RES MILITARIS
REVUE EUROPEENNE D ETUDES EUROPEAN JOURNAL OF MILITARY STUDIES
Social Science Journal

The Effect Of Shell And Active Structures On The Sustainability Of Airport Terminals

By

Noor Muhammad Al-Chalabi
Al-Nahrain University, Faculty of Engineering, Department of Architectural Engineering
Email: eng.noor.alchalabi@gmail.com

Assistant Professor, Khalid Abdulwahab Al-Mudres
Al-Nahrain University, Faculty of Engineering, Department of Architectural Engineering
Email: almudres99@yahoo.com

Assistant Professor, Omar Shamal Farhan
Al-Nahrain University, Faculty of Engineering, Department of Architectural Engineering
Email: ommar_shamal2006@yahoo.com

Abstract

The concept of sustainability in contemporary architectural design is linked to the development of technology and its employment in architectural production. It represents a motive for architects to present new and innovative formulas for interacting with the surrounding environment on several levels, including environmental, social, and economic ones. Structural systems vary to meet the functional requirements, especially in interactive spaces that require large areas, such as airport buildings in order to enhance the principle of sustainability in the performance of those buildings. Hence, it is necessary to define the field of study of those systems and reduce the field of research by stating only two types, which are shell and active facilities, Due to scarcity of using them in local architecture, and lack of knowledge. Some specialists consider it one of the best types of coordinated construction systems for the link between architectural form and expressive performance in contemporary architecture.

It stems from the need to shed light on the shell and active construction methods and define their characteristics to achieve the requirements of environmental, functional, and economic sustainability and to achieve security and protection for users in those buildings.

The present study aims at "clarifying concepts related to shell and active building systems, and how they achieve the principles of sustainability, analyzing the relationship between these systems and sustainable airport buildings, and building a theoretical framework that combines the main and secondary paragraphs and applying them to a series of projects", represented by sustainable distinct global airport buildings.

Shell and active structures in airport buildings achieved their goal, which is sustainability in the buildings through the requirements of sustainable design at high rates.

Keywords
Shell facilities, active facilities, sustainable facilities, sustainable airports.

Introduction

Airport sustainability is defined as "a comprehensive approach to airport management to ensure safety, economic and operational viability, efficiency, conservation of natural resources, and social responsibility (Ashford, 2011). Sustainable design in airports is the integration of design, planning, and occupancy together, through the coordination of building systems. It is not possible to achieve all these requirements without the structural system being effective and complementary to the elements of sustainable design, so the present study is concerned with addressing the impact of the technology of shell and active structural systems in terms of achieving sustainability on contemporary architectural production in general and airport buildings in particular. The shell systems technology witnessed An outstanding great development in the methods of its implementation and its coverage of wide ranges and the least amount of materials and the diversity of construction materials in it and its ability to provide the building with natural light, in addition to the diversity of its forms and its high aesthetics, so the research problem is represented by the lack of local knowledge of the effects of the shell and attached structural systems on the sustainability of buildings in general And airport buildings in particular. The present study assumes that the technology of shell and active systems has the ability to achieve the goal of a nation in local architectural production. The descriptive analytical approach is adopted, and the standards adopted in the analysis of sustainability in airport buildings are extracted. Then, the hierarchy of its effective indicators in order of importance. A review of the situation of shell and active building systems in the selected models of international and Arab projects and a diagnosis of the extent to which they meet these standards in an attempt to generate different standards and present them in the form of evaluation results, enhancing local expertise, enriching knowledge, and diversifying local production with non-traditional building systems.

2. Sustainable Airports

Contemporary trends in the design of airport buildings have been linked to the concept of sustainability in terms of their endeavor to upgrade to meet the requirements of the current era, which is the integration of environmental, social and economic aspects that apply the principles of sustainability in planning, design, and operation of its various areas. Passenger transport buildings are the central nucleus through which sustainable development can be achieved in society through linking multiple types of transportation in one place, and creating a state of interaction between the movement of users and the station spaces that must be attractive and cohesive. Studies define passenger transport buildings as the building or urban space that provides the appropriate conditions to achieve continuity in performance and operation (Edwards, 2005ranges, which is one of the most important planning and design requirements for airports.

In addition to being a source of economic and civilizational growth, the importance of airports lies in their being oases to which the traveler resorts when moving between his/her space on earth and his/her space in space. Therefore, special attention must be given to designing gardens and open external and internal spaces, focusing on afforestation, creating water spaces, and trying to benefit from these Spaces as areas for waiting and entertainment.

