

Performance Evaluation of an Existing Jordanian Low-Income Apartment Building and Exploring Impact of Sustainable Strategies

Zaid. M. Al-Zrigat¹, Esra'a Nawafleh^{*1}

Zaid. M. Al-Zrigat, Faculty of Engineering Architecture Department Hashemite University Az-Zarqa'-Jordan, Zadez6040@yahoo.com¹

Corresponding author : Esra'a A.Nawafleh, Faculty of Engineering Architecture Department Hashemite University Az-Zarqa'-Jordan/ Assistant Engineer in Petra Development & Tourism Region Authority, Esraa.adnawafleh@yahoo.com.

Abstract— A construction project can only be considered sustainable when dealing with all dimensions of sustainability (environmental, economic, social, and cultural). Reducing the environmental impact, enhancing human health, and increasing environmental awareness among users and sustainable apartments is the most appropriate strategy for achieving the physical and psychological well-being of the population.

The purpose of this study is to measure the problems related to comfort (thermal, visual and acoustic) and to satisfy the users of low-income residential apartments and improve the performance of the building by assessing the impact of the proposed strategies for sustainability in building performance. This research paper was based on the selection of a sample of residential apartments Abu Alanda, Amman, Jordan, and the problems they suffer from, the harsh conditions, and a study of energy and water consumption of this sample to reach a series of results. The research includes two main axes, the first axis focuses on measuring problems related to the comfort of apartment users (low-income families) through the research questionnaire, and the second axis is how to improve the performance of the building by assessing the impact of the proposed strategies on building performance through a simulation program (Design Builder Program). The need for such research is increasing in Jordan, especially in the housing sector (residential apartments) as there are no indicators to specifically measure sustainable buildings in residential apartments.

Finally, a set of instructions will be issued to decision-makers involved in the production of low-income units from the decision on paper to architectural design with a more comprehensive view of the future and its path and ending with disposal of the unit after its life or renewal.

Key Words— Building performance; Simulation program; Low-Income apartments; Thermal Comfort; Visual Comfort; Sound Comfort

1 INTRODUCTION

The idea of the success or non-success of housing for low-income people remain controversial in the local or international domain, and this is due to whether housing has provided the most basic requirements for the shelter and has it raised its residents to a level of decent life commensurate with their living, culture, and social life, studies recommend finding solutions to design residential apartments for people with low incomes that take into account economic, social, and demographic criteria, as the target group of their residents constitutes a large proportion of the population. [4].

Jordan is one of the middle-income countries according to a classification prepared by the World Bank in 2016, Jordan suffers from limited resources and it is an importing country. What is not in doubt is the high costs and the high cost of living. These conditions must be compatible with the income of these families.

There are no studies or research concerned with designing apartments for people with low incomes in Jordan or at least the presence of national building codes that obligate and impose instructions on that category of projects, as a law was issued for the building system and entered into force in 2018 and the latest organization at the city level as a whole where it

has not been The level of the building, its quality, details of the building and its materials, or even stages of applying this system, from direct permits for issuing licenses or permission to work. [4].

From this point, there is necessary need to enhance the quality of the low-income apartment and its performance especially in Jordan and it's a limitation on water and energy resources and its worth to create an indoor environment with a minimum standard for physiological and physical comfort for the people who live in this apartments. [13].

1.1 Research Justification

The need for such research is increasing in Jordan, given its limited resources, especially in the housing sector, where there are no indicators for measuring sustainable buildings, especially in apartments for low-income groups, appropriate strategies must be taken into account to improve the internal environment related to mental health and provide a limit minimal comfort for residents, creating good specifications for housing with the lowest costs and reducing energy and water use.

1.2 Research Problem

The research problem is the lack of application of standards and codes of sustainability for buildings in Jordan, especially low-income residential apartments.

1.3 Research purpose

The purpose of this study is to measure the problems related to comfort (thermal, visual, and sound) and satisfy the users of low-income apartments (families or individuals) in creating a safe and healthy environment that reflects that the citizen can achieve the aspirations of society of progress and growth and improve the performance of the building by assessing the impact of the proposed strategies for sustainability in building performance all of these reflect their health and well-being in their society.

1.4 Research Question

- How can we improve the performance of apartments for low-income people regardless of sustainability issues including physical and mental health?
- How can we enhance thermal comfort in low-income apartments?
- How can we enhance visual comfort in low-income apartments?
- How much we can reduce energy consumption in the low-income apartment?

1.5 Research Background and Context

The research target at the Abu-Alanda region, where the study is carried out on a low-income apartment in a residential building located east of the capital, Amman, Jordan. The region suffers from various problems related to sustainability standards, poor infrastructure, a comfortable lack of livelihoods, and health centers located at great distances. Forcing people to migrate and seek alternative housing, and the apartment can accommodate a family of five or less.

2 LITRATURE REVIEW

2.1 What is the Sustainable apartment?

Sustainable building is the result of an interactive process between users and the building itself, where sustainable buildings are classified as high performance to achieve a social and economic environment, raise health and internal efficiency, and produce renewable energy. [8].

With the spread of the concept of urbanization in residential suburbs, there became a merger between different types of

cities and suburbs, which led to an increase in the value of homes, and the government resorted to imposing taxes. Political activists have only benefited from wealthy families living in suburbs from these policies to reduce these new inequalities, opening suburbs by building low-income housing. [44].

Depending on how the declines in household size was distributed across the suburban housing stock, these trends could have generated large amounts of vacant shelter space. If the declines in household size occurred primarily in the large, child-oriented households. [44].

The literature on housing agreed to launch the term low-cost housing to residential complexes and housing small and low contour spaces. That is, in which the ratio of the cuff to the utility group decreases compared to the power finance for people with low incomes. [4].

