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Fig. 1 FNN Sustainability Centre:
a) entrance façade,
b) garden at the facade-shell interface,
c) green roof

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Development and Assessment of a Post-Occupancy Evaluation Scale for Sustainable Office Environments

Insights from the FNN Sustainability Centre

GREEN BUILDINGS
POST-OCCUPANCY EVALUATION
SUSTAINABLE ARCHITECTURAL DESIGN
SUSTAINABLE OFFICE
USER SATISFACTION

This study explores the relationship between users and the built environment through a post-occupancy evaluation (POE) conducted at the FNN Sustainability Centre, a noteworthy sustainable building in the region. The study involved a comprehensive approach, encompassing site visits, managerial interviews, and staff surveys. To establish a robust evaluation framework, a scale was developed by analysing pertinent literature, and indicators were identified to gauge various aspects of the building's performance. Throughout the scale development process, the SPSS data analysis program was used, and expert opinions were solicited to ensure a rigorous and comprehensive methodology. Evaluation categories included lighting, acoustics, climatic comfort and indoor air quality, use and comfort of systems, quality of space and perception, awareness of sustainability and productivity. The building emerged as a physically and psychologically conducive workplace that heightened employee awareness of sustainability. Specific concerns were identified, such as noise disturbance for open-office workers and glare-related issues, which serve as valuable feedback for potential adjustments.

Introduction

In the last two centuries especially, as humans are the only living species that is prone and capable of intervening in the environment and making it fit their needs instead of adapting to it, human activity has caused irreversible damage to the environment and nature, and thus to human lives. The planet on which we live is in danger of becoming unsustainable. With the process of globalisation and changes in consumption habits, the physical and environmental comfort needs of human beings have been increasing day by day. As a result, the damage to the ecosystem and natural resources has also been increasing. As the world becomes more urbanised and its population grows, the efficient use of limited, rapidly depleting resources and the widespread use of renewable energy sources are becoming increasingly important. It is essential that buildings, which account for approximately 40% (United Nations Environment Programme, 2017) of the world's energy consumption and carbon emissions, are sustainable and use energy efficiently throughout their lifecycle, from design to demolition.

A sustainable building can be defined through a design and practice that is environmentally responsible and encompasses processes throughout its life cycle, such as the siting decision, the design process, the construction site, the operation of the building, maintenance, repair, renovation and demolition (Darko et al., 2019: 501-511). The environment, society and economy as three components of sustainability, need to be considered in all buildings throughout a building's full life cycle in order for it to be deemed sustainable. Beyond just meeting physical requirements, a sustainable building or structure must also meet economic, environmental, and social standards that benefit or at the very least do not harm current and future generations (Feige et al., 2013: 7-34).

Reducing a building's energy consumption is the initial driver for green building development, as energy consumption is one of the most important aspects of building performance. Energy saving design is given the highest credit in almost all green building rating standards. Recent years have also seen an increase in research into whether green buildings, once occupied, achieve the designed energy saving target, as a result of the recognition of the performance gap. Therefore, studying the energy performance of buildings has become important (Geng et al., 2019: 500-514). Green building or high-performance building are other terms for sustainable building design. Several certification programs rate the sustainability of buildings, including LEED, BREEAM, CASBEE, Greenstar, GeSBC, and HHEQ. LEED was created by organizations in different countries (Wang and Adeli, 2014: 1-2). LEED (Leadership in Energy and Environmental Design) certification, one of the most effective, is organised by the U.S. Green Building Council. LEED is the most widely used green building rating system in the world and categorises buildings as Platinum, Gold, Silver and Certified. LEED v4.1 calculates this rating based on the following sustainable criteria: site and transportation, sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality (USGBC LEED Rating System). Sustainable buildings are commonly known as building design strategies that focus on minimising environmental impact by reducing energy and water consumption and minimising environmental disturbance from the construction site. Although less well known, sustainable buildings also aim to improve human health through the design of healthy indoor environments. Energy and water efficiency have been the subject of much research and documentation, but the human health benefits of sustainable buildings are less well understood. In terms of indoor environmental quality, sustainable buildings had lower levels of volatile organic compounds (VOCs), formaldehyde, allergens, environmental tobacco smoke (ETS), nitrogen dioxide (NO_2) and particulate matter (PM). Therefore, the benefits of indoor environmental quality in sustainable buildings are reflected in better self-reported health outcomes across a range of indicators. These include fewer Sick Building Syndrome symptoms, fewer reports of respiratory symptoms in children, and better physical and mental health. Occupants also report benefits that indicate that they are more productive at work in sustainable buildings (Allen et al., 2015: 250-258).

Studies on the interaction between sustainable buildings and their occupants have shown mixed results. This study aims to observe the relationship between the users and the building through a post-occupancy evaluation (POE) in sustainable buildings. In this context, FNN Sustainability Centre, one of the few sustainable buildings in the region, was selected for the POE, which involved visiting the office, interviewing the manager and surveying the staff.

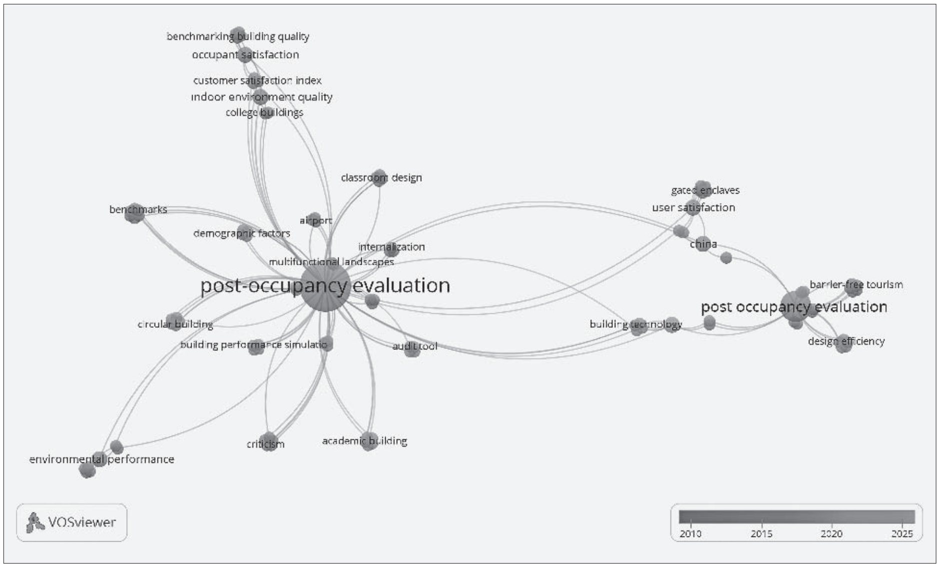


Fig. 2 Bibliographic data map of keywords (Generated by VOSviewer)