As for the concept of sustainability, it is the optimal use of available resources and human, material, or natural capabilities in an effective and balanced environmental and urban manner to ensure the continuity of sustainability without wasting the gains of future generations (Hilal et al., 2014). Environmental aspects address pollution reduction and reduce its impact based on environmental assessment systems. While social aspects achieve the highest levels of

passenger satisfaction in addition to the sustainability of awareness and education, which provides a high economic return depending on the provision of investment spaces within it with multiple privileges supporting the national economy, companies, and individuals (Hussain and Ramdan, 2020).

Thus, sustainable airport buildings can be defined as those in which sustainability principles are applied when designing new buildings or operating and maintaining existing buildings with their various internal and external spaces, with basic considerations of design patterns, as well as considerations of movement and flexibility, within an approach that integrates environmental, social, and economic aspects.

Modern roofing methods for airport buildings; There are many types of roofing methods for airports with wide scopes, but the focus will be on only two types of building systems, namely (shell and active) due to their distinguished aesthetic and environmental influence, the speed of economic implementation of construction and their locally rare use by specifying all Types and indications of their types, building materials used in them, and their advantages and disadvantages.

A. Shell structure systems; Shell structures are among the best fixed concrete structures. They are light in weight and more expressive of the origin. One of the advantages of shell structures is that they achieve formative relationships for space such as extension, continuity, and containment. They are lightweight and economical in the materials used. They have a flexible and solid structure in its formations. They resists forces through their outer shell. It is also easy to make big openings for natural lighting in the structure of the shell surface. They have resistance to fire, rain water, and temperature change. Despite the presence of some defects in shell structures represented in the fact that they require high skill in design and construction because most engineers are not fully aware of their design methods and their need for complex calculations, but they give impressive and unique forms that are the ones of their kind and very attractive in an economical way.

B. Active Structural Systems

Active systems are considered lightweight because their structural stability results from a pre-stressed shape rather than the mass of the materials used. Although they are lighter than traditional building systems, they provide high stability. The light weight advantage of the active systems provides unique characteristics such as mobility, adaptability, and transformation. Active systems are the most flexible convertible systems that are flexible in configuration and shape for a variety of spatial arrangements in response to social and climatic changes. Membranes' resistance to contamination is beneficial to their appearance and cost of maintenance. Nanotechnology can provide high durability and self-cleaning chemistry to fabrics. One of the most important qualities of active systems is optional transparency to provide adequate daylighting for users and reduce dependence on light bulbs. Moreover, when applied to the building surface, tensile fabric membranes provide radiant cooling effects. Lightweight active systems are usually integrated with thermal mass components in new and existing building designs to replace or assist mechanical ventilation systems in contemporary, extremely dry, high-density urban contexts such as airports*(Ardakani, 2016)*.

1. Factors influencing selecting construction systems for sustainable airport buildings

The complexity of sustainable airport building systems and the high flexibility they require, the specialization of airport engineering, and the urgent need for expansion in a short time are the main considerations that make the use of structural systems with long spans within the airport buildings one of the most important basic requirements in the design of the terminal.

The modern architectural movement deals with complex structural systems and new building materials to create an architectural form that respects local and traditional privacy (Basim and Vladimirovich, 2019). Therefore, the design factors for the construction systems that characterize the current generation of airport buildings are:

1. Design for flexibility and scalability
2. Ease of use for travelers
3. Safety and security through design, control, and electronic means
4. An environmentally friendly approach in the selection of materials and means of providing construction services
5. Organizing travelers and collecting them in separate groups ready for flights

These functions are related to each other and exchange roles among themselves (Edwards, 2005). The distinctive and unique structural design of the terminal building plays a major role in the success of the airport project as a whole. Improvements are made to the elements of the structural system, which must be economical and implemented in a responsive manner to meet the expected requirements of achieving the objectives of the project (Englot, 1998).

2. Environmental, economic, social, and technological aspects of sustainability in airport buildings

The challenge facing airport buildings in this century is to provide efficient and smart solutions to interact with the different needs of users, and to achieve passenger-friendly airport buildings that have attractiveness and excitement that contribute to raising the number of users of public transport and achieving economic and operational efficiency. In general, sustainable airport buildings can be expressed as Buildings that meet the environmental, economic, social, and technological requirements of sustainability.

A. The influence of construction systems on environmental sustainability in airport buildings; Environmental sustainability is a concept that has received a great deal of attention recently and can sometimes overlap with objectives and policies. But environmental sustainability is much broader and is concerned with identifying and implementing programs that reduce the impact on the environment, reduce the consumption of natural resources, and look for opportunities to replenish natural resources if possible while meeting the needs of the present. Natural resources, through the integration of systems, especially the structural system, as it has a significant influence on the internal environment of the airport terminal (Brown, 2010). The requirements of sustainable environmental design are achieved through maximizing the utilization of natural lighting and ventilation to reduce operational costs, the use of solar energy for heating and cooling, the exploitation of roofs to collect rainwater and its use for irrigation and cleaning, and the recycling and reuse of materials using construction systems that have the ability to achieve these requirements (Allan, 2014). The LEED international classification has been adopted in many airports - which Arab countries will adopt according to their climatic environment - within the supported categories in airport design, which include design, implementation, operation, new maintenance, interior design, and construction (Landrum and Brown, 2010).

