratio)
Bad Smells
Location
Spatial Settlement in Dwelling
Sunlight Receiving
Street Widths
~~Prevention of Construction Pollution~~
Eye Dryness
~~Environmental Product Declarations~~
~~Construction / Demolition Waste Management~~
~~Advanced Commissioning~~
Air Filtering
Equipped Green Space
Proximity to Urban Accessories
Thermal Comfort
Universal / Inclusive Design
On-Site Waste Separation and User Access
~~Reducing Light Pollution~~
Nausea
Spatial layout in compliance with the lifestyle (social environment)

~~Environmental pollution~~
Reporting complaints
~~Energy~~
Accessibility
Spatial comfort
Noise Control
~~Plan~~
Building management
~~Sustainable Land~~
Smoke Detectors
~~Regional Priority~~
Technical Quality
Open Spaces
User Control Level
Cough Problem
Access to facilities
Food Preparation and Waste Disposal
Dryness and congestion of the throat, nose
~~Air Pollution of the Region~~
~~Sustainability~~
~~Lighting and Electricity~~
Lead-Based Paint
Life
Health Problems Caused by Paints and Coatings
~~Obligations~~
Plan / Layout
Site Security
Private Open Area
Access of people with disabilities to green space
~~Units by Living Areas~~
Dining Area
Bathroom
~~Use of Raw Material~~
Inclusive Environment
~~Sustainable Houses~~
~~Lighting (Savings)~~
Environment and Society
Space and Security
Environment and Neighbourhood
Administrative Factors
Administration
Aesthetic/ Appearance
Location / Access to Community
Sense of Community
Perception of Community
Number of rooms
Floor plans
~~Rainwater Management~~
Immediate Environment
Privacy-related issues
Urban Life
Environmental Quality
~~Land Use and Ecology~~
~~Building Cost of Living~~
Variables of Physical Location
The appearance of the Dwelling Environment
Physical Characteristics of the Dwelling
Neighbourhood Relationships
~~Tracking Consumption Values~~
Pedestrian Safety
Lobby Equipment and Condition
Dizziness
Living Areas
Dwelling Design
Thermal Insulation
Infrastructure Issues
Dusty winds
Garden
Practicality
Ventilation
Accessibility to the Center
Public Transport Efficiency
~~Land Assessment and Land Development~~
Social Interaction with Neighbours
~~Basic Commissioning and Verification~~
~~Use of Low Emission Materials~~
~~Renewable Energy Use~~
Circulation and Storage
Perception of Control
Contact with Nature
Sports and Recreation Areas
Building Usage and Maintenance Information
Health and Comfort
Number of Parking Areas

Waste management
Building Maintenance
Chemical substance-related disturbances
~~The economy in the construction Process~~
Social Accessories
Security
~~Integrated Process Management~~
~~Ecology~~
~~Emissions~~
Seasonal illnesses
~~Non-Residential Environment~~
Visual comfort
Service Quality
Health Conditions
~~Impact on the Non-Residential Environment~~
Headache
Visual Impact
Landscape Layout
Eliminating system malfunctions
Thermal comfort
Thermal Environment
Resolution of Complaints
Neighbourhood
Location
Noise Sources
Landscape
Playgrounds
Car park
Access to the Dwelling Unit
Furniture
Bedroom
Kitchen
Services
~~Adaptability~~
~~Eco-homes~~
~~Material Content~~
~~Design and Construction~~
Thermal Environment
Health Conditions
Social Factors
Communities
Field Facilities
Maintenance
~~Construction Cost~~
Perception of Neighbor
Number of Bedrooms
Internal conditions
Location of the Dwelling
Physical Environmental Conditions
Behavioral
Household
Lighting
~~Use of Local Materials~~
Socio-economic Status in the Neighbourhood
Neighbourhood Conditions
Social Facilities and Open Spaces
Accessibility and Transportation
Quality of Open Spaces
Access to the Building
Privacy Systems
Availability for Users with Disabilities
Artificial Lighting
Service Areas
Project Location
Moisture Insulation
Lighting Competence
Factory Smoke
Neighbor Relations and Family Union
Indoor Comfort Conditions
Distance Between Buildings
General Dwelling
Lighting Quality
~~Reducing Building Life Cycle Impact~~
Home Privacy
Infectious Control
Environmental Cigarette Smoke
Outdoor Lighting
~~Reducing Water Use~~
Fresh Air
~~Use of Eco-Friendly Materials~~
Homeworking
Public Transportation
Lachrymation
Dominance Against Systems

Source: Prepared by the Authors.

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Table 3. Grouping the indicators obtained

Health	Comfort Conditions	Dwelling-Environment Relationship	Systemic Characteristics and Service Features
Seasonal diseases (depending on heating, cooling, ventilation systems)	Visual comfort	Location	User control and challenges
Eye dryness / lachrymation / rashes	Thermal Comfort	Transportation	Familiarity with and knowledge of systems
Dryness and congestion of the throat, nose	Auditory Comfort	Access to facilities	Adequacy of in-dwelling technical equipment
Headache / dizziness / nausea	Spatial Comfort	Accessibility	Building maintenance
Unidentified allergic reactions	Air Quality	Social facilities and open green spaces	Waste management
Cough problem		Environment/neighbourhood quality and scenery / visual impact	Water loop and disposal/drainage systems
Infectious diseases		Density / crowd	Security
Fatigue		Compliance with lifestyle / homogeneity	Operating costs
Chemical disturbances (paint / VOC etc.)		Relationships in the community and neighbourhood relations	Building management and ease of access to management
			Notification and resolution of system malfunctions and complaints

Source: Prepared by the Authors.

3.2 Data Analysis

In the model development processes firstly, explanatory factor analysis is conducted for the exploring the factor structure of the research scale. In this process, factors determined according to the eigenvalue >1 criterion and varimax rotation method was used.

After two replicate explanatory factor analysis the reliability of the obtained structure was tested with the Cronbach's alpha test. Then spearman correlation test was performed to measure intraclass correlation relationships and finally to an independent t-test was conducted with the upper and lower %27 of the participants to test the distinctiveness of research items.

In this analysis the scale total score was obtained by the sum of the total scores of the scale factors, and the scores of the factors were obtained by summing the scores of each item related to the factor.

