ARCHITECTURE CIVIL ENGINEERING ENVIRONMENT
The Silesian University of Technology No. 2/2024

doi: 10.2478/ACEE-2024-0012

EVALUATION OF AIRPORT BUILDINGS AGAINST TERRORIST ATTACKS IN THE CONTEXT OF ARCHITECTURE AND PLANNING CRITERIA: FIVE CASE STUDY

Pelin SARICIOĞLU [a], Aslı YILDIZ [b]*, Asena SOYLUK [c]

[a] MSc, Res. Assist.; Gazi University, Faculty of Architecture, Department of Architecture, 00600, Ankara, Turkey

[b] PhD, Res. Assist.; Nevşehir Hacı Bektaş Veli University, Faculty of Architecture, Department of Architecture, 50300, Nevşehir, Turkey

*Corresponding author. E-mail address: *aslydz@gmail.com*

[c] PhD, Assoc. Prof.; Gazi University, Faculty of Architecture, Department of Architecture, 00060, Ankara, Turkey

Received: 28.05.2023; Revised: 4.06.2024; Accepted: 28.06.2024

Abstract

Terrorist attacks are increasing worldwide with the impact of developing technologies and war tactics. One of the most common types of structures where these attacks are carried out is airport structures due to their international visibility and intense human circulation. Necessary precautions should be taken against possible terrorist attacks both in the planning and utilization process of airports. In this study, planning and architectural design criteria that can be taken against terrorist attacks are determined by utilizing literature data. Within the scope of these criteria, five airports were analyzed: Istanbul New Airport (IGA), Ankara Esenboğa Airport, İstanbul Sabiha Gökçen Airport, Antalya Airport, and Izmir Adnan Menderes Airport. In the selection of the buildings, the buildings with the largest passenger capacity in our country were preferred. As a result of the evaluations, the strengths, and weaknesses of the structures against terrorist attacks are presented in a table. According to the findings of the study, most of the airports are located in dense urban areas as a result of inaccurate predictions of urban growth and development. This makes these structures vulnerable to terrorist attacks. It was also found that perimeter walls do not provide sufficient visual and physical barriers at airports. Instead of concrete shear walls, most of the structures are secured with wire fences between concrete pillars. In conclusion, the planning and design of airports against possible explosions and terrorist attacks should be considered as a whole with its surroundings. Buildings should be evaluated as a whole with their land, and planning should be realized by taking into account the direction of urban growth and development.

Keywords: **Airport Buildings; Terror, Terrorist Attacks; Planning Criteria; Explosions.**

1. INTRODUCTION

Airline transportation is one of the most important means of transportation today. The preference for airlines has increased not only between continents and countries but also between cities. The importance of airlines increases day by day as they are convenient and comfortable and provide significant time savings compared to other means of transportation. Airports are the thresholds where countries are open to the outside world. Any incident that occurs at airports is very quickly reported in the world press. For this reason, they are often subjected to terrorist acts. As a result of these attacks, many people either lose their lives or are injured and the structures are seriously damaged. Since it cannot be predicted when and how terrorist attacks will take place, security measures should be taken to integrate the structures either in the design phase or in their current situation. Today, thanks to modern technology and systems, it has become possible to take faster and more comfortable security measures than in the past. With the help of technological devices, it is possible to prevent many possible attacks on vehicle routes, entrances, and exits for passengers and personnel. However, measures are still insufficient due to the size, intensive use, and functional diversity of the buildings. According to Harris, the dangers at airports are not only limited to passengers and vehicles but also increase due to the use of cargo, catering, maintenance and supply services, cleaning services, and similar uses. Therefore, security control of all elements should be ensured to create an effective security level at airports [11]. Security measures to be taken during the planning phase of airports are an important parameter of the design. Proper planning in terms of structure, technology selection, and architecture minimizes security vulnerabilities.