The structural system can affect the sustainable environmental design of airports. This is achieved through maximizing the utilization of natural lighting and ventilation to reduce operational costs. It can be achieved on several levels through the integration of building systems, especially the structural system, which is compatible with the local environment for airport buildings.

B. The influence of construction systems on economic sustainability in airport buildings; Previous studies have indicated many aspects related to the economic dimension in sustainable airports, as well as the various strategies adopted by contemporary projects, the most important of which are construction techniques (Griffiths, 2012). Most of the embodied energy and some of the operational energy of the building are associated with the structural system. Hence, one possibility is to reduce the building's energy consumption by changing its structural design. Another possibility is to increase the service life. There is also a possibility to apply computational methods to obtain an optimal design from the point of view of energy efficiency and sustainable building design (Surendran et al., 2015).

The energy consumption of the building can be reduced by changing its structural design, increasing its service life, and applying computational methods to obtain an optimal design from the point of view of energy efficiency and sustainable building design, especially when the smart building system is integrated with various sub-systems to make them operate more efficiently to increase system performance and reduce investment and cost of the airport building.

C. The influence of construction systems on social sustainability in airport buildings; Social sustainability is a continuous activity that aims to improve the quality of life of all segments of society in the present and the future. Social sustainability combines physical domain design with social world design (Dette and Gartner, 1987). This obliges airports to provide good transportation, meet user requirements, create social interaction between users in the station's entertainment and service spaces, provide ease of access, and secure security and safety requirements (Allan, 2014). The principles of social sustainability are applicable through synergy between the architectural and construction goals that It works to embody a local, innovative and creative environment and creates a balance between freedom, performance, diversity, surprises, simplicity and engineering complexity and provides fertile ground for improving quality, sustainability and joy in airport buildings (Khouri, 2017).

The local historical and cultural patterns can be embodied through the use of construction systems that work to embody a local, innovative and creative environment and create a balance between freedom, performance, diversity, surprises, simplicity and engineering complexity and provide fertile ground for improving quality and sustainability in airport buildings to achieve passenger satisfaction and respect for the local context and provide attractiveness and promote art and promote Travelers experience and comfort in the speed of services.

D. The influence of construction systems on technological sustainability in airport buildings

Technological sustainability is defined as the technology that achieves sustainability in one way by converting resources into useful products and integrating science and design with human horizons and designers' creativity to create future designs (Abbas, 2015). The airport industry is the world's largest energy consumer, which negatively impacts the environment. The use of BIM technology helps greatly in improving energy performance in various ways and improving emissions and controlling them during the design phase (Kareem et al., 2021). The focus of new facilities is on light weight, large areas, functionality, efficiency and economy. This gave rise to new developments of model outcome structures, i.e., a set of tools and strategies for finding the 'structural minimum' shape - in cortical structures where surface stress is mainly in plane with compression, tension, and shear (Brown, 2010). Integration of simulation with BIM software can validate sustainable design against standards set by internationally accredited rating systems such as LEED (Khan, 2021).

The design model includes low-tech solutions in addition to innovative space designs that aim to improve the functional effectiveness of the airport, not only from an economic point of view, but also from an operational point of view, and to improve the means of reducing energy consumption and the environmental footprint of the building. The large canopy and the typical tent structural system provide lighting and natural ventilation openings, thus making the building more sustainable.

Planning, Design, and Detail Requirements for Construction Systems for Sustainability at Airports

Various modern transport projects worldwide have sought to improve passenger transport facilities in urban areas, stress the need to apply a sustainable transport system to all transport infrastructure services, and to make the transport system more vital (Allan, 2014). A modular sustainable architectural design follows a general progression from the design concept to detailed construction drawings and specifications. Since sustainability and high energy efficiency are the main goals to be achieved in design, including materials, building performance, building energy consumption, etc., and subsequently - during construction, including high level of development of the construction site, protection of the environment and surroundings during construction (DULIŃSKI, 2016).