Confirmatory factor analysis was carried out to test the construct validity of the scale, which was finalized because of exploratory factor analysis and whose factor structure was determined in a four-factor structure.

Finally, the research scale, which is accepted as a valid and reliable scale, was tested around a model and in this model, overall residential satisfaction level was accepted as the dependent variable, while the four sub-dimensions of the research scale were accepted as independent variables and multiple linear regression test was performed.

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4. Data, Variables, and Model

Multi-stage sampling method was used in the sample selection of the study. In multi-stage sampling methods, sampling of mass units takes place in multiple stages (Singh, 2003). In Turkey, which was determined as the universe, the energy efficient houses in the Istanbul cluster were determined. Two dwelling projects out of the determined 42 dwellings were determined as suitable for reaching the sample and the sample of the study was chosen from two energy efficient dwellings located in Esenyurt, Istanbul and Şişli, Istanbul (Figure 4). One of the dwelling projects is LEED Gold- and the other is LEED Silver-certified residential buildings (Figure 5).

Figure 4. The locations of the residential buildings on which the field survey was conducted in the model development process, Istanbul, Turkey

Source: Taken from Google Maps.

Figure 5. Residential buildings on which the field survey was conducted in the model development process, Istanbul, Turkey

Source: Taken by the Authors.

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In the process of determining the indicators and creating assessment proposals, experts working in different fields were also interviewed and their opinions were received. In the light of the obtained parameters, a form containing 108 assessment proposals to be answered by the users in the field survey was prepared.

The form prepared consists of two parts. The first part includes questions about the demographic and socio-economic characteristics of the participants. The second part consists of the proposals to determine the satisfaction levels of the users. Likert scale was used in the proposals. Each of the statements in the form prepared for the present study includes a five-point Likert scale, namely "1- Strongly Disagree", "2-Disagree", "3- Neutral", "4- Agree" and "5- Strongly Agree".

The fieldwork was carried out in October 2020. The Multi-Stage Sampling Method was used as the sampling type, so residents selected from energy-efficient residences were randomly included in the study.

Since the Multi-Staged Sampling method was used, all the accessible residential users, 206 participants, were reached (Questionnaires were delivered to 245 people and 206 responses were received. The response rate is 84%). The findings regarding the demographic information of the participants are presented in Table 4 below.

Table 4. Demographic information of participants.

Data	Description	Frequency	%
Gender	Male	71	35
	Female	135	65
Age	18-29	16	8
	30-39	63	31
	40-49	78	38
	50-59	31	15
	over 59	18	8
Marital status	Single	57	28
	Married	149	72
Ownership status	Property owner	131	64
	Renter	75	36
Education status	Literate	0	0
	Primary and secondary school	4	2
	High school	41	20
	Associate degree	16	8
	Undergraduate	111	54
	Graduate	34	16
Profession	Unemployed	9	4
	Civil servant	31	15
	Private sector employee	68	33
	Worker	1	1
	Businessperson	17	8
	Retired	36	18
	Other	44	21
Monthly household income (TL)	0- 3000	11	5
	3001- 7500	70	34
	7501- 10000	52	25
	over 10000	73	36

Source: Obtained by the authors using SPSS data analysis.

The data obtained from the field survey were examined through various analyses. The analyses are discussed in detail.

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4.1 Exploratory factor analysis

Validity indicates that the variable(s) that are intended to be measured can be statistically measured with different variants. The construct validity of the scale survey questions shows the degree to which the tool can accurately measure an abstract concept (factor) in the context of the desired behaviour (Tavşancıl, 2002). Therefore, factor analysis is performed to measure the construct validity of the questions involved in a scaled questionnaire (Büyüköztürk, 2002). SPSS 25 program was used the factor analysis and all analyses of the study. Of the factors conceptualized within the framework of the present research, Comfort Conditions were abbreviated and used as "CC", Dwelling Environment Relationship as "DER", Health as "HEA" and Systemic Characteristics and Service Features as "SCS".

Initially, Explanatory Factor Analysis was administered to 108 evaluation proposals/questions involved in four different and main dimensions pre-determined for the present study to check the construct validity and distribution by the factors statistically. To ensure consistency of the results, statements in the same scale group and having different qualitative expressions were grouped in the same way. As presented in Table 5, at the end of the factor analysis, the questions of the study were collected under 4 factors, which had eigenvalues greater than 1 and the explanatory rate of which was 42.916%. The explanatory rate was found sufficient to explain the phenomenon considering the literature findings. A rate between 40% and 60% is considered sufficient (Büyüköztürk, 2002; Tavşancıl, 2002). In the analysis, the lower limit of the factor load value was assigned as 0.400.

Table 5. **Factor analysis of the research scales**

Factor	Initial Eigenvalues			Tensile Sum of Square Loads			Rotation Sum of Square Loads		
	Total	Variance %	Cumulative %	Total	Variance %	Cumulative %	Total	Variance %	Cumulative %
1	32.410	30.009	30.009	32.410	30.009	30.009	16.423	15.207	15.207
2	5.494	5.087	35.096	5.494	5.087	35.096	10.743	9.947	25.154
3	4.505	4.171	39.267	4.505	4.171	39.267	9.604	8.893	34.047
4	3.940	3.648	**42.916**	3.940	3.648	**42.916**	9.578	8.869	**42.916**

Source: Obtained by the authors using SPSS data analysis.

In the first factor analysis performed, the distribution of the questions by the factors under the Component Distribution Matrix was examined. Accordingly, CC2, CC4, CC5, CC12, CC14, CC15, CC23, CC32, CC38, DER14, SCS4, SCS5, SCS10, SCS11, SCS14, SCS15, SCS17, SCS20, SCS 23 SCS24-labeled questions were not included as an explanatory under any factor, and thus removed.

20 proposals corresponding to 18.5% of 108 evaluation proposals were removed and the analysis continued with the remaining 88 proposals. The results of the new factor analysis are presented in Table 6 below. In the new factor analysis from which non-explanatory proposals were removed, the total variance explanation rate of the 4 factors raised to 46.407%, which is a better score.

Following the reliability test of the scale questions through the first-degree factor analysis, reliability analysis was administered to the questions. Theoretically, a secondary validity analysis is conducted following the reliability analysis, and the distribution of each scale question under the factors is examined.