Post-Occupancy Evaluation (POE)

In order to find reliable sources of information on Post-Occupancy Evaluation, a search and analysis was carried out using the Web of Science. An analysis of the Web of Science search for "Post-Occupancy Evaluation" shows that 129 out of the 934 publications in the core collection are in the field of architecture (Web of Science Core Collection). These 934 sources related to Post-Occupancy Evaluation were exported as "Tab delimited file" for use in the VOSviewer database and a map based on bibliographic data was created. In the full counting method, "Co-occurance" analysis type and "Author keywords" analysis unit were selected. This bibliographic data map is shown in Fig. 2. As can be seen in this map, although POE is focused on building performance and user satisfaction, it is close to many concepts, evaluations are made with different indicators.

Post-Occupancy Evaluation (POE) is defined by Zimring and Reizenstein as the assessment of the effectiveness of an occupied, designed environment for the human user. These specific evaluations, usually concentrated on a single type of designed environment, tend to give a description rather than manipulation, and are usually application-oriented. Although they vary within this broad framework, it is useful to catalogue them in terms of generality, breadth of focus and applicability (Zimring and Reizenstein, 1980: 429-450). Post-occupancy assessment is a diagnostic tool and system that helps facility managers to systematically detect and appraise important aspects of building performance. In the 1960s, POE was introduced due to significant issues with building performance, particularly focused on the viewpoint of the building occupants (Preiser, 1995: 19-28). The information obtained from POE provides a better definition of what is valuable or useful, based on real knowledge, and thus defines what users want or need. The data obtained from the POE is also used to improve the next design and production processes, in addition to improving the functioning of the building (Zimmerman and Martin, 2001: 168-174).

Depending on the purpose and target of use, different techniques can be used individually or in combination in POEs. Data collection and profiling, walkthroughs (walk around the study site and take a visual record for the purpose of evaluation; Preiser and Vischer, 2005), on-site physical measurements, questionnaires, interviews, focus group meetings are some of them (Leitner, Sotsek and Santos, 2020). The duration of the POEs also varies greatly. For some a single interview or visit may be sufficient, while for others it may take years of keeping or accessing data (Bae, Martin and Asojo, 2021: 445-459). Furthermore, some are limited to a single area or building, while others use the same indicators across many buildings (Park, Loftness and Aziz, 2018). POE can also be carried out in adaptive re-use buildings. User satisfaction and the suitability of the new use may be in question (Hamida and Hassanain, 2020: 29-40). POE can be performed shortly after occupation to provide feedback to the design process in designed buildings, and repeated at intervals for more accurate results, revised if necessary.

Even though POE has not yet become the norm in the construction industry, it has grown quickly over the past ten years and will

Table I Indicators and sub-indicators of the scale and sources/authors

Indicators (dimensions)	Sub-indicators	Sources/authors
Lighting	Natural lighting	Asojo, Bae and Martin, 2020 Bakker et al., 2017 Kong et al., 2018 Freihoefer et al., 2015 Hamida and Hassanain, 2020 Hassanain and Mahroos, 2023 Bortolini and Forcada, 2021
	Sunshade shell	
	Artificial lighting	
	Reflection-glare	
Acoustic	HVAC-induced sounds	Park, Loftness and Wang, 2022 Park, Loftness and Aziz, 2018 Mahbub, Kua and Lee, 2010 Thatcher and Milner, 2012 Hamida and Hassanain, 2020 Hassanain and Mahroos, 2023
	Indoor sounds	
	Outdoor sounds	
Climatic comfort and indoor air quality	Heating	Darko et al., 2019 Geng et al., 2019 Allan et al., 2015 Leitner, Sotsek and Santos, 2020 Juan, Gao and Wang, 2010 Park et al., 2018 Bortolini and Forcada, 2021 Frontczak et al., 2012 Ildiri et al., 2022 Bae, Martin and Asojo, 2021 Geng et al., 2019 Thatcher and Milner, 2012 Hamida and Hassanain, 2020 Hassanain and Mahroos, 2023
	Mechanical ventilation	
	Cooling	
	Natural ventilation	
Use and comfort of the systems	Automation system	Hassanain and Mahroos, 2023 Bortolini and Forcada, 2021 Messinger et al., 2011 Baudach et al., 2013
	Building maintenance	
	Waste management	
Space quality and perception	Building design	Feige et al., 2013 Hamida and Hassanain, 2020 Li, Froese and Brager, 2018 Allen et al., 2015 Ildiri et al., 2022 Hassanain and Mahroos, 2023
	Interior design and material choices	
	Location-transportation	
	Space size-number of users relation	
Awareness of sustainability and productivity	Green roof	Feige et al., 2013 Thatcher and Milner, 2014 Bryd and Rasheed, 2016 Leder et al., 2016 Kellert, 2005 Thatcher and Milner, 2012 Bortolini and Forcada, 2021 Hassanain and Mahroos, 2023
	Sustainable material	
	Efficient use of water	
	Climate change and renewable energy sources	
	Dissemination of sustainable buildings	
	Productivity	

continue to do so as more people become aware of how critical it is to assess actual real-time performance and the significance of occupant input. From a deeper look, it is encouraging that occupant input has become the primary focus of POE research outside of the area of social scientists. Even in studies within the building sciences, which have traditionally concentrated on the physical performance of the structure, an occupant survey has become a fundamental component of most POE approaches. This reflects the fact that a broader spectrum of researchers now recognize that the people who occupy the spaces have the power to determine a building's success or failure (Li, Froese and Brager, 2018: 187-202).

Methodology

The indicators of the scale used in the study were determined by analysing relevant studies in the literature. The studies analysed are given below. In the research, FNN Sustainability Centre building located in Adana, Turkey is considered. In order to conduct a post-occupancy evaluation of the building and to obtain the opinions of its users, a questionnaire survey was conducted.