1. Planning requirements for construction systems in sustainable airports; Sustainable development affects the site, land use planning, and airport design. During the theoretical planning stage for the development of the airport building, factors must be taken into account to improve the performance of the building: including building orientation, maximizing the use of daylight to reduce the amount of artificial lighting, and conducting experimental programs to test materials and new construction systems, and development of the potential scope for achieving 'green building' objectives in the initial stage of planning including systems commissioning, daylight modeling, energy modeling, etc. (Brown, 2010).
2. Design requirements for construction systems in sustainable airports The focus is on the philosophy of sustainable design and management of its means through coordination between open spaces, natural places and the surrounding environment through low energy consumption and provision of the highest quality levels of natural and artificial lighting, preservation of materials and natural resources, and improvement of the quality of the internal environment, as well as the preservation of internal and external water sources. There are indications that the integration of the design approach increases the chance of compliance with the objectives of sustainable design ((Abbas, 2015).

The structural design requirements identified by the 2018 Sustainability Guidelines for Sustainable Airport Buildings include the following (Sustainable Guidelines, 2018):

First; Functional requirements; They include space organization, physical and visual interconnection of the station spaces, aesthetic form and function, interest in defining entrances, and provision of service spaces.

Second; Kinetic spaces requirements; These requirements include providing movement sequences according to sequential travel activities, reducing the walking distance between the entrance and the boarding platform, providing clarity in movement axes, limiting intersections in corridors, and separating movement.

Third; Safety and Security Requirements; These requirements include controlling entrances, providing electronic and human monitoring, providing defending space and protection from external conditions, and providing emergency requirements such as exits and escape corridors.

Fourth; Sustainable Environmental Design; It includes reliance on renewable energy sources for power generation, respect for the identity and climatic conditions of the station site, and the use of local materials that are resistant to different weather conditions (Sustainable Guidelines, 2018).

2. Detailed requirements for construction systems in sustainable airports

In sustainable airports, structural design is concerned with much more than science and technology. It is also concerned with art, common sense, sentiment, willingness, relishing the task of creating suitable schemes to which scientific calculations add the final touches, proving that the structural system is sound and robust according to the requirements. It must Absorb all details and experiences until it becomes completely familiar with all phenomena of stress and deformity in a natural and intuitive way (Torroja et al., 1960).

By reviewing previous global experiences, the points to be followed in designing construction systems for sustainable airport buildings can be drawn as follows:

First; The requirements of sustainable environmental design can be achieved in transport buildings, depending on the appropriate construction systems through the following:

A. Relying on natural ventilation to reduce operational costs through: designing open central courtyards and internal green gardens, and relying on the open plan system of the station instead of the closed system, which provides pure natural ventilation with the help of the structural system. It depends on the climate of the country, which means that it is not suitable for all countries, especially warm ones.

B. Using the technology of smart ceiling vents with electronic closure to maintain air conditioning and control the internal temperature.

C. Optimizing the use of natural lighting and reducing the energy consumed through the use of transparent glass ceilings and facades that are protected from direct sunlight, the use of the central courtyard to ensure that natural lighting reaches all spaces, and the optimal orientation of spaces.

D. openness in the kinetic corridors of multi-store buildings to reduce pollution with toxic gases, depending on open spaces with few walls and ceilings with wide spaces.

E. The use of environmentally friendly local materials that are resistant to weather conditions in construction and finishing.

And - the use of surface and vertical indoor gardens that act as withdrawals for toxic carbon dioxide gases, by relying on ceiling openings and the introduction of natural lighting.

G. Respecting the site's specifics and the privacy of the area and its relationship to the surrounding neighborhoods in choosing the construction system.

H. Achieving sound insulation and noise treatment, and providing thermal insulation through thermal insulation materials in the structural system.

I. Benefiting from collecting rainwater from the roof of the station, recycling, and using the water for cleaning (Sustainable Guidelines, 2018).

Second; Providing requirements for use and operation that contribute to encouraging people to use public transport by caring for creating a clean, healthy, and safe environment for passengers, providing safety requirements inside the station, providing security monitoring, controlling the entrances to the station, and maintaining security inside and around the station.

Third; Paying attention to increasing social interaction and achieving economic efficiency by emphasizing meeting and waiting areas and internal gardens that enhance the value of social sustainability, and increase commercial opportunities and investment spaces. Building designs must take into account the communication with the cultural heritage and the emphasis on the identity of the region (Al-jorani, 2015).

The influence of shell and active structures on the sustainability of airport buildings

Airport buildings reflect construction technology more than any type of specialized building. Airport technology is a reflection of the advanced and continuous technology of aircraft. There are four elements that can be identified in sustainable airport buildings, including the search for weightlessness, the poetic expression of separate parts in space, the process of expression About movement, and Preferring thinness over thickness. All of this is represented by the use of cortical systems. Some of them reflect the movement of aircraft. Through the cortical structural system, technological efficiency is expressed. It is designed to be independent of the internal divisions of the building sections to preserve the expressiveness of the origin and help direct the movement (Edwards, 2005).