The use of these structures and their size are effective in determining the necessary measures and security measures for airports. Airport structures generally contain three main functions: transfer of transit or connecting passengers, passenger transactions (tickets, baggage, etc.), and the transition of passengers from air transportation to land transportation or vice versa. The standard spaces that should be available in airports for these operations are check-in hall, ticket sales areas, waiting and resting areas, arrivals and departures hall, flight gate hall, common areas, air operations area, food and beverage service areas [4, 16]. In addition to these uses, airports are now developing to accommodate mixed-use areas such as hotels, cinemas, restaurants, and shopping centers. The size of airports varies according to the location and use of the terminal building and aprons. Simple, linear, pier, satellite, transit, multiple linear, and multiple island types are the most common building typologies (Figure 1). In addition, airports are also classified in various ways according to their passenger capacity; airports with a passenger capacity of 20 million or more are called international airports, those with a passenger capacity of 2–20 million are called national airports and those with a passenger capacity of up to 2 million are called regional airports [6]. In addition, airports are also classified as small-scale, medium-scale, and large-scale according to their scale. Small-scale airports are facilities with an annual passenger capacity not exceeding 2 million and provide transportation only between cities. They usually consist of a rectangular or square terminal structure, aprons, and parking areas. Medium-sized airports have an annual passenger capacity of up to 10 million. Apart from the terminal building, they consist of offices, air traffic control units, aprons, and parking areas. In large-scale airports, the annual passenger capacity is over 10 million and these structures provide intercontinental transportation. Apart from the terminal building, they are quite complex structures with offices, air traffic control unit, hotel, shopping center, aprons and parking areas. As the scale and size of airports change, security measures and precautions must also change according to the conditions. Whereas a local airport needs to be protected on the basis of a single structure, a large-scale airport accommodates many structures. When aprons and runways are included, they correspond to a very large area. Therefore, the larger the building scale, the more difficult it is to control and monitor the area.

When the current publications on terrorist attacks are evaluated within the scope of the study; some studies have examined the static strength and structural responses of buildings against explosions [7]. In some studies, risk analysis of buildings and cost analysis for structural improvements were conducted [21, 22, 26]. In their study, Lavy and Dixit [20] identified areas and elements that pose a security risk against terrorist attacks in and around public buildings. In the study of Öğünç [24], an assessment was made against terrorist attacks on an urban scale. Information is given on the possible destruction that may occur in car bomb attacks depending on the amount of explosive material and measures to reduce

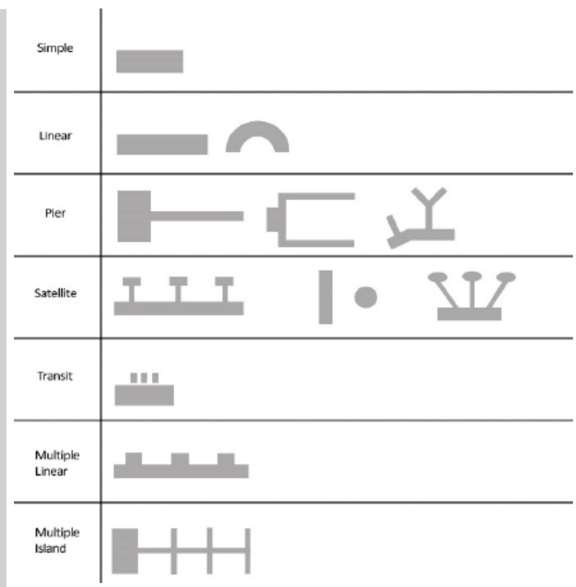

Figure 1.
Airport plan types (drawn by the authors)

the destruction in cities. In Brandt's [5] study, an assessment of terrorist attacks against commercial airports was made. Information on possible threats and solution proposals is provided. Kaya and Kartal [14] focused on human and technology factors in airport management. In this study, the focus is on airports, which are one of the types of structures most exposed to terrorist attacks. Airports are attractive targets for terrorist attacks due to their international visibility and intense human circulation. It is necessary to determine the existing conditions of the structures in order to both improve them and to identify the issues that need to be considered in new structures. In line with this goal, data and guidelines in the literature were analyzed in the context of terrorist attacks. Criteria that should be considered in the design of airports in terms of planning and architecture are identified. Within the scope of these criteria, five airports with the largest passenger capacity in Turkey (Istanbul New Airport (IGA), Ankara Esenboğa Airport, Sabiha Gökçen Airport, Antalya Airport, and Izmir Adnan Menderes Airport) were evaluated and recommendations were presented for the improvement of existing structures within the scope of the findings obtained.