Table 6. Total variance explained

Factor	Initial Eigenvalues			Tensile Sum of Square Loads			Rotation Sum of Square Loads		
	Total	Variance %	Cumulative %	Total	Variance %	Cumulative %	Total	Variance %	Cumulative %
1	27.614	31.379	31.379	27.614	31.379	31.379	15.553	17.674	17.674
2	5.271	5.989	37.368	5.271	5.989	37.368	9.114	10.357	28.031
3	4.365	4.960	42.328	4.365	4.960	42.328	8.323	9.458	37.489
4	3.739	4.249	46.577	3.739	4.249	46.577	7.998	9.089	46.577

Source: Obtained by the authors using SPSS data analysis.

4.2 Reliability analysis

Before the validity analysis, reliability analyses were conducted. Scales, the validity of which is not proven by statistical analysis methods, are not considered valid (Bindak, 2005). Cronbach's Alpha Reliability Test, the most widely used and valid test method in the literature, was administered to the scales of the study. According to this test method, despite variations in different disciplines, a reliability coefficient of 0.70 is regarded sufficient for scientific studies and 0.85 for studies including talent, interest, and skill scales (Şencan, 2005). In general, there is a consensus in the literature that a reliability coefficient of 0.70 and above is sufficient to ensure the reliability of a scale (Nunnally, 1978, Liu, 2003).

The results of the Cronbach's Alpha reliability test performed on the 88 questions, after removing the non-explanatory questions, are presented in Table 7. The reliability coefficient of the scale was found 0.974, which is adequate and at an excellent level.

Table 7. Reliability test of the scale

Cronbach's Alpha	Number of Items
0.974	88

Source: Obtained by the authors using SPSS data analysis.

The changes in the Cronbach's Alpha score were also examined in the case when the items were not included in the test. There was no positive effect of not including any item in the test on the reliability score, and it was concluded that no further improvement was required in terms of the reliability analysis of the scale.

4.3 Factor structure of the scale

Principal components factor analysis was administered to 206 participants' responses to the scale questions to determine the factor structure of the scale. While forming the analysis scale, CC2, CC4, CC5, CC12, CC14, CC15, CC23, CC32, CC38, DER14, SCS4, SCS5, SCS10, SCS11, SCS14, SCS15, SCS17, SCS20, SCS, 23 SCS24-labelled items were removed from the test variables as they decreased the reliability and validity according to the results obtained from the initial factor analysis and the Cronbach's Alpha reliability analysis.

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The results of the Kaiser - Meyer Olkin (KMO) coefficient and Bartlett's Test of Sphericity, which are used as a measure of whether the variables can be subjected to factor analysis or not, were examined.

The value obtained for the Kaiser - Meyer Olkin (KMO) coefficient was greater than 0.70, and the result of the Barlett's Test of Sphericity was found statistically significant (Significance Value should be Sig <0.05) (Büyüköztürk, 2002). As there is a significant relationship between the scale questions, the Direct Varimax rotation method was used, and the minimum factor load was taken as 0.40.

The results of Kaiser - Meyer Olkin and Bartlett's Test of Sphericity are presented in Table 8. According to the results, the Kaiser - Meyer Olkin test score, which was 0.892, was greater than 0.70 and found excellent (Büyüköztürk, 2002). It is classified as very good, very close to the 0.90 limit. The Significance Value (Sig.) of the Barlett's Test of Sphericity was less than 0.05, which was 0.000 and significant. These results present that the scale questions are suitable to conduct factor analysis and examine the factor structure.

Table 8. **Kaiser- Meyer Olkin and Bartlett's Test for Sphericity**

Kaiser-Meyer-Olkin Sampling Proficiency Testing.		0.892
Barlett's Test of Sphericity	Approximate Chi-Square	14653.155
	Df	3828
	Sig.	0.000

Source: Obtained by the authors using SPSS data analysis.

As suggested by the validity and reliability analyses, the study scale was finalized, and the factor structure of the scale is presented in Table 9 below.

Table 9. **Factor structure of the scale**

	Factors			
	1	2	3	4
CC1, CC3, CC6-11, CC13, CC16-22, CC24-31, CC33-37	0.408-0.723			
CC39	0.484			0.445
CC40-42	0.466- 0.573			
CC43	0.468			0.444
DER1-2			0.581-0.625	
DER3		0.459	0.486	
DER4-13, DER15-21			0.462-0.483	
DER22	0.409		0.522	
DER23-31			0.409-0.645	
HEA1-9				0.662-0.814
SCS1-3		0.541-0.656		
SCS6		0.504	0.450	
SCS7		0.543	0.480	
SCS8		0.526	0.410	
SCS9		0.487	0.408	
SCS12-13, SCS16, SCS18-19, SCS21-22, SCS25		0.446-0.531		

Source: Obtained by the authors using SPSS data analysis.

As for the distribution of the scale questions by the factors, there is a regular distribution under the factors in which the questions are conceptualized. In addition, CC39, CC43, DER3, DER22 and SCS6,

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SCS7, SCS8, and SCS9-labelled question items were collected and assessed under the factor with a high factor explanatory load. As a result, Comfort Conditions was determined as the 1st Factor, Systemic Characteristics and Service Features as the 2nd Factor, Dwelling Environment Relationship as the 3rd Factor, and Health Conditions as the 4th Factor.

4.4 Examination of the reliability and validity analysis of the sub-factors

In this section of the study, the reliability and validity of the 4 factors obtained are examined. Following the elimination of the variables to improve reliability, the factor questions obtained by the distribution were grouped and subjected to the Cronbach's Alpha test. As for validity, factor loadings obtained previously are reported.

At first, the statistical reliability of the Comfort Conditions sub-dimension, which was determined as the first factor of the study, was evaluated within the framework of the Cronbach's Alpha test. The test score performed on the 34 items of the Comfort Conditions sub-dimension was determined to be perfect with 0.950, which did not require any additional improvement on the sub-dimension. The Cronbach's Alpha reliability test result was obtained on the 15 items of Systemic Characteristics and Service Features, which are the second sub-dimension of the research scale as an excellent value of 0.917, and no additional procedure was required. The Cronbach's Alpha reliability test administered on 30 items of the Dwelling-Environment Relationship, the third sub-dimension of the research scale, resulted as an excellent value of 0.943 and no additional procedure was required. Finally, the results of the Cronbach's Alpha reliability analysis, administered on 9 items of Health Conditions, which is the fourth sub-dimension, are presented. The results of the Cronbach's Alpha analysis showed an excellent reliability score of 0.943. Regarding these results, the scale did not require any additional processing in terms of reliability (Table 10).