The determination of the low-cost housing concept depends on the housing costs and the financial capacity of the low-income population, i.e. the concept of low-cost housing must depend on the proportionality of costs with the financial ability of this group, and we agree with the prevailing social and economic customs and traditions. Therefore, the elements that must be available can be limited to Low-income housing is as follows:

Minimum sanitation (kitchen and bathroom) and Building materials shall be protected and strong enough to resist natural factors, and maintain conditioning, and do not need great maintenance. It should provide accommodation, lighting, and autonomy for the family, in addition to the ability to expand in case an increase in the number of family members in the future, and the dwelling be built in residential organization areas away from sources of pollution, such as smoke and factory waste and others. [4].

The appropriateness of housing is closely related to the formation of the individual's personality and his social and economic level, and since the individual is linked to society, it stems from his connection with his residence, and this justifies the adoption of housing policies by the governments, and since society is the family, so how can we secure a better future for the family despite the low costs of housing For low-income people, therefore, it must achieve the primary goal that housing is an environment conducive to creating a citizen capable of achieving the aspirations of the society in progress and development. [4].

2.2 Housing standards for low-income

People Low-income people to live in different house styles, including damaged residential areas in the city center, bypassing settlement areas, informal settlements of special nature, camps, integrated housing projects, multistory housing, and complex housing. [4].

Housing strategies mainly aim to provide suitable conditions for housing different segments according to common and accepted standards, however, defining these criteria include some difficulties, including the definition of acceptable housing, varies depending on the resident's view of the importance of social, economic, material, and environmental conditions, and the difficulty to observe and measure the impact of investments Various housing (improving water sources, sanitation, adequate nutrition, health care, and other social programs) in achieving the welfare of the population. [37].

Among the most important housing standards currently approved are planning and designing criteria, and an attempt to integrate between them, and the area and cost standard stands out as a concept that fits with the direction of sustainability and the lack of financial resources to implement housing projects. [21].

Sharing the furniture component in achieving the economic sufficiency of buildings through the use of tanks as separators (instead of partitions) between the architectural units, and the use of seats and tables that can be folded and saved in the tanks and taken out for use when needed, and the use of beds in the form of cabinets can save light furniture and collectibles inside. [40].

Construction methods that lead to the economic efficiency of the buildings: a comparison between the different construction methods, especially the method of construction in the load-bearing buildings, and a comparison between the different foundation methods, in particular, the use of continuous foundations of the bearing building leads to the economic efficiency of the buildings and the optimal use of materials and savings in their quantities without prejudice to the integrity of the building. [4].

2.3 Enhance of sustainable apartments

The concentration of internal pollutants in families that are characterized by a low social and economic level is high. Therefore, the diversity in these exposures is related to the effects of the sources of their internal and external types, existing structures and patterns of population activity. [5].

Addressing internal exposures is challenging because it includes contributions from both internal and external sources and because it may be influenced by socioeconomic variables (for example, size of housing) and institutional factors that determine the quality of housing and neighborhood characteristics (such as surrounding pollution). [15].

- **Structural Performance**

The lack of understanding of the links between housing and health has expanded beyond sanitation, infectious diseases and safety to include a wide list of factors associated with morbidity and mortality, such as radon; asbestos and chemicals in wall painting associated with the structural features of

the building primarily. [5].

Structural features may be socioeconomic and can be rooted causes of multiple exposures such as peeling home paint is an indication of water leakage, and an indicator of the development of mold, moisture, and structural deficits that may provide entry points for cockroaches and other pests. The principles of sustainability are rooted in providing building codes with the necessary standards to create a building structure for low-income families that improve living performance and lasts as long as possible in an environmentally friendly period. [36].

- **Indoor Air Quality environment**

Indoor air quality (IAQ) is an important issue that has both short term and long-term impacts on the health of users, the low-income population has smaller homes, which tend to enhance the influence of internal sources. Research has shown that some multiple-family units may have low air discharge rates in addition to insufficient ventilation, which will support the effect of internal sources. [35].

The quality of the indoor environment is an important internal experience for the internal environment of buildings, which includes aspects to design, analysis and operation of buildings and health areas, energy-saving and comfortable, including HVAC systems, thermal comfort, indoor air quality, lighting, and acoustics. [55].

At present, we can keep pace with internal environmental quality models, and classify them as a basic criterion in identifying and correcting problems and supporting the idea of internal sustainability at the level of small housing units. [55].

2.4 Quality of Social Environment

- **Sustainability of the Site**

Site planning is a very important and decisive matter in architectural drawings, and therefore small details must be given great importance to make them sustainable, and for the site planning to be sustainable it must be participatory starting from the owner to the architect to the engineer and ending with the contractor and therefore the greatest benefit from the site features is applied and making it more sustainable. [18].

A typical Architectural site plan must include some basic items such as the accessibility, circulation, and driveway to the site, surrounding streets, green areas, parking, land drainage, privacy, security, shelter, property lines and all boundaries, the existing and proposed conditions of the site with well-detailed dimensions. [18].

On a sustainable site plan, it should have the least impact on the environment it provides Being able to foster a healthy community, satisfying and meeting client needs, and promoting community activity, in short, planning a healthy environment and a better life. [16].

- **Thermal Comfort**

Thermal comfort in buildings is considered to be important and difficult variables that the architecture must address, so it must be deep for the idea of sustainable architecture, thermal comfort, thermal mass, orientation and other physical elements that are important in calculating the solar heat gain rate must be taken into account in addition to its architectural decorative function. [9].

Each building must be studied as a separate case in terms of engineering design, ratios of heights and openings areas on each side, the height of area and many other engineering features that differ from one building to another, all of which play an important role alongside the influence of thermal properties. [40].

The process of rationalizing energy consumption or maintaining its efficiency is a method of sustainable design. It is a process of reducing fossil fuel consumption, as buildings are used in their heating, air-conditioning and lighting processes as well as in their construction. [28].