2. THE RELATIONSHIP BETWEEN AIRPORT STRUCTURES AND TERRORISM

Although the concepts of terror and terrorism are frequently encountered in many fields, these concepts are defined in different ways depending on spatial and temporal conditions. According to Sönmez and Graefe [25], terrorism is an act of violence against civilians or members of the security forces in pursuit of pre-planned goals. In terrorism, violence is both planned and organized for specific purposes, while action is only a tool. Terrorists aim for their actions to have an impact on the masses and prepare the ground for chaos [15]. According to O'Sullivan [23], terrorism aims at a large loss of life and property, restricting people's freedom of movement, creating an atmosphere of fear and panic, opposing the state and authority, and harming the economy. Terrorist acts at airports are carried out in various ways. It is possible to classify the types of actions under four headings: suicide bombings, vehicular attacks, hijacking of aircraft, and attacks on the airport [3]. Thanks to the strict measures taken at airports in recent years, it has become difficult to carry out terrorist acts on airplanes and airside. Therefore, the main targets of terrorists have started to be airport buildings [5].

In vehicular terrorist attacks, different vehicles ranging from bicycles to trucks are used. The vehicles to be used are determined according to the target and the amount of explosives. The percentage distribution of car bomb attacks in Turkey is as follows: 37% with cars, 21% with minibusses, 14% with pickup trucks, 10% with trucks, 8% with bicycles or motorcycles, 7% with commercial vehicles, and 3% with off-road vehicles [24].

Airports play an important role in the service sector as they provide regional and international connectivity and are often subject to acts of terrorism due to their high concentration of people. Terrorists who aim to create an environment of chaos by disrupting the structure and functioning of society prefer airports because of the density of people and the security gaps in airport buildings [28]. Thanks to technological developments, airplanes provide easy and comfortable transportation. Within 24 hours, both passengers and goods can be transported to the remotest parts of the world. While these opportunities strengthen logistical capabilities, they also make airlines attractive targets for terrorists.

3. SECURITY SYSTEMS IN AIRPORT PLANNING

In airport planning, technology-supported security requirements are as much an essential element of planning as physical and spatial requirements. During the airport planning phase, security measures should be included in the design from the very first stage. Architects and engineers should also consult security experts and airport authorities for technical information. Planning should be handled systematically while taking security measures. The scope of the security measures to be taken according to the size of the airports also varies. These measures should be taken in a way not to delay the passenger, baggage, cargo, mail, and crew circulation of the airport. Therefore, flexibility and functionality should not be ignored while taking security measures during the design phase. Otherwise, future security needs will bring extra costs and create new needs in the current planning. In the planning of security systems, regional zoning should be made according to the importance of the areas requiring security. Especially the areas with high passenger circulation are the areas where the danger level is the highest. In addition to these, air traffic services, radio navigation aids, fuel storage areas, and power plants, which have an important place in air transportation, should also be protected (Airport Planning Guide, 1987).

Various technological devices are used at airports to ensure that all kinds of elements passing through the checkpoints are free from dangers. Speed and time factors are important for these devices to function effectively and efficiently. Considering that passengers are increasingly bored due to the prolonged security procedures, the need for fast and effective advanced devices and competent personnel who can use these devices is increasing [14]. Today, a wide variety of devices are used at airports to meet security requirements. The table shows the devices and their features that can detect passengers entering airports, personnel, baggage, cargo, and hazardous materials that can be used in terrorist acts. The use of these devices at airports varies according to security requirements (Table 1).