Post-Occupancy Evaluations are divided into several categories, depending on the focus they seek to achieve. POE uses different indicators, subdividing them into sub-indicators to understand different relationships. One of the most widely used types of POE is those that focus on thermal comfort and energy efficiency, evaluating the thermal performance predicted at design and measured by determining the energy performance (Geng et al., 2019: 500-514; Juan, Gao and Wang, 2010: 290-297; Park, Loftness and Aziz, 2018: 1-24). Several POE papers focus on Indoor Environmet Quality and examine it in different situations and indicators (Bortolini and Forcada, 2021; Frontczak et al., 2012: 119-131; Ildiri et al., 2022; Bae, Martin and Asojo, 2021: 445-

Table II Total variance explained of the scale (factor analysis)

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	11,548	32,993	32,993	11,548	32,993	32,993	9,161	26,175	26,175
2	6,439	18,398	51,392	6,439	18,398	51,392	5,655	16,156	42,331
3	4,883	13,952	65,343	4,883	13,952	65,343	5,654	16,154	58,485
4	3,858	11,024	76,368	3,858	11,024	76,368	3,909	11,167	69,652
5	2,737	7,821	84,188	2,737	7,821	84,188	3,897	11,133	80,786
6	2,018	5,766	**89,954**	2,018	5,766	**89,954**	3,209	9,169	**89,954**

Extraction method: Principal component analysis

459; Geng et al., 2019: 500-514). Under the headings of lighting conditions, natural and artificial lighting, automatic or manually controlled lighting, daylight and glare, POE was used to assess visual comfort (Asojo, Bae and Martin, 2020: 239-250; Bakker et al., 2017: 308-321; Kong et al., 2018: 135-148; Freihoefer et al., 2015: 457-472). Since indoor air acoustic quality affects the health, comfort and productivity of users, both noise from the external environment and acoustic problems from internal sources have been an important part of POE studies (Park, Loftness and Wang, 2022; Mahbub, Kua and Lee, 2010: 213-223; Thatcher and Milner, 2012: 3816-3823, Hamida and Hassanain, 2020: 29-40; Hassanain and Mahroos, 2023: 564-581). Studies on the relationship of users to the built environment, the reflection of this relationship in business life, the level of satisfaction and comfort of employees and their productivity are also common (Feige et al., 2013: 7-34; Thatcher and Milner, 2014: 381-393; Bryd and Rasheed, 2016; Leder et al., 2016: 34-50). The studies focusing on physical and psychological health issues support the studies in this area by providing feedback (Allen et al., 2015: 250-258; Ildiri et al., 2022).

After analysing the existing studies, the indicators to be included in the scale were determined. The indicators of the scale are lighting, acoustic, climatic comfort and indoor air quality, use and comfort of the systems, space quality and perception, and awareness of sustainability and productivity (Table I).

After the scale and indicators were determined, a questionnaire form with evaluation propositions was prepared to evaluate each of the indicators. The questionnaire consists of two parts. In the first part, demographic information of the users including gender, age, occupation and education level were requested. In the second part; evaluation propositions were included under six headings: lighting, acoustic, climatic comfort and indoor air quality, use and comfort of the systems, space quality and perception, and awareness of sustainability and productivity.

The first version of scale and questionnaire was reviewed by two green building experts, two architects, employees of a green building consulting firm, and two professors conducting green building research for both content validation and applicability in the office building. After the revisions made following the expert opinions, the questionnaire was updated. Various analyses were then carried out using SPSS data analysis software to measure the validity and reliability of the scale. First, exploratory factor analysis (EFA) was conducted to determine the construct validity of the scale and to reveal its factor structure. Principal components and varimax orthogonal rotation methods were used for this purpose. As a result of EFA, it was found that the scale consisting of 38 items was formed in a structure with six sub-dimensions (factors) and these six factors explained 89.954% of the total variance. When the literature was analysed, this rate was considered sufficient to explain the phenomenon. According to the researchers, a rate between 40% and 60% is considered sufficient (Büyüköztürk, 2020; Tavşancıl, 2019). Therefore, it was concluded that the scale is valid. Furthermore, the first subdimension explained 32.993% of the variance, the second 18.398%, the third 13.952%, the fourth 11.024%, the fifth 7.821%, and the sixth 5.766% (Table II).

After the validity analysis, Cronbach Alpha reliability analysis was carried out to determine the reliability of the scale and it was found to be a=0.906 (Table III). In addition, the reliability of the lighting sub-dimension was a=0.791, the reliability of the acoustic sub-dimension was a=0.707, the reliability of the climatic comfort and indoor air quality sub-dimension was 0.719, the reliability of the use and comfort of systems sub-dimension was 0.854, the reliability of the space quality and perception sub-dimension was 0.739 and the reliability of the sustainability and productivity awareness sub-dimension was 0.895 (Table IV). Therefore, it is accepted that the scale, including the sub-dimensions, is a reliable measurement tool. This is because a Cronbach alpha value of 0.70 or more is considered sufficient for the reliability of a measurement tool (Büyüköztürk, 2011: 171). The radar chart tool was used to visualize the data. The user opinions obtained for each indicator were presented on the radar chart together with the sub-indicators.

After revisions, the finalized questionnaire was distributed to all employees in the office building. Twelve out of 14 employees of FNN Sustainability Centre completed the questionnaire, representing a response rate of approximately 86%. The findings related to the six indicators analysed with the evaluation

Table III Total reliability statistics of the scale

Cronbach's alpha	Cronbach's alpha based on standardized items	N of items
,906	,921	38

Table IV Reliability statistics of the dimensions

Dimension	Cronbach's alpha	Cronbach's alpha based on standardized items	N of items
Lighting	,791	,808	5
Acoustic	,707	,682	3
Climatic comfort and indoor air quality	,719	,696	4
Use and comfort of the systems	,854	,852	5
Space quality and perception	,739	,704	8
Awareness of sustainability and productivity	,895	,897	13

Fig. 3 FNN Sustainability Centre: a) museum section, b) archive section, c) office section

Table V Demographic information of participants

		n	%
Gender	Female	3	25
	Male	9	75
Age	18-29	2	16.7
	30-39	7	58.3
	40-49	2	16.7
	50-59	1	8.3
Education Status	Primary and secondary school	0	0
	High school	1	8.3
	Undergraduate	7	58.3
	Graduate	4	33.3
	Doctorate	0	0
Occupation	Executive	3	25
	Office staff	6	50
	Other	3	25

propositions in the questionnaire are presented in graphs and comparisons are made. The manager of FNN was interviewed to obtain information about the green building certification process of the building. Under the guidance of the manager, the active systems used in the building and the passive methods preferred in the design process were examined and photographed.