Table 10. **Reliability analysis of the sub-dimensions**

Sub-dimensions	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	Number of Items
Comfort conditions sub-dimension	0.950	0.951	34
System characteristics and service/service features	0.917	0.919	15
Dwelling-environment relationship sub-dimension	0.943	0.945	30
Health conditions sub-dimension	0.943	0.945	9

Source: Obtained by the authors using SPSS data analysis.

To measure the distinctiveness of 88 items used in the scale, the scores of 206 participants were ranked from high to low. According to this ranking, two groups of 56 people, corresponding to 27% of the sample, were obtained. While the first of the groups refers to the first 56 people with the highest scale score, the other refers to the 56 people with the lowest score. Independent T-Test was administered to compare the Lower and Upper group means. According to the Independent T-Test analysis, the participants' mean scores for 88 questions were found significant with 0.05 for all questions. This result shows that each of the questions is distinctive to what is meant to be measured. Therefore, 88 assessment proposals/questions met the criteria that can be included in the final form of the scale. Table 11 presents the Spearman correlation coefficients matrix for the overall scale and inter-correlation between each sub-dimension.

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The correlation coefficient approaching 1 indicates that there is a very strong correlation between the variables, the value between 0.7 and 1 indicates a high, 0.3-0.7 medium, and 0.3-0.0 indicates a weak correlation. In cases where the sign of the relationship is negative, there is a reverse correlation (Büyüköztürk, 2002).

Table 11. Correlation analysis of the scale total Scale sum and sub-dimensions correlation analysis

		Total Scale*	Comfort Conditions	Dwelling-Environment Relationship	Health	Systemic Characteristics and Service Features
Total Scale	p	1	.918**	.862**	.681**	.851**
Comfort Conditions	p	.918**	1	.661**	.546**	.769**
Dwelling - Environment	p	.862**	.661**	1	.469**	.622**
Health	p	.681**	.546**	.469**	1	.522**
Systemic Essence.	p	.851**	.769**	.622**	.522**	1

Total Scale*= total score was obtained by the sum of the total scores of the scale factors ** = sig <0.001
Source: Obtained by the authors using SPSS data analysis.

Table 12. The status of the research scale because of the analysis

Comfort Conditions	Dwelling-Environment Relationship	Health	Systemic Characteristics and Service Features
Visual comfort	Location	Seasonal diseases (depending on heating, cooling, ventilation systems)	User control and challenges
Thermal Comfort	Transportation	Eye dryness / lachrymation / rashes	Familiarity with and knowledge of systems
Auditory Comfort	Access to facilities	Dryness and congestion of the throat, nose	~~Adequacy of in-dwelling technical equipment~~
Spatial Comfort	Accessibility	Headache / dizziness / nausea	Building maintenance
Air Quality	Social facilities and open green spaces	Unidentified allergic reactions	~~Waste management~~
	Environment/neighbourhood quality and scenery / visual impact	Cough problem	Water loop and disposal/drainage systems (assessment proposals have changed)
	Density / crowd	Infectious diseases	Security
	Compliance with lifestyle / homogeneity	Fatigue	Operating costs
	Relationships in the community and neighbourhood relations	~~Chemical disturbances (paint / VOC etc.)~~	~~Building management and ease of access to management~~
			Notification and resolution of system malfunctions and complaints

Source: Prepared by the Authors.

Within the scope of all these analyses, the final version of the research scale is presented in Table 14. As a result of the exploratory factor analysis, the questions of the study were grouped under 4 four factors with eigenvalues greater than 1, and the explanatory rate of these 4 factors was found 46.577%, which is sufficient as it is above 40%.

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Furthermore, the opinions of experts working in different fields were taken during the determination of the indicators and the creation of assessment proposals/questions. Face-to-face interviews were made with the researchers who conduct research on user satisfaction in energy efficient buildings. Especially for the Indicators under the Health Theme, face-to-face interviews were made with the faculty members of the Department of Public Health of Çukurova University and Otolaryngology-Head and Neck surgery specialists.

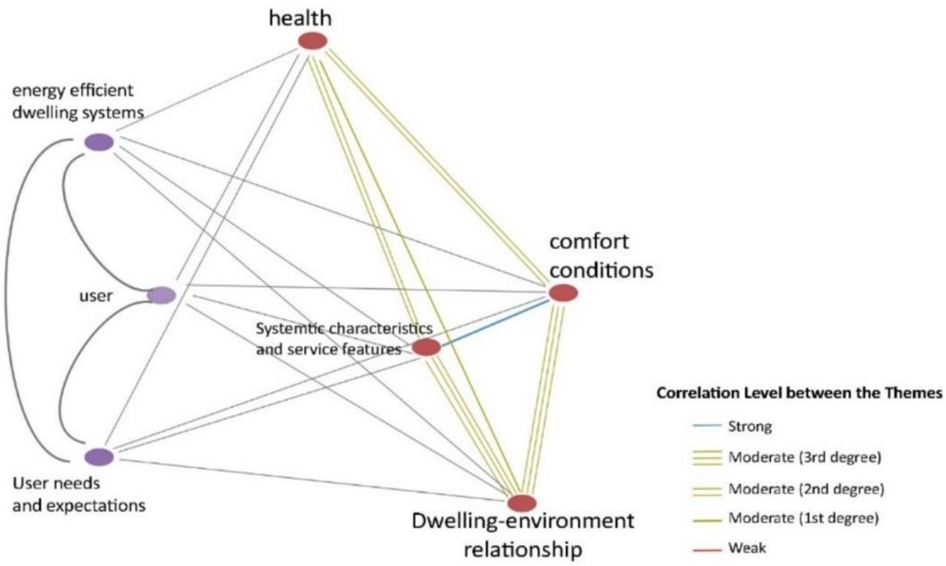
After the Reliability, Validity, and Factor Structure Analyses and expert opinions, the indicators that were not included in any factor were removed from the scale, and one indicator was deemed appropriate to be added to the scale. Table 12 presents the final version of the scale. In the table, indicators extracted from the scale are strike-through, and the added indicator is underlined.