One of the clear examples of the use of shell ceilings is (Queen Alia Airport). The airport is located in Amman. It serves about 8 million passengers annually, which puts it in the group of medium-sized regional transit airports. Given the climatic conditions at the airport site, the implementation of the idea was directed mainly to the effective use of the sun's energy and the maximum heat gain (temperature rise) from the sun's rays at the same time. That is why the architect decided to design a canopy roof as a system of modular (prefabricated) concrete shell roofs, covered with photovoltaic cells and equipped with small skylights that allow light to enter the building. The sun's rays reaching the interior of the building reach glossy floors that reflect the rays towards the ceiling in order to diffuse natural light throughout the interior. The use of natural light reduces the need for additional support for artificial light, and a concrete sunblock (canopy roof) limits heat gain, stabilizes humidity at the right level and allows air conditioning units to act as an auxiliary installation, sometimes lowering the indoor temperature. The building is also equipped with an integrated system for collecting and using rainwater. This significantly reduces the environmental footprint of the plant, which leads to significant operational savings at the same time (DULIŃSKI, 2016).

Second; Active Systems; Active systems are used in sustainable and green airport buildings with the aim of reducing carbon emissions and their impact on biodiversity, using less energy, water and other resources, and thus reducing their impact on the built environment. This is made possible by advances in high-strength and lightweight materials, design expertise, manufacturing technology and technical installation. This system is characterized by its flexibility and its ability to open, install and replace it. The damaged building units bear the huge origin. These may be small units including rooms, halls, or offices or even large units of

building or street. The structural structure system in the giant construction systems is extremely complex. It is permeated with mechanical, electrical and sanitary services systems, and even vertical and horizontal movement systems (Blow, 1991). A distinctive example of the use of active facilities is (Colorado 4 International Airport, USA)). Fabric active ceilings work to introduce sunlight and thus add luster to the interior space and help direct movement. The active ceiling works as a strong central element inside the station as it helps to facilitate the movement of people and accommodate the various airport activities and adds aesthetic expressiveness to the space.

Therefore, the design capabilities of giant shell and active structural systems and their influences on airport sustainability are:

1. The ability to use building materials to their full potential and improve their quality by adding new materials that add high strength and greater flexibility in installation.
2. Using the idea of active space and the emergence of active spaces with wide ranges that cover vast distances and have a lighter weight.
3. The apparent complexity in the systems of these projects necessarily led to the emergence of the principle of integration in service systems in order to work with greater unification and higher capacity with advance and detailed planning.

Indicators Of The Theoretical Framework

From the theoretical framework, the present study extracted a measuring base for evaluating indicators of achieving sustainability in shell or active construction systems in airport buildings by generating different measurable standards in an attempt to do what is not considered a quantitative indicator. Measurable quantitative evaluation, access to quantitative results through statistical methods, and the use of a questionnaire based on specific impressions of the users of the mentioned airports, which were developed by the airport staff, to obtain common results until the time of analysis, evaluate them and indicate the extent of their effectiveness and the amount of what has been achieved in each research sample with Maintaining its commitment to local solutions.

Description of the selected projects

A. Changi Jewel Airport in Singapore; The airport won the award for the best airport in the world for six consecutive years. The project received a platinum rating from the (GreenMark) program in Singapore for environmentally sustainable buildings. In addition to the fact that its structural system is a shell system consisting of a lattice shell dome made of steel and smart glass, it can be noticed that the shell structures in the airport building work to surround and wrap the building with the least number of columns, thus increasing the possibility of internal divisions and enhancing flexibility in the plan and working on the diversity of activities In addition to its ability to accommodate different types of activities.

B. Hamad International Airport in Doha/Qatar; This airport won the first place as the best airport in the world for 2022. Hamad International Airport was designed and built to conserve the energy needed to keep the temperature cool. The walls of the passenger lounge are coated with sun-reflecting material. The ceiling is insulated and designed

with drop-shades. That is why Hamad International Airport is considered one of the best-designed airports in the world. The departure hall at Hamad International Airport features an undulating lit cortex ceiling and steel-framed glass walls that provide clear views of the ticket halls, allowing passengers to easily find their destinations.

C. Beijing Daxing New Airport / China; The new airport, designed by architect Zaha Hadid, is the largest single building in the world, as it includes one terminal and four runways. It has been awarded the LEED Platinum Certification in Sustainable Development. The airport's design is based on the principle of traditional Chinese architecture in connecting the different spaces in one common courtyard, which reduces the time of the traveler to reach the gates and helps in reducing the carbon footprint by not using internal trains. It depends on the shell ceiling in providing energy and entering light through manholes of various shapes and sizes and providing an interior area free of dirt Columns to facilitate the direction of passengers.