All studies related to the thermal comfort performance of housing are the main concern of all because it looks to reduce energy consumption and compatibility with human comfort as a primary goal. [9].

While people spend 96.6% of their time indoors at. Housing projects amount to the largest proportion of the built area in the world and mostly consume energy and the largest place to stay at home must receive great attention. [9].

A comprehensive understanding of energy-saving buildings gives architectural designers a more comprehensive picture of saving energy using simple design steps, but it has a fundamental impact on human life. [29].

- **Visual Comfort**

Visual comfort is a personal reaction to the amount and quality of light in any space at a particular time. It depends on our ability to control the levels of light around us. As very little light or too many leads in turn to visual discomfort in the same importance, that the variation in Levels of light or sharp change causes fatigue and fatigue. A variety of aspects, such as aesthetic quality, lighting and viewing atmosphere: — Views of outside space and connected to nature, light quality, luminosity, Absence of glare. [51].

The assessment of the visual environment requires analysis of three main factors - light sources (artificial/natural), light distribution within space (color, intensity) and its perception. Scientists have begun to understand how light affects the body and mind as it has a direct impact such as sleep, mood, and alertness, as it has a major role in health and well-being in addition to our awareness and experience of the surrounding

environment. [10].

So there is no doubt that the comfortable source of lighting for the eye is natural daylight in addition to that it gives us information about the hour of the day, seasons and weather, which makes us feel psycho-social balance. [38]. [10].

Daylight in residential buildings is one of the main design parameters that affect the visual comfort of users and energy efficiency in buildings, where there is a close relationship between lighting levels, space direction, wall-to-window ratio, and indoor surface reflection materials. [38]. [10].

Natural daylight must be entered as a starting point from the design process through openings, scaling and misleading, orientation towards the south is of great importance increased lighting level up to 50% compared to the north direction and to avoid unwanted amount of lighting, use appropriate shading methods to introduce light. [47].

- **Sound Comfort**

Acoustics in architecture is concerned with improving sound in different environments. There are two terms for understanding sound are sound insulation and processing, which means less noise and better sound quality. [46].

All materials have acoustic properties that can absorb, reverse or transmit sounds. When properly handling rooms, the echo is minimized. Sound absorption is defined as the falling sound that collides with a substance that does not reflect again. The open window is a good absorber because the sound that passes through it is not reflected again. [19].

There are dangerous effects of unwanted sounds on health, including hearing loss, high blood pressure, headache, cardiovascular disease, physical and mental illnesses, hormonal changes, sleep disturbances, physical and mental performance, aggression, constant feelings of displeasure, frustration, in general well-being. [32].

The most effective way to reduce noise is to get rid of the noise source, for example, using a highly efficient propeller fan reduces the resulting noise. Also, the airspeed is reduced by increasing the air duct diameters, thereby reducing pressure and reducing noise. [15].

Architects' knowledge of the acoustic properties of the materials inspires them to gain a better understanding of the behavior of the designed spaces. Some of them need good sound absorption and some of them need effective sound insulation or both, but finally it is confirmed that the best result and sound comfort for the users are met and their needs also. [19].

2.5 Effects of residential density

General housing projects for people with low incomes are characterized by the high population density, and its correlation with large negative impacts. Tenants go to the experience

of overload because most of their daily social activities occur in this residential environment and most of the time is spent in it. [35].

The idea of high population density (congestion in the building) is associated with feelings of loss control, safety and privacy in the direct residential environment, problematic social relations between tenants, alienation and dissatisfaction with the residential environment in general, and these criteria are classified on their ability to achieve a sustainable building from a psychological point of view if employed in a manner. [12].

2.6 Health in the apartment's environment

Health services in the general are not sufficient to meet the needs of the residents of low-income areas in developing countries such as Jordan, and the inappropriate environmental conditions in these areas (such as housing, drinking water, sanitation, etc.) result in unhealthy conditions that, along with malnutrition, increase the incidence of diseases and its spread to a degree that exceeds the ability of prevention and treatment means and services to cope with it. [39].

Low-income housing often has many internal health risks. Among them, the infection of pests, the use of pesticides and allergens are recognized as common risks affecting the health of the population. [52].

- **Create healthy environments**

It has been observed through many studies that housing regulations, especially in developing countries such as Jordan, do not take into account modern health issues, and the cost of housing adjustment to meet health housing standards can be very expensive; however, costs are greatly reduced if it is. These elements can be combined during the construction of new homes or major rehabilitation of homes and apartment buildings for low-income families. [36].

To create a safe and healthy living environment for families with low incomes, the World Health Organization has developed several initiatives and programs to reduce the negative impact on health, the most important of which is the integration of a focus on health in housing-based initiatives, and the provision of adequate funding for programs to combat diseases caused by mold, moisture, and bad odors. [42].

- **Physical comfort levels**

Housing plays an important role in achieving the goal of sustainable development. Therefore, it is necessary to ensure that comfort is achieved at all levels, including physical. Lack of comfort has many implications for it which includes health and safety problems and spending less time at home and less input at work and could lead to crime for the youths. Sustainability advocates for comfort physical in houses. [40].

Improving the performance of the apartment for those with poor incomes and achieving the idea of insulation internally and externally to reduce visual and audio inconvenience and provide standards for sustainability that relate to mental, and physical health, and the use of architectural finishes with environmental thinking are the most important foundations for achieving the family's physical comfort. [40].

- **Disease-free environments**

Environmental problems are common, and studies have shown that more than half of low-income households, especially in developing countries, suffer from problems of household exposures such as secondary combustion products, secondhand smoke, chemicals, pests, insufficient ventilation, allergens, and other chemicals, including Specific health endpoints are respiratory irritation, asthma development and exacerbation, and cancer. [6].