According to the results of the Cronbach's Alpha reliability test administered on 88 questions, the reliability coefficient of the scale was at a sufficient level with 0.974.

In addition, T-Test Analysis revealed that each question/assessment proposal is distinctive to what is meant to be measured. The final version of the themes, indicators, and assessment proposals in the Research Scale is included in Appendix B.

At the end of all the analyses made in Section 4, the explanatory rates of the themes were found to be sufficient. Themes: “Comfort conditions”, “dwelling-environment relationship”, “health” and “systemic characteristics and service features” and their correlations are presented in Figure 6.

Figure 6. The main themes of the model



Source: Elaborated by the Authors.

The indicators of the model were gathered under four main themes (comfort conditions, dwelling-environment relationship, health, systemic characteristics, and service features) because of the analyses performed (Figure 7). Statistically significant correlations were found between the overall model score and the sub-dimensions of the model, *inter se*. The highest correlation coefficient was seen in the "Comfort Conditions", "Dwelling- Environment Relationship", "Health" and "Systemic Characteristics and Service Features" sub-dimensions, respectively. Thus, statistical relationships between the sub-dimensions and the overall model were revealed (Figure 7).

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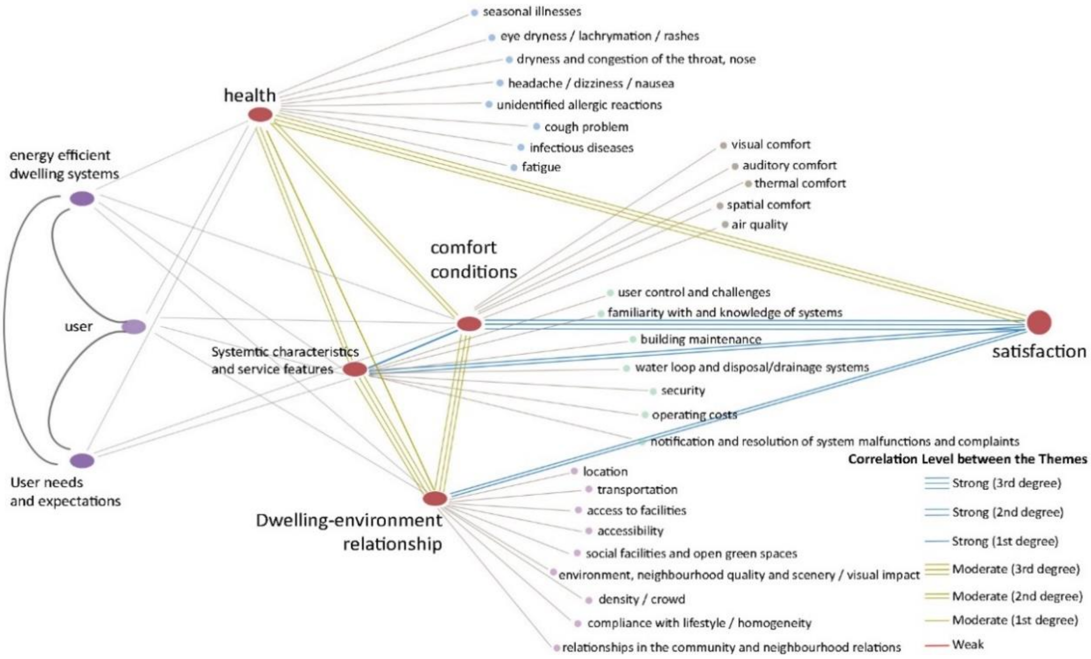
Figure 7. User satisfaction model in energy efficient dwellings



Source: Elaborated by the Authors.

To justify the construct validity of the research, scale the final structure examined within the framework of CFA (Confirmatory Factor Analysis).

The construct validity values of the four-factor structure obtained in the confirmatory factor analysis were obtained as follows; CMIN/DF = 2,456 (<0,05), GFI = ,967, (>0,900) CFI = ,930 (>0,900); RMSEA=0,068 (>0,080) which are indicates a strong structural validity. (Tabachnick & Fidell, 2019). Overall, these scores indicate that the research scale is suitable for testing in the framework of the hypothesis.

4.5 Hypothesis Testing

After the scale development process, the finalized scale was tested within the framework of a model and this model was tested within the newly collected data. For the testing in the research scale in a statistical model the hypotheses created are presented below:

- H1: Comfort conditions are a significant predictor of the overall residential satisfaction.
- H2: Dwelling-environment Relationship is a significant predictor of the overall residential satisfaction.
- H3: Health is a significant predictor of the overall residential satisfaction.
- H4: Systemic Characteristics and Service Features are a significant predictor of the overall residential satisfaction.

A new data was collected again with the scale developed to test the hypotheses. The sample of the study was chosen from an energy efficient dwelling located in Şişli, Istanbul. The dwelling project is a LEED Gold- certified residential building. The findings regarding the socio-demographic information of the participants are presented in Table 13 below.

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Table 13. Socio-Demographic information of participants

Data	Description	N	%
Gender	Female	56	44
	Male	73	56
Age	18-29	38	29
	30-39	32	25
	40-49	29	22
	50-59	22	17
	60 and above	8	7
Marital Status	Married	54	41
	Singe/Divorced	75	59
Property Status	Property Owner	83	64
	Tenant	46	36
Educational Status	Literate	3	2
	High School Graduate	49	38
	Bachelor's Graduate	46	36
	Postgraduate	31	24
Career	Unemployed	11	9
	Civil Servant	29	23
	Private Sector Employee	61	48
	Businessperson	20	15
	Retired	5	3
	Other	3	2
Household monthly income	0 - 3000 TL	12	9
	3001 - 7500 TL	24	19
	7500 - 10000 TL	50	39
	10000 TL and Above	43	33
Household size	1-2	58	45
	3-4	49	38
	5 and above	22	17

Source: Elaborated by the Authors.