D. Istanbul New International Airport / Turkey; The airport is the largest LEED-certified building worldwide. The design is based on the architectural character of Istanbul. It includes vaulted ceilings topped with cortex ceilings, which contain skylights in the form of ancient Byzantine domes, whose mission is to bring daylight into the interior. A modern airport that is suitable for people with special needs and environmentally friendly using the latest technologies. Materials with recycled content and materials of local origin are used.

E. Incheon International Airport in Seoul / South Korea; Incheon International Airport topped the rankings every year for the ranking of the best airport in the world by Airports Council International (ACI) from 2005 to 2011. The curved cortex ceiling in the Great Hall consists of a rope suspended between two points. A building based on the ideals of advanced technology, sustainability, efficiency and flexibility, an environmentally friendly airport facility was created using a variety of plants to maintain the freshness of the interior spaces. The airport is increasing the production of renewable energy through solar cells as the most environmentally friendly sustainable airport in the world. The shell roof is equipped with solar photovoltaic panels to reduce energy consumption.

f. Marrakech-Menara International Airport / Morocco; It ranked seventh as the best airport in the world for 2022 according to the classification of Skytrax International, an international organization for the classification of air transport. The airport also has a quality certificate in the environmental field (14001) (ISO for 2004). It is designed to be as environmentally friendly as possible. The windows of the building serve a dual purpose. Instead of being made of glass, they are pyramids built from photovoltaic modules. This helps in generating K energy. The application of net or transparent shell structural systems works to improve the environment through more very light glass surfaces to introduce natural light and improve the internal environment. The use of suspended elements to support the shell ceiling helped to give a special aesthetic to the station and give wider spaces and ease Moving between parts of the building.

Indicators Of The Theoretical Framework

Table (1) *Applying paragraphs related to achieving sustainability through the shell and active systems in airport buildings and measuring their variables*

Percentages	Total values	Selected projects F	E	D	C	B	A	Codification	Possible values	Sub-paragraphs	Main paragraphs
93%	28	5	4	5	5	4	5	X-1	Achieving material and visual correlation	Functional requirements	Achieving the requirements of sustainability using Shell and active ceilings in airport buildings X
90%	27	4	5	5	4	5	5	X-2	Hierarchical sequence of space organization		
77%	23	5	4	3	5	3	3	X-3	Reducing walking distance to reach planes	Kinetic requirements	
90%	27	5	5	5	5	4	3	X-4	Clarity of kinetic and visual axes		
87%	26	4	4	4	5	5	4	X-5	Designing the defending space, the open space, and the securing space	Security and safety requirements	
83%	25	3	3	5	5	5	4	X-6	Control over entrances and exits and clarity of vision and openness		
83%	25	4	5	5	3	4	4	X-7	Maintenance and use of terminations, ease of cleaning, interchangeable and wear resistant	Proper use requirements	
90%	27	3	3	5	4	4	4	X-8	Ease of escape in emergency		
100%	30	5	5	5	5	5	5	X-9	Ceiling openings for ventilation and natural lighting		
50%	15	5	5	1	2	1	1	X-10	Solar cells integrated with the structural system	Sustainable environmental design requirements	
77%	23	5	5	5	3	2	3	X-11	Respect the privacy of the area by using local construction materials		
87%	26	4	5	3	4	5	5	X-12	Provide good thermal and acoustic insulation and improve the internal environment		
77%	23	4	4	5	3	4	3	X-13	Reducing material costs by using local and recycled materials	Achieving economic efficiency	
87%	26	5	5	4	4	3	5	X-14	Reducing electricity consumption		
		87%	89%	68%	81%	77%	74%		Evaluation percentage for the main paragraph X for each project		

The results of the main paragraph of achieving sustainability requirements of airport buildings with shell and active ceilings

Sustainability requirements were achieved through shell and active facilities in varying proportions, but they are considered fairly good. For example, the functional requirements achieved 93%, the kinetic requirements and clarity of kinetic axes achieved 90%, while the security and safety requirements represented in openness and clarity of vision achieved 83%. The requirements of safety of use, ease of escape, and ease of maintenance achieved 90%. As for the requirements of sustainable environmental design, it achieved the highest percentage 100%, and the economic efficiency requirements achieved 77% by reducing energy consumption. Most of the projects have obtained relatively high evaluation rates in achieving sustainability requirements for airport buildings with shell and active ceilings, given that the research samples are divided into three projects with shell and three active facilities. Through the evaluation ratio for the main paragraph X for each project, the rates of achieving requirements of sustainability varied. The samples E and F achieved high percentages, while the samples A and D achieved the lowest percentage because they did not have solar cells integrated with the structural system, which leads to a greater use of electrical energy than the other samples.