The concept of morbidity from infectious and chronic diseases, injuries, malnutrition and mental disorders was linked to the quality of housing for low-income people. Global health officials are working on most of the health problems facing the poor category, whether it is bad sanitation or overcrowding, and not providing the minimum appropriate ventilation and reducing infectious diseases and risks related to fires to reduce injuries. [30].

Currently, global public health departments are using sustainable strategies to develop and improve housing, most notably: implementing guidelines and housing laws, implementing "healthy homes" programs to improve internal quality performance, making a periodic evaluation of a different housing condition, and supporting and disseminating the idea of healthy housing at affordable prices (inexpensive), To create a safe, disease-free environment in low-income residential apartments. [39].

- **The materials and health levels**

The concept of building materials is associated with the health risks of families, especially those with low incomes because of the resulting lack of light and natural ventilation internally, moving to a less stressful area and maintaining it healthily has positive effects on mental health. [55].

World Health Organization studies with the housing sector indicated that building materials used in low-cost housing despite their unprecedented durability and capabilities to resist fire, good insulation, and low cost, however, it was found that they have damage to human health regarding physical and mental health with long-term use for them and most notably: Asbestos, lead, and mold (toxic substances). [39].

- **Independence and Identity**

The primary goal in the concept of health is to look at the different needs of people and know-how low-income adults

view their independence, health, and identity relationship to their place of residence, especially since these concepts related to the elderly and people with disabilities. [2].

We have to take into account the concept of accessibility for people who are disabled when they have a ramp, they do not feel helpless and thus the concept of independence is strengthened for them, and this reflects the term Lifetime Home meaning there dimensions of everything and this enhances the concept of self-confidence and gives the person a value (space of freedom so that each special touch distinguish it). [2].

2.7 Material used in the apartments

The indoor environment in residential buildings is mainly controlled by the external conditions, the heating method, the specifications of the materials used, and the thermal insulation of the walls and ventilation. [21].

The high energy cost in Jordan and the poor thermal specifications of the materials used in the walls of the buildings are the two main factors that cause the internal living environment during the cold season to be short of wetting and unsanitary conditions. [43].

In most cases, the attempt is to keep the heat indoors without ventilation (infiltration only), this increases humidity and leads to less comfort and the appearance of moisture effects on wall materials, especially in low-income housing. [43].

- **Minimizing needs for new materials in apartment buildings**

Materials have a major role in reducing environmental degradation and the construction of healthy buildings can be sustainable not only for the environment but for its residents. [50].

Reducing the demand for the use of different materials makes the effect simple from the complexity or number of separations or reducing the different types, making the quantities above the need for reuse in another area of the same residential building, and therefore a very small percentage of death will be almost non-existent in some cases. [12].

The increasing demand for using materials in the building increases the consumption of carbon dioxide that is produced at every stage of the life cycle stages, from design and manufacture to use until the end of life. [7].

Building materials come at a certain environmental cost of some kind, so the first strategy to use sustainable and environmentally friendly materials is to reduce the demand for new materials, so designing small houses with well-designed spaces and reducing waste by pre-made units and avoiding unnecessary finishes by choosing Low-cost maintenance materials and thus maintain their life over the life of the building.

[7].

- **Using existing materials**

The available materials, as well as their localities, are distinguished by their ease of operation and rapid construction, thus reducing costs, especially in developing countries that are concerned with providing housing for people with limited incomes, in addition to economic housing, it is a sustainable and environmentally friendly housing. It is preferable to use the materials available in a region because these materials reduce by 30 % Of the total construction budget in addition to that it does not contain toxicity about reuse, unlike manufactured materials that need more studies on the toxicity of its better use. [47].

Jordan's climate is characterized by moderate and extremely dry weather conditions. The residential buildings are well constructed with an external white stone layer on the walls, and windows using a type of heat and sound insulating glass. [43].

Currently, the use of local building materials to reduce the cost of transporting and importing materials from abroad is encouraged, and the most prominent materials used locally in residential buildings in Jordan are concreting blocks, masonry, plaster, and insulating materials such as rock wool at a very low value suitable for families with low incomes. [1].

- **Recycling strategies in apartment**

One of the most important sustainability strategies linked to the concept of recycling building materials to reduce the negative impact of them on the environment. One of the most successful methods of local recycling in Jordan is the use of a rock waste from quarries, where it has proven that it has aesthetic value, and the result is local facades of different colors. [1].

2.8 Energy consumptions

- **Strategies to minimize energy using in low-income apartment**

The behavior of people residing in low-income apartments ranges from simple to more complicated to adapt to the environment, and this may include opening a window or door, adjusting the curtains, changing clothes, using fans, turning lights on or off, and also drinking cold or warm liquids as a regulator of heat or Personal heating. [28].

May cause panic to people due to time delays in producing hot water from faucet due to the loss of pipe heat loss and therefore it is advised to use hot water only when needed, as well as the opposite of cold water. [29].

Homeowners are more committed to preserving private property and look at the importance of energy more and that general knowledge about energy and the use of means plays an important role in guiding behavior. [23].

The architect must design HVAC systems so that the temperature can be regulated in the home without affecting the rate of fresh air supply. There are also effective methods such as insulation of the ceiling and floors (first importance), doors and walls. [15].

- **The energy and social characteristics**

Residential buildings are among the largest sectors consuming energy sources that come from fossil fuels. There was a close relationship between the amount of energy consumption and household income, as this varies from country to country. [34].

Fuel poverty means that the owners of extreme poverty and its members cannot afford enough warmth at a reasonable cost, to study their income and this is human health. Some studies have indicated poor internal conditions that increase mortality, especially in low-income apartment buildings. Especially with the recent high fuel prices. [34].

In residential buildings for people with low incomes, per capita consumption of energy and electricity increases, due to the poor quality of the buildings envelop. From this standpoint, energy policies for residential buildings should be developed as a priority to improve the quality of the cover for homes in which people with low incomes live. [1].