Study Case Project: FNN Sustainability Centre

FNN Sustainability Centre selected for the study is located in the city of Adana in the Mediterranean region of Turkey. The building was selected because it is one of the most important examples in the region in terms of having sustainable, green building qualities and incorporating sustainable design strategies in its construction, design and use processes.

In 2017, a competition was organized for a building to contain an archive, museum (exhibition) and administrative offices. Within the scope of the program; the archive section that will include all the projects of the construction company to which the building will belong, the museum where old equipment and visual materials with memorabilia value will be exhibited, and the offices of the relevant maintenance units were requested to be located together. The project, which was selected and deemed worthy of implementation as a result of the competition, was requested to be built in accordance with sustainable design strategies and green building standards. The building, which has 2775 m^2 of closed area, is structurally constructed of steel and reinforced concrete. The construction process was completed in 2020. While the archive section is designed as a closed area as a program, it is structurally constructed as a reinforced concrete structure. The office areas are designed to show the steel structure completely within the building, supported by transparent glass facades. The museum is considered as the foyer and meeting point of two different programs at the intersection of this fully closed and fully open program. A steel shell wraps these programs, which are separated from each other by their different characters from the outside and brings them together. The semi-permeable and dynamic steel shell creates gardens, private and social spaces at the façade-shell intersection by moving away from and approaching the building, and by descending and ascending from time to time. This shell also helps to provide climate control by preventing the building from direct sunlight (Figs. 1, 3; Arkiv, n.d.).

The FNN Sustainability Centre was awarded “Platinum” certification in the “LEED v4 Building Design and Construction: New Construction & Major Renovation” category by the LEED (Leadership in Energy and Environmental Design) green building rating system, which aims to develop and disseminate standards for environmentally responsible design, implementation and operation at the building and city scale. The building received 84 out of 110 points (USGBC, n.d.).

Preliminary efficiency analyses on the use of water and energy resources were carried out in the early stages of the project and the project design was guided by this data (Altensis, n.d.). There are solar panels on the roof to meet some of the energy needs of the building from renewable energy sources. Energy efficient armatures and systems are preferred in the building. To save water, rainwater is stored and the stored water is used for green roof and green area irrigation and toilet reservoir water needs. Electric vehicle charging stations are located in the parking areas and priority parking spaces are reserved for low emission vehicles. Emissions from vehicle use have been reduced with bicycle parks. To reduce the heat island effect, it is seen that the use of light colours is dominant in the selection of roof and floor materials. This is also supported by the green roof application.

According to the information received from the team conducting the certification process of the building, the VOC (volatile organic compounds) content of the construction chemicals used in the interior spaces during construction was checked for compliance with international limits. The necessary design criteria for the ventilation of interior spaces were integrated into the project by ASHRAE 62.1-2010 standard (Altensis, n.d.).

Findings and Analyses

A survey was conducted with 12 of the 14 employees of the building examined within the scope of the study. The findings regarding the demographic information of the participants are presented in Table V.

In the study, various indicators were examined to evaluate the post-occupancy performance of the building. These are lighting, acoustic, climatic comfort and indoor air quality, use of systems and maintenance, space of quality and perception and awareness of sustainability. Indicators were divided into sub-indicators and comparison analyses were carried out with the sub-indicators. Finally, the main indicators of the study were analysed comparatively.

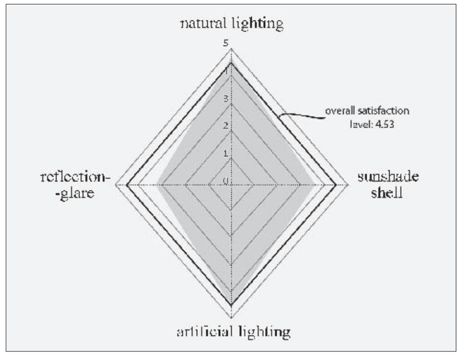
The lighting indicator was assessed using four sub-indicators as natural lighting, sunshade shell, artificial lighting and reflection-glare (Fig. 4). According to the survey study; the satisfaction level of natural lighting has been reached as 4.66 out of 5. Sunshade shell's satisfaction level is 3.7; the satisfaction level of artificial lighting is 4.58 and the satisfaction level of reflection-glare is 3.31. According to the findings, natural lighting and artificial lighting are found sufficient by users. On the other hand, compared to the natural lighting and artificial lighting sub-indicators, the satisfaction levels of the reflection-glare and sunshade shell sub-indicators were lower and their values remained below 4. It is understood that the users have problems on reflection and glare situation due to the excess of glass surfaces on the facade. It can be interpreted that the sunshade shell, which surrounds the structure and has semi-permeable properties, is insufficient to eliminate these problems.

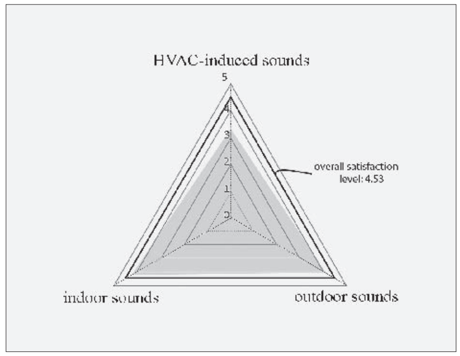
The acoustic indicator has been examined over three sub-indicators as HVAC-induced sounds, indoor sounds and outdoor sounds (Fig. 5). The satisfaction level of HVAC-induced sounds has been reached as 3.41 out of 5. Outdoor sounds' satisfaction level is 4.16 and the satisfaction level of indoor sounds is 4.25. The level of satisfaction with the HVAC-induced sounds sub-indicator was lower than the other sub-indicators. While the satisfaction levels of the indoor sounds and outdoor sounds indicators were above 4, the satisfaction level with the HVAC-induced sounds sub-indicator remained below 3.5. According to the findings, it is understood that the noise caused by the HVAC (heating, ventilating and air conditioning) systems used in the building reduces the satisfaction level of the users in the working environment.