4.5.1 Dependent Variable

The dependent variable of this research is the overall residential satisfaction, and the data of this variable is gathered with the question of "Rate your General Satisfaction Level with your Housing from 1 to 5". This variable measured with a 5-point likert scale (1= Lowest Satisfaction, 5= Highest Satisfaction).

4.5.2 Independent Variables

The residential satisfaction factors which expressed as the themes are the independent variables of this research (Comfort conditions, dwelling-environment relationship, health and system characteristics and service features). These factors consist of 5-point Likert scale (1= Strongly

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Disagree, 2= Disagree, 3=Neutral, 4= Agree and 5= Strongly Agree) type questions and scale scores are calculated by the method of sum.

- The comfort condition's theme includes the indicators that vary depending on the active and passive systems preferred in energy efficient dwellings, system control mechanisms, building and space design, materials, and fixtures used. The theme consists of five indicators: visual comfort, auditory comfort, thermal comfort, spatial comfort, and air quality (Table 14).

Table 14. Indicators and contents of the comfort condition's theme

COMFORT CONDITION'S THEME	
Indicators	Content of Indicator
Visual comfort	• Natural lighting • Reflection / flashing / glare or excessive contrast caused by window / glass surfaces • Sunlight control in the building • Artificial lighting (local sufficiency/insufficiency of lamps, led or spotlights • Selected equipment for artificial lighting (Spot / LED lighting etc.) • Glare, heat, shadow, or vibration caused by artificial lighting • Artificial lighting elements with sensors • Colours used in the spaces • Lighting within the site/landscape area (Open, green areas, social facilities, indoor facilities, etc.)
Auditory comfort	• Noises from indoor and outdoor units of HVAC (heating, cooling, ventilation) systems • Ensuring an auditory privacy
Thermal comfort	• Heating level and balance of spaces • Cooling level and balance of spaces • Heating/cooling level and balance of building common areas • Radiative heat (temperature directly coming/reflecting from the heat source) • Control system of heating/cooling equipment (central system, share meter, or whether each flat has its own system or not).
Spatial comfort	• Space organization and interior design (apartment plan, transitions, and relationship between rooms, space sizes) • Layout, dimensions, quality of fixed equipment (fixed elements such as kitchen cabinets), and armatures used in wet areas (taps, etc.) • Floor height • Suited for homeworking. • Vibration from vehicles, users, or wind • Circulation areas (width and usefulness of stairs, corridors, elevators, and other areas) • Common areas within the building (lobby, entrance area, common terraces, etc.)
Air quality	• The amount of fresh air in the indoor environment • Air quality from the ventilation system • Natural ventilation possibilities • Ventilation opportunity in wet areas • Airflow from HVAC systems • Airflow from natural ventilation • Dry air circulating • Air pollution-induced doors • The smell of the ingredients • Food fragrances • Toilet doors • Damp doors

Source: Elaborated by the Authors.

The contents of visual comfort, auditory comfort, thermal comfort, and spatial comfort and air quality indicators under the Comfort Conditions theme are explained in Table 14, specifically for energy efficient dwellings. It is recommended that the indicators should be assessed with the proposals (Appendix-B) prepared in consideration of these contents.

- In the theme of Dwelling-Environment Relationship, the relationship of the dwellings with its environment and the community relations within the dwelling/ site were questioned. This questioning was performed on nine indicators, being location, transportation, access to facilities, accessibility, social facilities and open, green spaces, environment, neighbourhood quality and scenery / visual impact, density/crowd, compliance with lifestyle/homogeneity, relationships within the community and neighbourhood relations. (Table 15).

Table 15. **Indicators and contents of the Dwelling-Environment Relationship theme**

DWELLING-ENVIRONMENT RELATIONSHIP THEME	
Indicators	Content of Indicator
Location	• The location of the dwelling • The distance of the dwelling to the city centre • Social life sufficiency of the dwelling area • Easily accessible location of the dwelling in cases of fire, earthquake, and other natural disasters.
Transportation	• Easy accessibility of the dwelling • Sufficiency of the public transport facilities around the dwelling • Access to public transport zones from the dwelling
Access to facilities	• Ease of access to basic education institutions • Ease of access to healthcare institutions • Ease of access to police units • Ease of access to shopping areas (shopping malls, markets, etc.) • Ease of access to entertainment areas
Accessibility	• The suitability of the housing structure for the access of people with disabilities and elderly people
Social facilities and open green spaces	• Sufficiency of open spaces in the site / around the building • Sufficiency of green areas in the site / around the building • Sufficiency of pedestrian roads/promenade areas in the site / around the building • Sufficiency of bicycle paths in the site / around the building • Sufficiency of the number of parking lots • Sufficiency of recreation areas in the site / around the building • Sufficiency and usefulness of children's park and playgrounds • Sufficiency of sports fields
Environment, neighbourhood quality and scenery / visual impact	• The quality of the environment/neighbourhood of the site/building • The scenery offered by the dwelling unit (Environment/neighbourhood view, the proximity of buildings, seeing the sky only, etc.) • The appearance of the site/building and its harmony with the environment
Density / crowd	• Dwelling density in/around the building (distance between blocks) • Occupancy rate and user density within the site/building
Compliance with lifestyle / homogeneity	• Compliance of the dwelling area with the culture and lifestyle of the user • Homogeneous distribution of the human profile living in the dwelling area
Relationships in the community and neighbourhood relations	• Neighbourhood Relationships • The positive/negative approach of the residents of the site/building to the solution of the problems

Source: Elaborated by the Authors.

The contents of the indicators named location, transportation, access to facilities, accessibility, social facilities and open, green spaces, environment, neighbourhood quality and scenery / visual impact, density/crowd, compliance with lifestyle/homogeneity, community relations, and neighbourhood relationships under the theme of Dwelling-Environment Relationship are explained in Table 15.

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It is recommended that the indicators should be assessed with the proposals (Appendix-B) prepared in consideration of these contents.

- The theme of health, one of the main themes of the model, includes indicators related to the health problems that residential users may face, depending on the systems and preferences used in energy efficient dwellings. The definition of the theme was made in line with the examination of the studies on the subject and the expert opinions taken. Health theme consists of eight indicators, namely seasonal diseases, dry eyes/tears/rashes, throat, dry and nasal congestion, headache/dizziness/nausea, unidentified allergic reactions, cough problem, infectious diseases, and fatigue (Table 16).