- **The energy and post occupancy**

The energy usage habits of low-income buildings do not only provide for their consumption but also indicate actual energy savings at a rate that may reach 20-30% of the building's total energy through optimal use of appliances, especially during periods of occupancy and presence within the space. [11].

The awareness of people in residential buildings when using the entire energy sources contributes to savings, and if it is simple behavior, for example, controlling the room temperature, and using class a devices (appliances), on the other hand, there are habits such as daily showering and excess of the normal range may consume more energy. [48].

2.9 Water Consumption

Recently, societies have seen an increase in the cost of providing water and sanitation, and factors that affect weak infrastructure, climate change, and significant population growth have been studied, especially for poor groups, shifts in areas with water shortages, and a decrease in follow-up to liquidation measures. Use of water, especially in apartments. [41].

Reducing water consumption in low-income housing is the most cost-effective way to reduce water use. This expands our supply even further, protects freshwater availability and saves money by reducing water bills and reducing sanitation bills.

These strategies support sustainability and reduce energy consumption and maintaining clean water sources. [17].

- **Strategies to minimize water consumption in apartment**

Strategies to reduce water consumption largely depend on the behavior of individuals, and the cultural and social norms of the family. (EDWARD VINE, 1987). Knowing the methods, and patterns of water consumption in a building is an essential step for purposeful planning and developing strategies to reduce water consumption. [3].

Among the most important integrated water management strategies in low-income developments are plumbing installations that save water, collect rainwater, reuse gray water, and enhance wastewater services by providing a clean, healthy water in homes for low-income people. [3].

- **Water systems (DSHWS) and cost**

Most developing countries, including Jordan, are characterized by the use of local solar hot water systems (DSHWS), especially in low-income housing, and this is linked to the economic aspect of poor families and their relationship to energy consumption, it is a natural choice for residential building technology. [25].

Where they supply hot water with an electronic shower head, which in turn reduced the demand for electricity use, and returned financial benefits from avoided carbon dioxide emissions and greatly reduced water consumption. [11].

- **Apartment Low-Flow Fixtures**

Water represents a good amount of cost, especially for families with low incomes, in addition to actual, cost of water, the costs of treating wastewater and the energy needed to heat the water increase the expenses and decrease the reserves of ground, and surface water, and to face these challenges we must preserve the water through the use of low-cost fixtures, especially In the bathroom because it constitutes the largest percentage of water consumption over 33% of total consumption and in kitchens. [54].

Low-cost strategies are less attractive, but better suited to older structures, most notably: repair and replacement of showerheads, toilets, washing machines, water meters, irrigation systems, and gray water purification systems for apartment buildings. [11].

3 RESEARCH METHODOLOGY

As per the specific research context, a cross-sectional design strategy was adopted. The data in this study was collected on a triangulation base that used two or more methods of data collection in one study. "Combining quantitative and qualitative methods. Its main principles which are the research ques-

tion must be focused, and the strengths, and weaknesses of each method. Triangulation is used to access verification of results as well as reliability and access to internal validity.

- Project Description

The target area of the research study is Base case Abu-Alanda, which is a Kareem housing that was built in 2008, and contains housing for low and middle-income people, public sector employees, the armed forces, and its general location in eastern Amman, Jordan, and contains several residential buildings that reached to (77) buildings, including (1773) low-income apartments, divided by users (type F, type JL, type KL, type JIII, type M, type K). [22].

According to many studies conducted on the buildings, the current residential apartments suffer from various problems that affect the residents' comfort (health, psychological, and thermal), and this is reflected in their behavior and level of satisfaction, it is the presence of a crack to the weakness of the materials used and their low cost, which affects the future structural system and the high rate of humidity that causes mold, respiratory diseases, and poor sanitation, especially in bathrooms and kitchens. [22].

The area of the apartments ranges between (90, 96, 113) square meters, and the average population of the region is about 9000 people, and we will choose a sample of (368) people to conduct a field study on them, most of them with a limited income and can provide a minimum of the requirements are for a decent life, and most of the residential buildings are made of locally manufactured brick materials with a non-insulated and low-cost single sliding glass type. [22].

- Table 1. Building summary

Title	Description
Location	Base case Abu-Alanda
Apartment Type	Apartment plan (M)
Spaces Type	Living room area (5.25 * 2.60 m2) kitchen area (3.40 * 3.30m2) (3) Bedrooms area of each room (3.40* 3.30 m2) (2) Bathrooms area for each bathroom (1.95 * 1.75m2) Balcony area (3.45 * 1.50m2)
Orientation	Different in the direction to the northeast, so we chose the most frequent model for the research study
Use	Residential facilities
Stories	One floor
Building Area	96 square meters
Structure	Reinforced concrete
Floor Height	3.30 m

4 Result

- Questionnaire Result

In the survey questionnaire, Comfort parameters on a various Likert scale that querying ability of the apartment to act as a good residential environment.so, the researchers measured comfort satisfaction according to populations' responses as the following:

Thermal comfort: According to the orientation, the results showed ,100% of the population feels that the temperature is moderate in the apartment, 25% of the students feel the temperature is comfortable, 40% feel somewhat comfortable, and 26% do not know whether the temperature is comfortable or not. 22% of the population feel that the temperature changes a lot during the day, 52% feel that the temperature changes slightly during the day, 17% feel that the temperature never changes during the day, and 14% of the population prefer to increase the temperature in the rooms, 24% prefer to lower the temperature in the room and 57% prefer to keep the temperature the same, 100% of students believe that the temperature is acceptable in the apartment. 28% of the population feel that the air inside the classroom is very constant, 13% of students feel that the air inside the apartment is fixed, 14% of the population feel that the movement of air inside the apartment is moderate, and 42% the residents in the apartment feel that the air is moving a little inside 24% of the population prefers to increase the airspeed inside the apartment, 57% of the population prefers to reduce the speed of the air inside the apartment, and 16% of the population prefers keeping the airspeed as it is, and 100% of the population feels that the airspeed is acceptable within the apartment 14% of the population feels that the rooms are in a wet degree, and 24% of the population feel the apartment is a little wet. 55% of the For residents that the humidity in the apartment is moderate, 26% of the population prefers that the humidity is less in the apartment, and 74% of the population prefer to maintain the humidity as it is in the rooms, 28% of the population feel that the humidity in the apartment is unacceptable, while 74% see Of the population, the humidity in the apartment is acceptable. 54% of the population did not prefer the location (bedrooms), because it is exposed to the south side, which increases the temperatures in the summer.