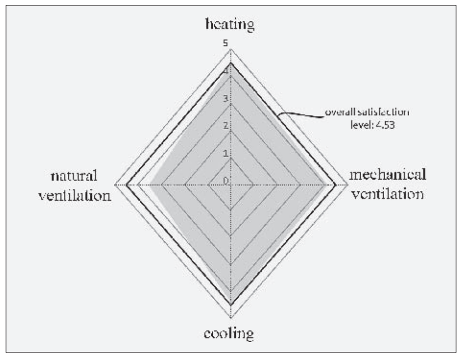
The climatic comfort and indoor air quality indicator have been examined over four sub-indicators as heating, mechanical ventilation, cooling and natural ventilation (Fig. 6). The satisfaction level of heating has been reached as 4.5 out of 5. Mechanical ventilation's satisfaction level is 4.08, cooling's satisfaction level is 4.41 and the satisfaction level of natural ventilation is 3.58. When the values are examined; it is seen that the satisfaction level of natural and mechanical ventilation is lower than that of heating and cooling. In particular, the satisfaction level in the natural ventilation sub-indicator was measured as around 3.5 and remained below the satisfaction levels of other sub-indicators. It can be said that the insufficient natural ventilation facilities of the building and the insufficient number of openable windows in the offices are effective in the lower satisfaction level of the natural ventilation sub-indicator compared to other sub-indicators.

The use and comfort of the systems indicator has been examined over three sub-indicators as automation system, building maintenance and waste management and recycling (Fig. 7). The satisfaction level of the automation system has been reached at 4.67 out of 5. Building maintenance's satisfaction level is 4.67 and the satisfaction level of waste management and recycling sub-indicator is 4.25. According to the data obtained; it is understood that thanks to the automation system used in the building, users can easily control the systems and the sensitivity levels of the systems are satisfactory. In addition, waste management, waste segregation and recycling activities in the building are also welcomed by the users. It is seen that the level of satisfaction regarding the periodical maintenance processes of the building is also high.

The space quality and perception indicator has been examined over four sub-indicators as building design, interior design and material choices, location-transportation and space size-number of users' relation (Fig. 8). The satisfaction level of building design has been reached as 4.75 out of 5. Interior design and material choices' satisfaction level is 4.24, location-transportation sub-indicator's satisfaction level is 3.9 and the satisfaction level of space size-number of users relation is 4.33. According to the results; users are very







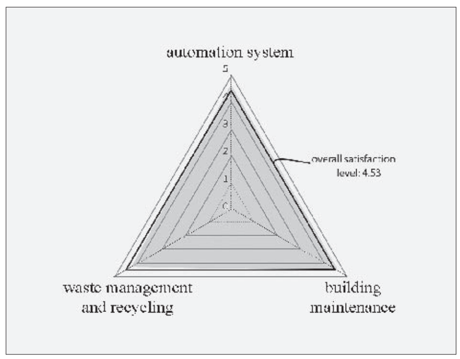
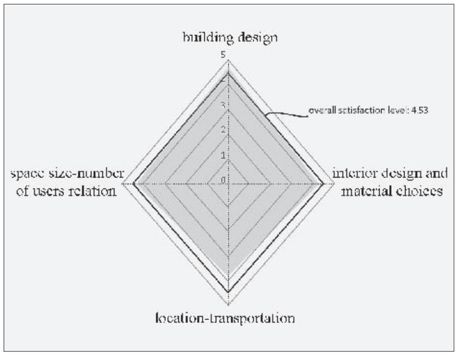


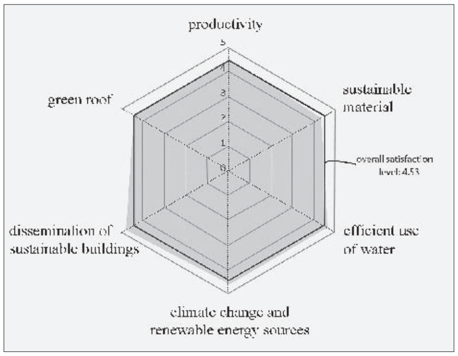
Fig. 4 Satisfaction with sub-indicators of lighting

Fig. 5 Satisfaction with sub-indicators of acoustic

Fig. 6 Satisfaction with sub-indicators of climatic comfort and indoor air quality

Fig. 7 Satisfaction with sub-indicators of the use of systems and maintenance





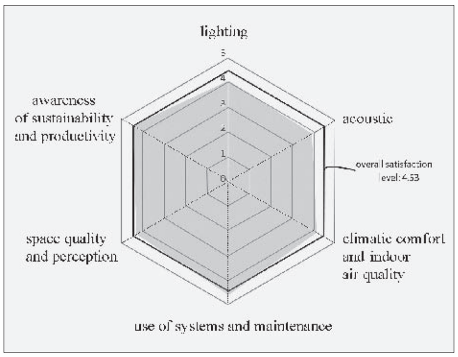


FIG. 8 SATISFACTION WITH SUB-INDICATORS OF SPACE QUALITY AND PERCEPTION

FIG. 9 VALUES ABOUT AWARENESS OF SUSTAINABILITY AND PRODUCTIVITY

FIG. 10 COMPARISON OF SATISFACTION VALUES OF INDICATORS

satisfied with the design of the building. It is seen that the satisfaction level in subjects such as interior design, material selections and the size of the spaces are positively received by the users, with values above 4. Compared to other situations, users' satisfaction level is lower in location and transportation. It can be interpreted that the fact that the building is located far from the city center, that public transportation is limited and that it is not sufficiently convenient for transportation by alternative transportation methods such as bicycles are factors in these results.

The awareness of sustainability and productivity indicator has been examined over six sub-indicators as green roof, sustainable material, efficient use of water, climate change and renewable energy sources, dissemination of sustainable buildings and productivity (Fig. 9). The level of green roof has been reached as 4.5 out of 5. Sustainable material's level is 4.33, efficient use of water sub-indicator's level is 4.62, climate change and renewable energy sources' level is 4.6, the level of dissemination of sustainable buildings is 4.77 and the level of productivity is 4,5. According to the findings, it can be said that the users' awareness about sustainability has increased thanks to the systems used in the building they work in and the sustainable qualities of the building. On the other hand, it is seen that users think that their productivity has increased after switching to a sustainable office.