Conclusions

1. Sustainable airport buildings are buildings in which environmental, social, economic and technological aspects of sustainability are integrated. All these work to apply the principles of sustainable transport by defining the design requirements for providing a safe and efficient transport environment for all users.
2. The structural system is linked to the aspects of sustainability through the environmental aspect, which is the extent to which economy is achieved with construction materials, reduction of their consumption, and reduction of their impact on the environment after the end of the life span of the building. The economic aspect is related to reducing the economic costs of the construction process in addition to achieving profits by reducing the consumption of energy and raw materials. The social aspect is related to the expressive and cultural aspects and the extent to which design goals are embodied, especially the local character of airport buildings. As for the technical aspect, it is related to the effectiveness, development, and integration of systems to achieve sustainability in airport buildings.
3. Sustainable design is the integration of design and planning together. The first design decisions have a strong influence on the energy efficiency of sustainable design, which is considered integrated when every element is part of a larger whole through coordination between open spaces, natural places, and the surrounding environment through: (low energy consumption Providing the highest quality levels of natural and artificial lighting, preserving materials and natural resources, improving the quality of the internal environment, as well as preserving internal and external water sources. There are indications that the integration of the design approach increases the opportunity to comply with the goals of sustainable design. Design requirements of passenger transport buildings include functional requirements, kinetic spaces requirements, and security, safety, and sustainable environmental design requirements. It is not possible to achieve all these requirements without the structural system being effective and complementary to the elements of sustainable design. Therefore, it is crucial to carry out transformational operations on the traditional construction systems and to innovate other systems that meet the complex architectural requirements of airport buildings, including the shell and active structural systems.

4. Shell and active structures meet the requirements of sustainability in buildings by achieving functional, kinetic, security and safety, and sustainable environmental design requirements, in addition to achieving the desired economic efficiency of the design.

References

Abbas, S. (2015). The Nature Imitation Strategy and the Sustainable Architectural Form Analytical Study for Organic Forms. University of Technology, 41(2), 10–32.

Allan, A. (2014). Sustainability and the Design of Transport Interchanges. Construction Management and Economics, 32(3), 313–319. https://doi.org/10.1080/01446193.2013.877149

Dette, H. and Gartner, J. (1987). Design and performance of large scale beach foods. In: 1987 Proc. Coastal & Port Engineering in Developing Countries, Second Int. Conf., (Beijing, China: Sep. 7-11, 1987), I, Nanjing.

DULIŃSKI, W. (2016). Sustainable airport passenger terminal design - the review of selected examples. Czasopismo Techniczne, 2015 (Budownictwo Zeszyt 4-B (28) 2015), 93–98. https://doi.org/10.4467/2353737XCT.15.408.5039

Edwards, B. (2005). The Modern Airport Terminal: New Approaches to Airport Architecture, http://books.google.com/books?id=Vq5nyv3-k3wC&pgis=1

Kandavalli, S. R., Wang, Q., Ebrahimi, M., Gode, C., Djavanroodi, F., Attarilar, S., & Liu, S. (2021). A brief review on the evolution of metallic dental implants: history, design, and application. *Frontiers in Materials*, 140.

M. Lourens, A. Tamizhselvi, B. Goswami, J. Alanya-Beltran, M. Aarif and D. Gangodkar, "Database Management Difficulties in the Internet of Things," 2022 5th International Conference on Contemporary Computing and Informatics (IC3I), Uttar Pradesh, India, 2022, pp. 322-326, doi: 10.1109/IC3I56241.2022.10072614.

Prabha, C., Arunkumar, S. P., Sharon, H., Vijay, R., Niyas, A. M., Stanley, P., & Ratna, K. S. (2020, March). Performance and combustion analysis of diesel engine fueled by blends of diesel+ pyrolytic oil from Polyalthia longifolia seeds. In *AIP Conference Proceedings* (Vol. 2225, No. 1, p. 030002). AIP Publishing LLC.

Abd Algani, Y. M., Caro, O. J. M., Bravo, L. M. R., Kaur, C., Al Ansari, M. S., & Bala, B. K. (2023). Leaf disease identification and classification using optimized deep learning. *Measurement: Sensors*, *25*, 100643.

Ratna, K. S., Daniel, C., Ram, A., Yadav, B. S. K., & Hemalatha, G. (2021). Analytical investigation of MR damper for vibration control: a review. *Journal of Applied Engineering Sciences*, *11*(1), 49-52.

Abd Algani, Y. M., Ritonga, M., Kiran Bala, B., Al Ansari, M. S., Badr, M., & Taloba, A. I. (2022). Machine learning in health condition check-up: An approach using Breiman's random forest algorithm. *Measurement: Sensors*, *23*, 100406. https://doi.org/10.1016/j.measen.2022.100406

Mourad, H. M., Kaur, D., & Aarif, M. (2020). Challenges Faced by Big Data and Its Orientation in the Field of Business Marketing. *International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)*, *10*(3), 8091-8102.