Visual comfort: According to the orientation, the results showed, 25% of the population; they feel that the intensity of the lighting in the apartment is very comfortable, and 23% of the population feel that the intensity of the lighting in the apartment is somewhat comfortable, 30% of the population feel that the intensity of the lighting in the apartment is a little annoying, and 16 feel % Of the population feels that the intensity of the lighting in the apartment is uncomfortable, and 53% of the population feel that the intensity of the lighting in the residential apartment should increase, 14% of the population feel that the intensity of the lighting should be less, and 25% of the population feel that the intensity of the lighting should It remains the same, and 573% of the population feels that the intensity of the lighting in the apartment is acceptable, while 45% of the population feels that the Light in rooms is not ac-

ceptable. 41% of all responses in the room apartment (bed-rooms) located in the south, which indicates the same intensity of illumination. On the contrary, 33% of all responses in the apartment room (the living and dining room), located in the northeast, prefer an increase in the intensity of the lighting.

Acoustic comfort: According to the orientation, the results showed, on the subject of noise, the sources of noise were divided into sources from neighboring apartments and sources from outside the apartment. 39% of the population feel that the sounds coming from outside the apartment are not annoying, 14% of the population feel that the sounds coming out of the apartment are somewhat annoying, 26% of the population feel that the external sounds are disturbing, and 16% feel that the sounds coming from outside the apartment are disturbing Extremely, 24% of the population feels that the sounds coming from the apartment yard or adjacent apartments are somewhat tense, and 26% of the population feel that the sounds coming from the adjacent apartment apartments are annoying, and 45% of the population feels that the sounds coming from the apartment yard or adjacent apartments Very troublesome.

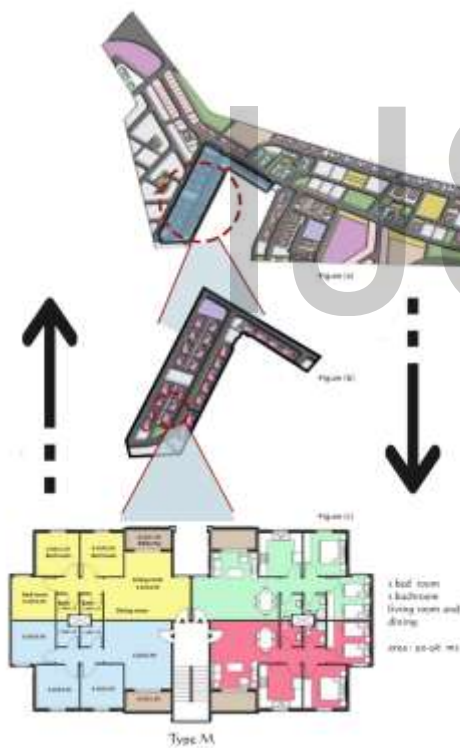


Figure (1): (a) Master Plan Residential Apartments, Abu-Alanda, East Amman / (b) Block Plan of the Type of Apartment (M) / (c) Architectural plan of a residential apartment for low-income people type (M).

• Design-Builder/ Energy Plus Program Result

In the simulation program, the results were measured for the whole year period from January to December, unload high dry temperature ranges from 7 to 32 ° C, peaked in August, the air temperature reaches 23 ° C, which corresponds to the popula-

tions 'answers at a comfortable temperature In the results of the questionnaire section, the total design capacity is 128.07 kW, the total flow rate is 7.76 m³ / s, the total cooling load is 108.07 kW, reasonable power 95.05 KW, and latent power 15.72 KW in the whole year, the air comfort temperature is 23.17 ° C, which corresponds to the population accounts in the temperature comfortable in the section of the questionnaire results.

5 Discussion

• Discussion simulation program

In simulation program we made different alternatives: enhancement in walls (adding 20 cm block, adding polystyrene, adding rock wall to the wall), enhancement in roof layers (adding phenolic foam), enhancement in windows layer (type of windows, type of glazing ,frame of window and adding shading devise).

• Discussion questionnaire

Based on our survey, which answered by the residents of Karim Sakan - Base case Abu-Alanda, on their websites and groups, where the questionnaire includes (30), and the questions require either short answers or choose from several options, and the questionnaire does not take more than 15 minutes to complete, The questions were answered on 21/April/ 2020, by (55) low-income people. (87%) answered almost all of the questions regarding thermal, visual, and acoustic comfort, (3%) avoided answering the question of the monthly income level.

Residents of residential apartments made suggestions through the questionnaire, the most important of which are: to provide better insulation in the walls to save energy, reduce high heat in summer, and use a good type of insulation in the windows, especially orientation to the south and to reduce the noise of shared outdoor spaces, and also increase the sun and air entry into the interior spaces, especially (Living room). All of them correspond to the alternatives that have been proposed and applied to the design-builders simulation program to achieve the maximum possible comfort for the population.

• Discussion of the Observation

Through the researcher's visit to the apartment, the researcher's observations have a major role in the results and discussion section of this research, as they were linked to the results of the questionnaire and the results of the simulation program and appeared as follows.