Finally, a comparative analysis of lighting, acoustic, climatic comfort and indoor air quality, use of systems and maintenance, space quality and perception and awareness of sustainability, which are the main indicators used in the study, was made (Fig. 10). Lighting's satisfaction level has been reached as 4.06 out of 5. Acoustic's satisfaction level is 3.94, climatic comfort and indoor air quality's satisfaction level is 4.14, use of systems and maintenance's satisfaction level is 4.6, space quality and perception's satisfaction level is 4.3 and the level of awareness of sustainability and productivity is 4.56. In general terms, it can be said that satisfaction levels are high in the climatic comfort and indoor air quality, use of systems and maintenance, and space quality and perception indicators in the building. Users' awareness of sustainability has also been high. It is observed that user satisfaction is relatively lower in lighting and acoustic indicators compared to other indicators. As explained in detail above, the main reasons for this can be listed as the problems experienced in the control of natural light due to the large glass surfaces on the facade of the building and the noise problem due to the HVAC systems.

DISCUSSION AND CONCLUSION

According to Kellert, the green architectural design criteria included in green building certification systems can reduce the impact on the environment, but they are not sufficient to strengthen and enhance the bond between man and nature that supports human well-being and productivity (Kellert, 2005). In addition, Thatcher and Milner conducted a study to measure the physical and psychological well-being of users of green buildings. The design of the study is longitudinal and consists of two different times. Time 1 refers to before any of the users moved, and Time 2 refers to six months after the treatment group moved into the green building. There is a treatment group in which employees have moved from their existing buildings to the new green building and a control group in which employees have remained in their existing buildings. The authors compared the results of the well-being status according to an online survey of about 1200 people from each group. Contrary to the claims of some green building certifications, users in the treatment group reported no noticeable physical or psychological well-being or increase in productivity during the six months between Time 1 and Time 2. However, physical conditions such as thermal comfort, noise, and ventilation were significantly better in the Green Building at Time 2 (Thatcher and Milner, 2012: 3816-3823). On the contrary, in this study, it was observed that users' satisfaction values were high in awareness and productivity indicators. Users found their current working environment more productive than the building they worked in before. In this respect, the study overlaps with the study conducted by Bortolini and Forcada in 2021. According to Bortolini and Forcada, building age is associated with overall end-user satisfaction, as newer buildings are more satisfying to occupants, mainly because they meet higher standards of comfort (Bortolini and Forcada, 2021).

By analysing a case study from Saudi Arabia, Hamida and Hassanain conducted a post-occupancy evaluation of an adaptive reuse building in 2020. The original design of the case study building was meant for student accommodation at a university campus and was converted into an office building. This study has shown that an adaptively reused building can be aligned with the performance requirements of its new use. POE results showed that occupants are generally satisfied with identified performance categories including thermal, visual and acoustic comfort, indoor air quality, fire protection, furnishings and parking (Hamida and Hassanain, 2020: 29-40). In the building examined in this study, thermal, indoor air quality and parking were considered adequate by the users (>4), while satisfaction with acoustic and visual parameters was lower.

Another POE study, by Hassanain and Mahroos, assessed the satisfaction of occupants working on one typical floor of a five-storey office building. This research involved three data collection methods, namely walk-through assessment, user interviews and satisfaction survey. Thermal comfort, visual comfort, acoustic comfort and user awareness of the fire safety system were included in the technical performance factors. Except for visual comfort, the case study office building users were generally satisfied with all the technical performance elements. Functional performance factors included the layout, circulation and facilities. Two functional performance elements, office layout and building equipment, were also unsatisfactory (Hassanain and Mahroos, 2023: 564-581). The results of this study and those of Hassanain and Mahroos' study are similar in terms of visual comfort and thermal comfort. Although visual comfort was low in both studies, the importance of reflection and glare on user satisfaction was revealed. In terms of thermal comfort, both studies were positive. In terms of acoustic comfort, the level of satisfaction was found to be higher in Hassanain and Mahroos' study.

The importance of designing adaptable spaces and providing user-centred control of HVAC and lighting systems is underlined by another study in this area. Allowing occupants to control over the lighting and the indoor environment is shown to improve satisfaction. Facility managers, who should also provide occupants with control over their indoor climate, operable windows and blinds, are responsible for implementing energy efficiency measures (Bortolini and Forcada, 2021). In the current study, it is seen that the satisfaction level of the users is high in terms of the use and control of the systems. The systems can be controlled by users through automation and manually.

Although the actual energy use of green buildings varied widely, on average the energy performance of green buildings was better than that of conventional buildings in the same region. Once occupied, a building's energy use can differ significantly from that as designed, and many green buildings saved less energy than expected (Geng et al., 2019: 500-514). The use of sustainable design approaches such as solar panels and green roofs in the analysed building increases the energy performance of the building, and it has been determined that the awareness of the users has increased thanks to the direct relationship and use of these systems.

In 2011, Messinger et al. produced a comprehensive project funded by FOSTA (Forschungsvereinigung Stahlanwendung e.v.) and supported by the German Federal Ministry of Economics and Technology through the Joint Industrial Research and Development Programme. The P881 project, launched in January 2011, was supported by and involves architecture and engineering firms, partners from the IT sector, steel producers and construction companies. An interdisciplinary research team worked on the development of tools that would support engineers and architects in the decision-making process for sustainable building design. They considered environmental, economic, architectural, socio-technical and socio-cultural aspects of sustainability. The team aimed to produce a handbook with recommendations for action, a catalogue of components and an IT tool that incorporates different aspects of sustainability and their assessment (Messinger et al., 2011: 740-749). According to Baudach et al., who are the part of the P881 project, the life-cycle approach to building design is a prerequisite for sustainability. The socio-technical systems approach, shows how buildings can have a direct impact on social quality through concepts of concentration, communication and regeneration opportunities for employees and organizations. The analysis of future changes in office work concludes that flexibility in building design is crucial for long-term productivity and value. It is found that office buildings made of steel and steel composite construction have the necessary characteristics for the creation of such flexible conditions (Baudach et al., 2013: 18-25). In the building, the company's own production steel is used as the structural system, and the steel material is also used as a sunshade shell on the facade. This structural element, which forms a second envelope, has enabled the creation of interior gardens with flexible use in the design. While the users found these inner gardens positive, they did not find the semi-permeable sunshade shell sufficient for reflection and glare.