Table 16. Indicators and contents of the health theme

HEALTH THEME	
Indicators	Content of Indicator
Seasonal illnesses	• It refers to the seasonal illnesses of residential users.
Eye dryness / lachrymation / rashes	• It refers to the cases of dryness, tearing, and redness in the eyes, which occur because of the lack of proper humidity adjustment and air dryness, which the residential users experience in their dwellings.
Dryness and congestion of the throat, nose	• It refers to the dryness and congestion in the throat and nose caused by the lack of proper humidity adjustment and air dryness that the residential users experience in their dwellings.
Headache / dizziness / nausea	• It refers to the insufficient supply of fresh air and oxygenation problems, as well as headache, dizziness, and nausea that occur because of altitude that the residential users experience in their dwellings.
Unidentified allergic reactions	• It refers to allergic reactions that can occur because of air dryness, acceleration of airflow due to heating/cooling/ventilation systems, and increased particle transport in the space, which residential users experience in their dwellings.
Cough problem	• It expresses the cough problems that residential users experience in their dwellings, especially because of air dryness and oxygenation problems.
Infectious diseases	• It refers to the infectious diseases experienced by residential users, especially when they spend a long time in the dwelling (Filter selection (not using HEPA filter), cleaning and maintenance and not making the filter change at the right time can be listed as the main reasons)
Fatigue	• It refers to the feeling of fatigue experienced by residential users in their dwellings, especially due to the inadequate supply of fresh air.

Source: Elaborated by the Authors.

The contents of the indicators named seasonal diseases, dry eyes/tearing/rashes, dryness and congestion in the throat and nose, headache/dizziness/nausea, unidentified allergic reactions, cough problem, infectious diseases, and fatigue under the Health theme are explained in Table 16. It is recommended that the indicators should be assessed with the proposals (Appendix-B) prepared in consideration of these contents.

- Systemic Characteristics and Service Features theme consists of seven indicators, namely user control, and difficulties, familiarity with and knowledge of systems, building maintenance, water cycle, and disposal/drainage systems, security, operating costs, reporting and resolution of system malfunctions and complaints (Table 17).

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Table 17. Indicators and Contents of the Systemic Characteristics and Service Features Theme

SYSTEMIC CHARACTERISTICS AND SERVICE FEATURE'S THEME	
Indicators	Content of Indicator
User control and challenges	• Individual controllability of heating and cooling systems (central or room-based user control) • Individual controllability of ventilation systems (central or room-based user control) • Individual controllability of lighting/shading elements (lighting control) • Enough openable windows (Natural ventilation control) • Ease of using control panels/devices (heating, cooling, ventilation, security, etc.) • The adjustability of devices by the user with the sensitive adjustment level (heating, cooling, ventilation devices, electric stove heating level sufficiency)
Familiarity with and knowledge of systems	• Sufficiency of user manuals prepared • Comprehensibility of user guides
Building maintenance	• Building maintenance and waste management frequency and quality • Checking and renewing fixtures and equipment periodically
Water loop and disposal/drainage systems	• Water drains, plumbing leakage, leakage, etc. situations • The existence of stormwater storage and network water treatment systems, whether the amount of water used by the user is clearly included in the bills and economical savings in the water bill or not
Security	• Safety of dwelling areas from burglary • Safety of dwelling areas from fire and natural disasters • Sufficiency of in-site / indoor security
Operating costs	• Affordable building operating costs (common use electricity, subscription expenses, etc.)
Notification and resolution of system malfunctions and complaints	• Notification of system malfunctions and other problems and easy resolution of the problems

Source: Elaborated by the Authors.

The contents of the indicators named user, control and difficulties, familiarity with and knowledge of systems, building maintenance, water cycle, and disposal/drainage systems, security, operating costs, reporting system failures and complaints, and solution indicators under the Systemic Characteristics and Service Features Theme are explained in Table 17. It is recommended that the indicators should be assessed with the proposals (Appendix-B) prepared in consideration of these contents and finalized through the field studies. In the table 18 below the shows the results of the multiple linear regression model that conducted for the testing the research's hypotheses. According to the results there is a statistically significant, positive relationship between the general satisfaction level and comfort conditions ($B=0,214$; $sig<0,05$), dwelling-environment relationship ($B=0,188$; $sig<0,06$), health ($B=0,138$; $sig<0,05$) and systemic characteristics and service features ($B=0,298$; $sig<0,05$).

According to these relationships comfort conditions, dwelling-environment relationship, health and systemic characteristics and service features are the significant predictors of the overall residential satisfaction. When these significant relationships are examined; when the comfort conditions of the individuals increases at %1 the general satisfaction increases as the %21,4, when the dwelling-environment relationship level increases at %1 the general satisfaction level increases as the %18.8, when the health level increases as %1 the general satisfaction level increases as the %13.8 and for the system characteristics and service features, when the individuals' system characteristics and service features satisfaction increases %1 the general satisfaction increases %29.8.

Overall, in this perspective it could be stated that the systemic characteristics and service features ($B= 0,298$) has the most effect on the general satisfaction, and health has the least effect on the general satisfaction ($B= 0,138$). Finally, the variance explanatory power of the model was determined as 36.5%.

Table 18. The results of the multiple linear regression analysis

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	73,191	1,982		36,929	0,000
Comfort Conditions	0,214	0,057	0,185	3,918	0,028
Dwelling-Environment Relationship	0,188	0,081	0,161	2,687	0,016
Health	0,138	0,124	0,102	2,202	0,007
Systemic Characteristics and Service Features	0,298	0,097	0,105	3,029	0,003

Notes: R^2=36,4% Confidence Interval ci: 95%, Dependent Variables: Satisfaction Level
Source: Obtained by the authors using SPSS data analysis.

5. Results and Discussion

In the literature, special emphasis is placed on the relationship between residential user satisfaction and real user experience. In the studies examined within the scope of the present study, the inputs in both objective and subjective dimensions, covering many aspects in the context of user satisfaction, are among the indicators. In the general framework, dwelling and its environment are discussed together in these systems. It is also reported that some variables of the dwelling and its environment have significant effects on the level of dwelling satisfaction/dissatisfaction but are also related to culture and values. On the other hand, systems and systemic characteristics preferred in energy efficient dwellings and health-related conditions that develop as a result are effective indicators of dwelling satisfaction.