In the southern rooms, the sun enters the daytime due to the absence of shading to protect from the sun's rays, so the temperature in the apartment changes during the day and this is consistent with the results of the questionnaire taken, and the solution to this case is to put effective shading elements on the windows of the rooms. The entry of sunlight through the windows increases the intensity of the light inside the apartment,

which affects the vision of the residents.

We noticed that there is one glass window as shown above in every room in the apartment, which makes the distribution of noise between the rooms, and is consistent with the results of the questionnaire, as the residents answer that he feels a high level of noise coming from other rooms and apartments, the solution is to make these windows Double or triple glass for less noise mobility.

In addition to the windows of the apartment are close to the outside square, which causes noise to the residents, and this is consistent with the results of the questionnaire, which shows that the residents feel disturbed by the noise coming from the outside square, the solution is to make triple-glass windows.

Although to the lighting in the apartment, clearly shows a good and fair distribution of lighting for users, but it would have been better if the lamps were energy-saving to reduce energy consumption in the apartment.

Then, we noted that the ceiling material, wall, and temperature have a great impact on the cooling load, and it looks like the most optimal material for the specified ceiling and wall among many options, due to its colors, softness, design, and energy-saving from building elements such as walls, floors, windows, and ceilings. It was examined through a building simulation program The current flat, how can the combination of these improved elements with the effective air quality factor contribute to achieving the final energy-saving design The simulation results showed that the temperature in the cooling mode was 23 ° C which is an appropriate temperature that corresponds to the results of the questionnaire Collected from the population, but these results can also be improved by adopting triple or double glazing for windows.

6 Conclusions

In this paper, a mixed evaluation method was presented to assist designers in the decision-making process and to support the primary goal of sustainability in residential apartments, which is to promote healthy and vibrant living environments, including excellent levels of natural light and ventilation that affect the standards of the psychological and physical comfort of the population. With low incomes, sustainable apartment design increases the morale of all those who use it and enhances the performance and behavior of residents to become a more innovative approach to design and application.

The aim of analyzing the results in this study was to identify these factors and highlight the best ways to create environmental comfort standards, and to provide alternatives to reduce energy consumption in low-income apartment apartments.

To encourage sustainable design in residential apartments, materials with less negative health impact should be given great importance and more education of responsible agencies and designers (engineers) in assessing material performance

and providing the best solutions for thermal efficiency and user comfort.

Data were collected and analyzed through the use of questionnaires, observation and simulation programs, which highlighted the strengths and weaknesses of apartment design in regarding of application of sustainability standards, and the best methods to reduce energy consumption. Through these methods, three main axes have been found to illustrate the need for sustainable low-income residential buildings.

The results of the questionnaire and interviews showed that low-income people are dissatisfied with the thermal, acoustic and visual comfort inside the apartment, as the temperature is high in the summer and the cold in the winter in the rooms, the movement of air is slow and the humidity is high and the intensity of the lighting is unacceptable and the sounds outside the apartment are disturbing.

The observation results showed that the population suffers from problems of high internal heat in the rooms due to the wrong unsustainable orientation, the presence of lighting problems due to the small size of the windows in each room, the high level of noise due to the lack of insulation layer in the windows, and the poor building materials used in construction and finishes, As it causes diseases of mold, moisture, and asthma.

To achieve the greatest possible degree of satisfaction of low-income apartment residents, a simulation-designers program was used, which assesses the performance of the current apartment building and develops alternatives that seek to reach a more sustainable apartment building.

The results of the simulation program showed that the rooms directed to the south need more cooling and protection from the sun and that the rooms directed to the north need to be more isolated due to the acoustic discomfort of the adjacent apartments, this is done using double glazing in the internal windows of the building.

7 Recommendations

Based on the results obtained from the questionnaire, the design-Builder program:

- We recommend using a roof insulation layer, changing (opening) of the glass type, (U 0.65), which contributes to raising the internal temperature in the apartment during the winter season, so it achieves a thermal comfort for the user and also reduces the temperature gained from the outside in the summer, so it achieves the highest rate of coldness in summer.
- We recommend using the shading device, which contributes to a noticeable increase in the percentage of cooling inside the apartment in the summer and reduces the loss or gain of heat internally or externally

through the glass.