The FNN Sustainability Center is a pioneer in the use, diversity and awareness of regionally sustainable systems. This study aims to evaluate the sustainable office building of the centre after use and specifically aims to measure the satisfaction levels of office users through surveys. Within the scope of this study at the FNN Sustainability Center, a special scale was developed to use the survey. The development process of the scale included a detailed examination of relevant studies in the literature and was also enriched by obtaining expert opinions. Following this process, the validity and reliability analyses of the scale were carried out meticulously using the IBM SPSS data analysis program. Validity and reliability analyses of the developed scale were carried out using the SPSS data analysis program. These analyses included a comprehensive evaluation to show that the questions of the scale accurately measured the targeted topics and that the results were reliable. In this way, the scientific validity and reliability of the study was increased by establishing a solid basis for the strengths and usage areas of the scale. This scale development process provides a solid basis for the methodological framework of the study and contributes to making the data obtained more reliable and meaningful.

The effective use of sustainable systems of the FNN Sustainability Center, its diversity in structure and the general awareness of these systems assume an important role on a regional scale. The Post-Occupancy Evaluation (POE) study shows that the office building provides a positive experience for employees, both physically and psychologically, and raises awareness about sustainability. Based on the survey results, it has been determined that some individuals working in open-plan office areas are generally disturbed by noise, while another group of employees are disturbed by sun reflection and glare. This feedback means that office design and layouts can be revised to provide a better user experience. Simple layouts and optimized office layout can increase employee satisfaction. Additionally, employees making comparisons with old office buildings stated that working in a sustainable office is more productive and enjoyable. These findings suggest that sustainable office buildings can have a positive impact on employees' work performance and overall satisfaction. In this context, disseminating sustainable office practices and increasing awareness in this field can be important steps towards making working environments more sustainable and user-friendly.

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Bibliography and sources

1. Allen, J.G.; MacNaughton, P.; Laurent, J.G.C.; Flanigan, S.S.; Eitland, E.S.; Spengler, J.D. (2015) 'Green Buildings and Health', *Current Environmental Health Report*, 2, pp. 250-258. https://doi.org/10.1007/s40572-015-0063-y
2. Altensis. Available at: https://www.altensis.com/proje/fnn-surdurulebilirlik-merkezi/ [Accessed: 10 January 2024]
3. Arkiv. Available at: https://www.arkiv.com.tr/proje/fnn-sustainability-center/11646 [Accessed: 24 December 2023]
4. Asojo, A.O.; Bae, S.; Martin, C.S. (2020) 'Post-occupancy Evaluation Study of the Impact of Daylighting and Electric Lighting in the Workplace', *LEUKOS*, 16(3), pp. 239-250. https://doi.org/10.1080/15502724.2019.1602778
5. Bae, S.; Martin, C.S.; Asojo, A.O. (2021) 'Indoor Environmental Quality Factors that matter to Workplace Occupant: An 11 year Benchmark Study', *Building Research & Information*, 49(4), pp. 445-459. https://doi.org/10.1080/09613218.2020.1794777
6. Bakker, C.; Aries, M.; Kort, H.; Rosemann, A. (2017) 'Occupancy-Based Lighting Control in Open-Plan Office Spaces: A State of Art Review', *Building and Environment*, 112, pp. 308-321. https://doi.org/10.1016/j.buildenv.2016.11.042
7. Baudach, T.; Kokot, K.; Lingnau, V.; Zink, K.J. (2013) 'Einfluss von Nutzeranforderungen auf die ökonomische Bewertung von Stahl als Konstruktionswerkstoff für nachhaltige Bürogebäude, Ernst & Sohn Verlag für Architektur und technische Wissenschaften GmbH & Co. KG', *Berlin Stahlbau,* 82(1), pp. 18-25. https://doi.org/10.1002/stab.201201641
8. Bortolini, R.; Forcada, N. (2021) 'Association between Building Characteristics and Indoor Environmental Quality through Post-Occupancy Evaluation', *Energies*, 14, 1659. https://doi.org/10.3390/en14061659
9. Bryd, H.; Rasheed, E.O. (2016) 'The Productivity Paradox in Green Buildings', *Sustainability*, 8(4), 347. https://doi.org/10.3390/su8040347
10. Büyüköztürk, Ş. (2011) *Sosyal Bilimler İçin Veri Analizi El Kitabı – İstatistik, Araştırma Deseni, Spss Uygulamaları ve Yorum*. 15th ed. Ankara: Pegem Akademi.
11. Büyüköztürk, Ş. (2020) *Sosyal Bilimler İçin Veri Analizi El Kitabı.* 28th ed. Ankara: Pegem Yayıncılık.
12. Darko, A.; Chan, A.P.C.; Huo, X.; Owusu-Manu D. (2019) 'A Scientometric Analysis and Visualization of Global Green Building Research', *Building and Environment,* 149, pp. 501-511. https://doi.org/10.1016/j.buildenv.2018.12.059
13. Feige, A.; Wallbaum, H.; Janser, M.; Windlinger, L. (2013) 'Impact of Sustainable Office Buildings on Occupant's Comfort and Productivity', *Journal of Corporate Real Estate*, 15(1), pp. 7-34. https://doi.org/10.1108/JCRE-01-2013-0004
14. Freihoefer, K.; Guerin, D.; Martin, C.; Kim, H.; Brigham, J.K. (2015) 'Occupants' Satisfaction with, and Physical Readings of, Thermal, Acoustic, and Lighting Conditions of Sustainable Office Workspaces', *Indoor and Built Environment*, 24(4), pp. 457-472. https://doi.org/10.1177/1420326X13514595
15. Frontczak, M.; Schiavon, S.; Goins, J.; Arens, E.; Zang, H.; Wargocki, P. (2012) 'Quantitative Relationships between Occupant Satisfaction and Satisfaction Aspects of Indoor Environmental Quality and Building Design', *Indoor Air*, 22(2), pp. 119-131. https://doi.org/10.1111/j.1600-0668.2011.00745.x
16. Geng, Y.; Ji, W.; Wang, Z.; Lin, B. (2019) 'A Review of Operating Performance in Green Buildings: Energy Use, Indoor Environment Quality and Occupant Satisfaction', *Energy and Buildings,* 183, pp. 500-514. https://doi.org/10.1016/j.enbuild.2018.11.017
17. Hamida, M.; Hassanain, M.A. (2020) 'Post Occupancy Evaluation of Adaptively Reused Buildings: Case Study of an Office Building in Saudi Arabia', *Journal of Architecture, Civil Engineering, Environment,* 13(1), pp. 29-40. https://doi.org/10.21307/acee-2020-003
18. Hassanain, M.A.; Mahroos, M.S. (2023) 'A preliminary post-occupancy evaluation of the built-environment in office buildings: a case study from Saudi Arabia', *Property Management*, 41(4), pp. 564-581. https://doi.org/10.1108/PM-11-2022-0089
19. Ildiri, N.; Bazille, H.; Lou, Y.; Hinkelman, K.; Gray, W.A.; Zuo, W. (2022) 'Impact of WELL Certification on Occupant Satisfaction and Perceived Health, Well-Being, and Productivity: A Multi-Office Pre-Versus Post Occupancy Evaluation', *Building and Environment*, 224, 109539. https://doi.org/10.1016/j.buildenv.2022.109539
20. Juan, Y.; Gao, P.; Wang, J. (2010) 'A Hybrid Decision Support System for Sustainable Office