For security to be effective and efficient in airport planning, the issue should be handled as a holistic system. After determining the required security level, the areas to be protected at the airport should be defined. In passenger buildings, unauthorized persons should be prevented from crossing from the landside to the airside. For this purpose, systems such as X-ray devices, explosive trace detectors, baggage-controlled EDS systems, and metal detection portals should be used to inspect passengers and luggage [2]. The passenger inspection process is the first stage in which determinations are made about whether the passengers are suspicious or not. It should not be preferred to carry out this stage in areas with heavy circulation or near the aircraft gate. Technological systems such as airport passenger biometric identification, smart video systems, trace and odor detection devices, and blacklists should be used to identify passengers (Airports Planning Guide, 2015).

3. PLANNING PRINCIPLES OF AIRPORT STRUCTURES

Airport buildings today are a complex type of structure that includes various functions such as shopping, recreation, entertainment, and accommodation beyond the transportation function. As the diversity of functions increases, the scale of airports grows and in some cases, they are even considered as an urban design problem. They go beyond the scale of a single building and form an urban environment where many buildings come together [17]. Aesthetic concerns, functionality, flexibility, sustainability, and design approaches in harmony with the environment, which have gained value in today's architectural environment, have also affected airport structures, and these features have become the design data of contemporary airports.

Airports include aprons, aircraft maintenance and supply areas, arriving and departing passenger circulation/waiting and resting areas, customs, cargo services, security areas, and service areas, and the need to handle them in an integrated manner, which involves a very complex planning process.

First of all, the location of the airport is one of the most important criteria of the planning phase. Aviation activities, environmental conditions, access to land transportation, developability/flexibility,

Table 1.
Security systems used at airports (Homeland Security Research Corp, 2015)

Passenger information	It includes databases such as safety databases, driver databases, and the IRS.
X-ray systems	It can detect the densities and atomic structure of objects. This device consists of a unit, display, and control panel.
Explosive monitoring detectors	It is an improved version of X-ray devices, offering a three-dimensional image.
Luggage-controlled EDS	Detection of explosives in luggage.
Airport perimeter security walls and fences	Restricts access from the periphery into the building area.
Smart video systems	Includes camera systems.
Blacklists	Databases containing information on suspicious persons.
Biometric systems	Detects the faces of people entering a building.
Detectors	These devices, which are generally used in the entrance-exit areas of facilities, detect metal objects on people.
Body scanning system	It can detect dangerous elements in the human body.
Trace and odor detection devices	They detect the possible presence of chemical substances in cargo and baggage. They are only used in suspicious cases.
Robots	They provide data to security stations through face detection software.

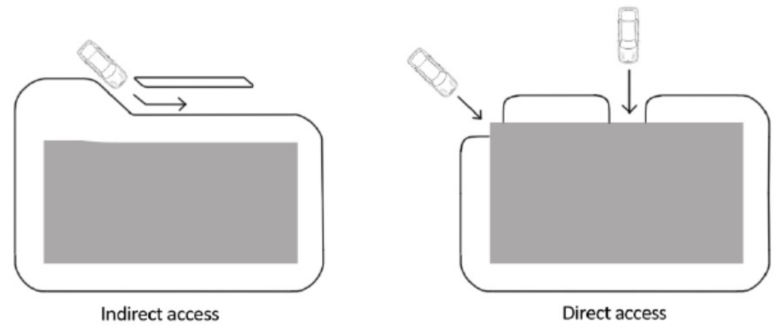

Figure 2.
Effect of street and alley layouts on vehicle speed (drawn by the authors based on FEMA 426)

topography, urban development, presence of other airports, and availability of services are taken into account in site selection (Airport Planning Guide, 1987, 73). After the site selection phase, airport designs are divided into airside and landside structures. On the airside, there are aprons and traffic control structures. On the landside, there are passenger buildings, cargo services, passenger circulation areas, and vehicle parks. There are also support services such as health centers, fuel stations, power plants, and flight maintenance areas.