In this study, it revealed that systemic characteristics and service features (B= 0,298) and comfort conditions (B= 0,214) are the most important predictors affecting the general satisfaction of residents, while dwelling-environment relationship (B= 0,188) and health (B= 0,138) have less effect on it. Comparing the results of this study with similar ones shows some similarities. Despite apparent similarities, the results of the current study have some differences from former studies.

According to Nicol & Roaf (2005) and Leaman & Bordass, (2017), system features and knowledge about the features are the most important predictors in terms of user satisfaction. The results are like this study and the current study in terms of systemic characteristics and service features being the most important predictor. In Şahin's (2016) study investigating user satisfaction in energy-efficient renovated buildings, it was concluded that the building's system features, and health conditions were the most important factors in the general satisfaction level, and the building-environment relationship was ineffective. In the current study, it is like the study in that the system features are the most effective predictor, and the building-environment relationship has a lower effect. In terms of health conditions, the two studies contradict. In the current study, health conditions were obtained as the predictor with the least effect on the general satisfaction level.

Acording to Baum, *et. al.* (2010) and Hipp (2010) structural attributes of housing is a significant factor affecting housing satisfaction. These attributes include objective comfort conditions of housing. In their study, Gündoğdu *et al.* (2019), have identified built environment characteristics as the important predictor of user satisfaction.

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Isaksson & Karlsson (2006) emphasized the importance of thermal comfort in user satisfaction in their study in Sweden. Samuelsson & Lüddeckens (2009) concluded in their studies that comfort conditions are an important predictor of user satisfaction in energy efficient dwellings. In Akgün's (2019) study on user satisfaction in energy efficient buildings, it was stated that comfort conditions have a significant effect on satisfaction. In the current study, comfort conditions were obtained as the second most effective predictor.

In this respect, the results of the current study are like the studies. Baker (2002) has observed that location characteristics are important considerations for understanding the formation of residential satisfaction among the users. According to Ariffin *et al.* (2010), the dwelling-neighbourhood relationship plays an important role in residential satisfaction. While the dwelling-environment relationship is the most effective predictor in these studies, it is the third effective predictor in the current study.

Buber *et al.* (2007) have investigated user satisfaction in energy efficient dwellings. In their study, comfort, well-being/health, and cosiness were stated as the most important predictors. In another study by Heerwagen (2009) show that well-being/health of users is the most effective predictor on user satisfaction. In the studies made by Thatcher and Milner in 2012 and 2014 and by Ornetzeder *et al.*, 2016, it is concluded that health conditions have a significant effect on satisfaction. Contrary to these studies, in the current study, health is the indicator that has the least effect on the overall satisfaction level.

In current study, it is expected that the systemic characteristics and service features will be obtained as the predictor with the highest effect on general satisfaction. Users are much less satisfied when they cannot understand how things work or how to control temperature, ventilation etc. in energy efficient dwellings. Information on use and operation of technical facilities is therefore crucial. The results show that the operation and use of energy efficient dwellings may be difficult for the users, and that if the technological facilities are experienced as too advanced, they are not used or not entirely understood. The occupants' behaviours also have a significant impact on a building's energy performance. This may lead to uncomfortable indoor climate.

The research also shows, once more, that perceived personal control and sufficient information on operation and use is crucial for an overall positive experience of the houses. In addition, the achievement of comfort conditions as the second most important predictor can be explained by the fact that active and passive systems and system control mechanisms (heating, cooling, ventilation, lighting etc.) preferred in energy efficient residences have a significant effect on the user. It is thought that the effect of comfort conditions on general satisfaction is greater due to these systems and preferences, which are the characteristic features of energy efficient dwellings.

6. Conclusions

This research aims to develop a model for user satisfaction to clarify what user satisfaction means in planning/design, implementation, and operation processes in energy efficient houses and to ensure assessing user satisfaction through user experience and feedback. The literature review has revealed that a more holistic and collective understanding of user satisfaction is needed in the abovementioned processes.

Developing a model with a range of indicators will help stakeholders involved in energy efficient dwelling design, implementation, and operation to gain a collective understanding of user satisfaction and take the necessary actions to increase user satisfaction over time.

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The user satisfaction model for energy efficient dwellings has been developed through a comprehensive research process that combines scientific articles, theses, and international assessment tools. With this approach, many factors were detected as they were analysed in various integration, screening, and grouping cycles to develop holistic themes of user satisfaction. The model developed for assessing user satisfaction in energy efficient dwellings consists of four main themes, being comfort conditions, dwelling-environment relationship, health, and systemic characteristics and service features. Each theme in the model contains indicators to put the theme into practice. To assess the indicators and the themes covering these indicators, assessment proposals are put forth corresponding to each indicator.

Various analyses were made during the model development process. To carry out the analysis, energy efficient dwelling users were reached, and data were collected. At the end of the analyses carried out in the study, it was concluded that every problem and assessment proposal have a good level of distinctiveness and the model is suitable for its intended use. According to the study results there is a statistically significant, positive relationship between the general satisfaction level and comfort conditions, dwelling-environment relationship, health and systemic characteristics and service features. According to these relationships comfort conditions, dwelling-environment relationship, health and systemic characteristics and service features are the significant predictors of the overall residential satisfaction. In this perspective it could be stated that the systemic characteristics and service features has the most effect on the general satisfaction, and health has the least effect on the general satisfaction. It has been revealed that the model can directly determine the user satisfaction themes that are considered/emphasized in the residential buildings and can reveal the neglected themes in the examination processes. Besides, using the model in case studies will help planners/stakeholders think ahead of time how to integrate themes of user satisfaction into the process, so using the model can be useful to guide the process of energy efficient dwelling design and implementation.

Due to the covid19 pandemic, there were difficulties in reaching more users. In future studies, it is thought that it would be good to work on a method to reach more users more efficiently. However, the fact that the systems and technology used in the dwellings examined in the study are at a good level and allow easy communication with the residents still turned this situation into a positive direction.

Author Contributions

Both authors contributed to all parts of the research. The first author conceptualized and developed the general structure of the article. The authors jointly discussed and finalized the writing.

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