Building Renovation and Energy Performance Improvement', *Energy and Buildings*, 42, pp. 290-297. https://doi.org/10.1016/j.enbuild.2009.09.006
21. Kellert, S.R. (2005) *Building for Life: Designing an Understanding the Human-Nature Connection*. 1st ed. Washington: Island Press.
22. Kong, Z.; Utzinger, D.M.; Freihoefer, K.; Steege, T. (2018) 'The Impact of Interior Design on Visual Discomfort Reduction: A Field Study Integrating Lighting Environments with POE Survey', *Building and Environment*, 138, pp. 135-148. https://doi.org/10.1016/j.buildenv.2018.04.025
23. Leder, S.; Newsham, G.R.; Veitch, J.A.; Mancini, S.; Charles, K.E. (2016) 'Effects of Office Environment on Employee Satisfaction: A New Analysis', *Building Research & Information*, 44(1), pp. 34-50. https://doi.org/10.1080/09613218.2014.1003176
24. Leitner, D.S.; Sotsek, N.C.; Santos, A.P.L. (2020) 'Postoccupancy Evaluation in Buildings: Systematic Literature Review', *Journal of Performance of Constructed Facilities,* 34(1), 03119002. https://doi.org/10.1061/(ASCE)CF.1943-5509.0001389
25. Li, P.; Froese, T.M.; Brager, G. (2018) 'Post Occupancy Evaluation: State of the Art Analysis and State of the Practice Review', *Building and Environment*, 133, pp. 187-202. https://doi.org/10.1016/j.buildenv.2018.02.024
26. Mahbub, A.S.; Kua, H.; Lee, S. (2010) 'A Total Building Performance Approach to Evaluating Building Acoustics Performance', *Architectural Science Review,* 53(2), pp. 213-223. https://doi.org/10.3763/asre.2009.0032
27. Messinger, M.; Baudach, T.; Breit, M.; Eisele, J.; Feldman, M.; Franz, C.; Hogger, H.; Kokot, K.; Lang, F.; Lingnau, V.; Pyschny, D.; Stroetmann, R.; Zink, K.J. (2011) 'Nachhaltige Bürogebäude mit Stahl, Ernst & Sohn Verlag für Architektur und Technische Wissenschaften GmbH & Co. KG', *Berlin Stahlbau,* 80(10), pp. 740-749. https://doi.org/10.1002/stab.201101478
28. Park, J.; Loftness, V.; Aziz, A. (2018) 'Post-Occupancy Evaluation and IEQ Measurements from 64 Office Buildings: Critical Factors and Thresholds for User Satisfaction on Thermal Quality', *Buildings,* 8(11), 156. https://doi.org/10.3390/buildings8110156
29. Park, J.; Loftness, V.; Wang, T. (2022) 'Examining In Situ Acoustic Conditions for Enhanced Occupant Satisfaction in Contemporary Offices', *Buildings,* 12(9), 1305. https://doi.org/10.3390/buildings12091305
30. Preiser, W.F.E. (1995) 'Post-Occupancy Evaluation: How to Make Buildings Work Better', *Facilities,* 13(11), pp. 19-28. https://doi.org/10.1108/02632779510097787
31. Preiser, W.F.E.; Vischer, J.C. (2005) *Assessing Building Performance*, Oxford, UK: Elsevier Butterworth-Heineman. https://doi.org/10.4324/9780080455228
32. Tavşancil, E. (2019) *Tutumların Ölçülmesi ve SPSS ile Veri Analizi*. 6th ed. Ankara: Nobel Yayınevi.
33. Thatcher, A.; Milner, K. (2012) 'The Impact of a "Green" Building on Employees' Physical and Psychological Wellbeing', *Work*, 41, pp. 3816-3823. https://doi.org/10.3233/WOR-2012-0683-3816
34. Thatcher, A.; Milner, K. (2014) 'Changes in Productivity, Psychological Wellbeing and Physical Wellbeing from Working in a "Green Building"', *Work*, 49, pp. 381-393. https://doi.org/10.3233/WOR-141876
35. United Nations Environment Programme: UNEP, Global Status Report (2017).
36. United States Green Building Council LEED Rating System. Available at: https://www.usgbc.org/leed/v41 [Accessed: 15 January 2024]
37. Wang, N.; Adeli, H. (2014) 'Sustainable Building Design', *Journal of Civil Engineering and Management,* 20(1), pp. 1-10. https://doi.org/10.3846/13923730.2013.871330
38. Web of Science Core Collection. Available at: https://www.webofscience.com/wos/woscc/summary/1847a9d3-0aa0-41da-a304-20f0f-37c4b33-b6b219d1/relevance/1 [Accessed: 14 December 2023]
39. Zimmerman, A.; Martin, M. (2001) 'Post Occupancy Evaluation: Benefits and Barriers', *Building Research and Information,* 29(2), pp. 168-174. https://doi.org/10.1080/09613210010016857
40. Zimring, C.M.; Reizenstein, J.E. (1980) 'Post-Occupancy Evaluation: An Overview', *Environment and Behavior*, 12(4), pp. 429-450. https://doi.org/10.1177/0013916580124002

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