Building Perimeter Design

During zoning planning, areas such as blind spots, hills due to topographical structure, reeds, and swamps around the land designated for the airport can be identified in advance and protection can be provided at the plan level. Infrastructure applications should be organized in a way that does not pose a potential threat to the area. Infrastructure systems should be organized in a way that does not allow access to the area and weapons storage. Airports should be planned so as not to create an urban density in the surrounding area and should be separated from areas of intensive use. In the selection of land for airports, land with a minimum level of uncontrolled areas and areas away from dense residential areas should be preferred.

Vehicle and Pedestrian Circulation

Access of vehicles to the airport should be prevented by various solutions such as barriers, landscape elements, and high sidewalks. Especially uncontrolled vehicles should be kept away from the building. If the parking lot area is solved as a separate building, a protected distance between the risky area and the airport can be provided. In addition, the location of the streets and alleys around the building is also important for vehicle circulation. Multiple perpendicularly connected streets make it easier for vehicles to exceed maximum speed limits. Where necessary, speed barriers should prevent vehicles from accelerating. Ideal roads are those that are separated from the site by a pedestrian road, have no pedestrian access, and run parallel to the building site (Figure 2).

Infrastructure

All infrastructure lines around the airport must have at least one backup line. Infrastructure lines that are damaged in the event of an attack leave the structure and its surroundings vulnerable and cause disruption of emergency interventions. Components such as critical energy distribution locations for emergencies should be away from main entrances and parking areas.

Landscape and urban design

Landscaping areas to be created in and around the building should not create potential hiding and surveillance areas for hazard centers (Figure 3). When landscaping, areas should be designed in a way that prevents information about the building and its surroundings from being obtained. Elevated areas are safer in terms of controlling the area. Insecure, uncontrollable areas such as water channels, dense landscape elements, hills, and ridges that can provide concealment should be avoided. The use of vegetation on its own may not have a direct impact on the safety of the structure, but landscape design organized with safety in mind contributes to its protection. Urban design elements such as curbstones, plant tanks, planters, trees, dividers, and electric and lighting poles should be used effectively for security as they restrict access to the building.

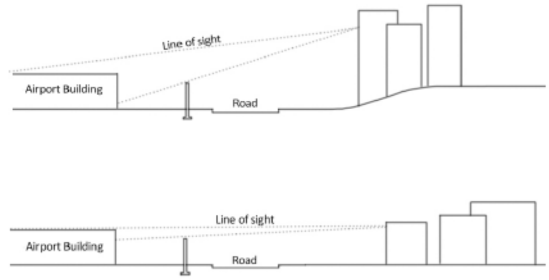

Figure 3.
Arrangement of the airport according to line of sight (drawn by the authors based on FEMA 426)

Access

Protective barriers not only limit access to the building and its surroundings but also help to define, orient and block the building. Access to the building and surrounding areas should be controlled. Physical barriers, reinforced fences, etc. should be used to provide controlled access and concrete barriers should be used to stop large vehicles. For the security of the perimeter of the building, reinforced concrete curtain walls should be built to delimit the land; these walls should be a minimum of 3 meters in height and should be supported with barbed wire where necessary (Figure 4). Reinforced concrete walls protect the structure against possible blast effects by reducing the pressure effect on the structure. In addition, these areas should be regularly checked by patrol vehicles. Fences and security walls should be increased in more security-sensitive areas and these areas should be monitored by guard stations or cameras (Airport Planning Guide, 2015). In addition, barriers to be used to prevent vehicle passage should be 60 cm to 1 meter high as standard. The spacing between the barriers should be between 110 cm and 120 cm to prevent vehicle passage.

Parking lot

Uncontrolled parking areas should not be allowed around the building. Designating parking areas in and around the plot and prohibiting parking on the periphery of the plot makes it easier to control vehicles. In particular, the greater the distance between the airport and parking areas, the greater the protection of the structure against vehicle-laden explosions. The ideal distance between the building and the parking lot should be a minimum of 10 meters and a maximum of 45 meters (Figure 5). In addition, measures should be taken to prevent the parking of vehicles closer than 50 meters to facilities and structures at risk of vehicle bomb attacks (FEMA, 2003).