8 REFERENCES

- [1] Khasawneh, J. (2011). *AREE -Aqaba Residence Energy Efficiency*. Retrieved from The Center for the Study of the Built Environment (CSBE).
- [2] Kohon, J. (2014). Exploring identity and aging: Auto-photography and narratives of low income older adults. *Journal of Aging Studies*.
- [3] Marinovski, A. (2014). Water End-Uses in Low-Income Houses in Southern Brazil. *MDPI*.
- [4] Abdul Waab, A. (2015). *Design housing standards for low-income people*.
- [5] Adamkiewicz, G. (2015, November). Moving Environmental Justice Indoors: Understanding Structural Influences on Residential Exposure Patterns in Low-Income Communities. *American Journal of Public Health (ajph)*.
- [6] Adamkiewicz, Gary. (2014). Environmental Conditions in Low-Income Urban Housing: Clustering and Associations With Self-Reported Health. *American Journal of Public Health (ajph)*.
- [7] Agency, I. E. (2019, March). Material efficiency in clean energy transitions.
- [8] Sassi, P. (2006). Strategies for Sustainable Architecture.
- [9] Asma' Bataineh, H. H. (2010). A Study of Thermal Performance Analysis of Low-Income Housing in Jordan: Case of SOS Buildings.
- [10] Atzeri, A. M. (2017). *Energy Efficiency, Thermal and Visual Comfort –integrated Building Performance Modelling and Measurement*.
- [11] Bing Dong, Z. L. (2015). An Investigation on Energy Related Occupancy Behavior for Low-Income Residential.
- [12] Brad Guy and Nicholas, K. H. (2005). DFD Design for Disassembly in the built environment. n
- [13] (2018). *Building system and organization in the city of Amman*.
- [14] Carolina M. Rodriguez, J. M. (2019). Thermal Comfort and Satisfaction in the Context of Social Housing: Case Study in Bogotá, Colombia.
- [15] Claude-A. Roulet, C. C. (2016). HEALTH, COMFORT, AND ENERGY PERFORMANCE IN BUILDINGS GUIDELINES TO ACHIEVE THEM ALL.
- [16] D Ayeni ,R Tukur. (2019). SUSTAINABLE SITE PLANNING AND THE ARCHITECTS' ROLE.
- [17] Development, U. D. (2014). *HUD.GOV*. Retrieved from Public Housing Environmental & Conservation Clearinghouse.
- [18] Dorcas A. Ayeni, C. A. (2017). SUSTAINABLE SITE PLANNING AND THE ARCHITECTS' ROLE.
- [19] Eduardo Souza, J. T. (2019). How To Improve the Acoustics of a Room.
- [20] EDWARD VINE, R. D. (1987). Domestic hot water consumption in four low-income apartment buildings. *ELSEVIER*.
- [21] Fundamentals, A. H. (2001). Sustainable desing architecture.
- [22] gerasanews. (2014). Beneficiaries of Kareem Abu Alanda housing offer their apartments for sale due to poor construction and finishing ... and demanding that the contractor be converted to corruption !!
- [23] Hand, C.M. (1986). Energy attitudes, beliefs, and behavior: a specification of situational and personal determinants of residential conservation behavior.
- [24] Hao Tang, Yong Ding, B C Singer. (2020). *Interactions and comprehensive effect of indoor environmental quality factors on occupant satisfaction*. Retrieved from semantic scholar.
- [25] Helena F. Napolini, H. F. (2012). Assessing the technical and economic viability of low-cost domestic solar hotwater systems (DSHWS) in low-income residential dwellings in Brazil. *ELSEVIER*.
- [26] Home is where the heart is—most of the time. (2007).
- [27] Ismahan Nadji Maachi. (2019). The natural lighting for energy saving and visual comfort in collectivehousing: A case study in the Algerian building context. *Journal of Building Engineering*.
- [28] Jared Langevin, P. L. (2012). Reducing energy consumption in low income public housing: Interviewing. doi:Applied Energy 102 (2013) 1358–1370
- [29] Kempton W, N. M. (1987). *Energy efficiency: Perspectives on individual behavior*.
- [30] Krieger, J. (2002). Housing and Health: Time Again for Public Health Action.
- [31] Landscape Architect's Portable Handbook. (2001).
- [32] Leardi, L. (2019). Basic Principles of Acoustics: Why Architects Shouldn't Leave It All To Consultants.
- [33] Leshnower, R. (2019). What Defines An Apartment. *The Sprue*, 2.
- [34] M. Santamouris, K. K. (2006). On the relation between the energy and social characteristics of the residential sector. doi:Energy and Buildings 39 (2007) 893–905.
- [35] McCarthy, D. (2015). Residential Density,

- Social Overload, and Social Withdrawal.
- [36] Nightingale, F. (2015). Healthy, Resilient, and Sustainable Communities After Disasters: Strategies, Opportunities, and Planning for Recovery.
- [37] Olson, E. (2015). Comparing Income Statistics from Different Sources – Aggregate Income. *Statistics Canada*.
- [38] Omar S. Asfour, A. Y. (2016). A Study of Daylighting Performance in Apartment Buildings with Reference to the Gaza Strip.
- [39] Organization World Health. (2016).
- [40] Pahat, B. (2014). *COMFORT IN LOW COST HOUSES: THEORITICAL FRAMEWORK DEVELOPMENT*.
- [41] Raucher, R. (2019). Developing a New Framework for Household Affordability and Financial Capability Assessment in the Water Sector.
- [42] Ross, T. (2016). Creating Safe and Healthy Living Environments for Low-Income Families.
- [43] S J. Sulaiman, N. B. (2011). Residential Building Walls and Environment in Amman, Jordan.
- [44] Saidu , A. (2020). Success Criteria Evaluation for a Sustainable and Affordable Housing Model: A Case for Improving Household Welfare in Nigeria Cities. *Sustainability*.
- [45] Seth, T. (2017). Income: Meaning And Concepts On Income. *Economics Discussion*.
- [46] Souza, E. (2019). Keys To Improve Architectural Acoustics: Sound Absorption and Diffusion.
- [47] Swaptik Chowdhury, S. R. (2013). Prospects of Low Cost Housing in India. doi:<http://dx.doi.org/10.4236/gm.2013.32008>
- [48] Tamás Csoknyai, J. L. (2019). Analysis of energy consumption profiles in residential buildings and impact assessment of a serious game on occupants' behavior.
- [49] Tamás Csoknyai, Jeremy Legardeur. (2019). Analysis of energy consumption profiles in residential buildings and impact assessment of a serious game on occupants' behavior.
- [50] Usman Aminu Umar, M. F. (2012). SUSTAINABLE BUILDING MATERIAL FOR GREEN BUILDING CONSTRUCTION, CONSERVATION AND REFURBISHING.
- [51] *Visual-Comfort*. (2014). solutions/visual-comfort
- [52] Wang, C. (2015). Survey of Pest Infestation, Asthma, and Allergy in Low-income Housing. *Journal of Community Health*.
- [53] Wasley, M. U. (2011). *LIHI Denny Park Apartments*. Retrieved from The Society of Building Science Educators.
- [54] Water Resources Engineering, I. S. (2002). *OVERVIEW OF RETROFIT STRATEGIES A Guide for Apartment Owners and Managers*. Retrieved from PATH.
- [55] Wolverton, S. (2019). Low-income housing: The negative effects on both physical and mental health. *NCRC*.
- [56] ASHRAE. (2012). Performance measurement protocols: best practices guide. American Society of Heating, Refrigerating and Air-Conditioning Engineers. Atlanta.