Ruban, S. R., Jayaseelan, P., Suresh, M., & RatnaKandavalli, S. (2020, December). Effect of textures on machining of carbon steel under dry cutting condition. In *IOP Conference Series: Materials Science and Engineering* (Vol. 993, No. 1, p. 012143). IOP Publishing.

Naidu, K. B., Prasad, B. R., Hassen, S. M., Kaur, C., Al Ansari, M. S., Vinod, R., ... & Bala, B. K. (2022). Analysis of Hadoop log file in an environment for dynamic detection of threats using machine learning. *Measurement: Sensors*, *24*, 100545.

Suman, P., Bannaravuri, P. K., Baburao, G., Kandavalli, S. R., Alam, S., ShanthiRaju, M., & Pulisheru, K. S. (2021). Integrity on properties of Cu-based composites with the addition of reinforcement: A review. *Materials Today: Proceedings*, *47*, 6609-6613.

Kandavalli, S. R., Rao, G. B., Bannaravuri, P. K., Rajam, M. M. K., Kandavalli, S. R., & Ruban, S. R. (2021). Surface strengthening of aluminium alloys/composites by laser applications: A comprehensive review. *Materials Today: Proceedings*, *47*, 6919-6925.

Sharma, Nisha, Anil Kumar Yadava, Mohd Aarif, Harishchander Anandaram, Ali Alalmai, and Chandradeep Singh. "Business Opportunities And Challenges For Women In The Travel And Tourism Industry During Pandemics Covid-19." *Journal of Positive School Psychology* (2022): 897-903.

Raja, R., Jegathambal, P., Jannet, S., Thanckachan, T., Paul, C. G., Reji, S., & Ratna, K. S. (2020, November). Fabrication and study of Al6061-T6 reinforced with TiO2 nanoparticles by the process of friction stir processing. In *AIP Conference Proceedings* (Vol. 2270, No. 1, p. 030002). AIP Publishing LLC.

Kumar, B., & Kumar, P. (2022). Preparation of hybrid reinforced aluminium metal matrix composite by using ZrB2: A systematic review. *Materials Today: Proceedings*.

Alalmai, Ali A., Gulnaz Fatma, A. Arun, and Mohd Aarif. "Significance and Challenges of Online Education during and After Covid-19." *Turkish Journal of Physiotherapy and Rehabilitation* 32, no. 2.

Tripathi, Mano Ashish, Ravindra Tripathi, Navneet Sharma, Surabhi Singhal, Muskan Jindal, and Mohd Aarif. "A brief study on entrepreneurship and its classification." *International Journal of Health Sciences* 6 (2022).

Kandavalli, S. R., Khan, A. M., Iqbal, A., Jamil, M., Abbas, S., Laghari, R. A., & Cheok, Q. (2023). Application of sophisticated sensors to advance the monitoring of machining processes: analysis and holistic review. *The International Journal of Advanced Manufacturing Technology*, 1-26.

Aarif, Mohd, and Ali Alalmai. "Importance of Effective Business Communication for promoting and developing Hospitality Industry in Saudi Arabia." *A case study of Gizan (Jazan)* (2019).

Aarif, Mohd. "A STUDY ON THE ROLE OF HEALTHCARE INDUSTRY IN THE PROMOTING OF HEALTH TOURISM IN INDIA." *A CASE STUDY OF DELHI-NCR* (2018).

Kareem, F. Abd, A. and Zahawi, R. (2021). Utilizing BIM Technology for Achieving Sustainable Terminal Building of Airport. IOP Conference Series: Earth and Environmental Science, 856(1). https://doi.org/10.1088/1755-1315/856/1/012053

Khouri, N. (2017). Structural grid shell design with Islamic pattern topologies.

Landrum, and Brown, (2010). Airport Passenger Terminal Planning and Design. Vol. (1).

Ardakani, H. (2016). Socio-environmental Framework for Integration of Thermal Mass Windcatchers with Lightweight Tensile Structures in Contemporary Hot-Arid Urban Context of Tehran, https://repository.arizona.edu/handle/10150/623085

Sustainable Guidelines, (2018). Sustainable Airport Areas Guidelines for Decision Makers, www.metropolis.org

Torroja, E. Condit, C. Polivka, J. and Polivka, M. (1960). Philosophy of Structures in Technology and Culture, Vol. (1), Issue (3), https://doi.org/10.2307/3101404

Helal, M. Mahdi, K. and Kareem, K. (2014). Sustainability in architecture: A study of the role of sustainable design strategies in reducing impacts on the built environment, Al-Azhar 13th International Engineering Conference.