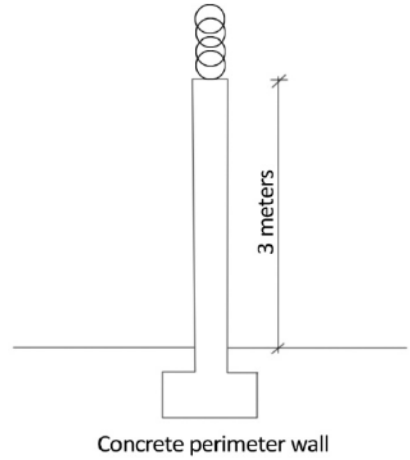

Figure 4.
Concrete walls and barriers around the airport (drawn by the authors based on FEMA 427)

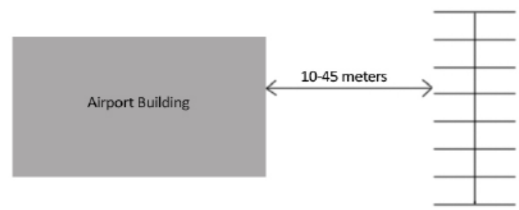

Figure 5.
Safe area between the airport and parking areas (drawn by the authors based on FEMA 426)

4. ARCHITECTURAL DESIGN CRITERIA OF AIRPORT STRUCTURES AGAINST EXPLOSIONS

Architectural measures should be taken against explosions during the preliminary design phase of airport structures or integrated into existing structures. Depending on the size of the airports, the measures to be taken vary, but in general, the issues to be considered are as follows;

Structure Form

When deciding on the building form, simple geometric forms without sharp corner lines should be preferred. While the effect of blast waves can be dampened in simple geometric forms, blast waves are more effective in forms with sharp lines. In addition, concave forms tend to reflect the shock waves generated by the explosive. Convex forms and circular forms should be preferred in building forms as they reduce the pressure of the shock wave (Figure 6). Parking floors, courtyards, protrusions, occupancy, and voids on the facade, buildings close to each other and with large surfaces are also severely damaged by the blast

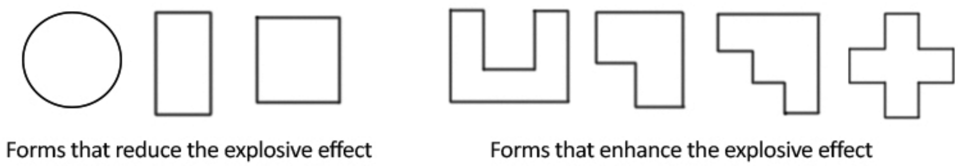

Figure 6.
Behavior of building forms in blasts (drawn by the authors based on FEMA 427)

pressure. As a precaution, building forms that will absorb the blast pressure and cause the least damage should be preferred. Structures with a narrow surface area, convex, away from the street-road, and surrounded by trees are safer. Eaves, overhangs, recesses, niches, and protruding surfaces in buildings create pressure absorption points in the event of an explosion. Simpler and plainer forms and surfaces should be created in building design.

Floor Area

In the design of terminal buildings, the low-rise horizontal settlement should be preferred instead of multi-story construction. In multi-story buildings, especially when the load-bearing structural system of the buildings is damaged, the possibility of the collapse of the building increases and causes great loss of life and property. Distributing the building units within the land as much as possible increases the safety of the structure against explosion risks.

Facade

The shock wave resulting from the explosion spreads globally and exerts high pressure on the surfaces of the objects closest to the explosion point. This pressure on the surface grows according to the intensity of the explosion and is reflected. This explosion pressure on the surface is continuously reflected; however, the pressure decreases after each reflection. Surfaces should be covered with pressure-absorbing elastic material (polyurethane foam, etc.) against explosions on the facade, and open chimneys should be arranged to absorb the explosion pressure. The materials used on the building facade should also be light, volatile, and resistant to fragmentation. The use of light materials such as wood and plastic instead of heavy materials such as stone, brick, and metal reduces the damage that may occur in explosions. Materials with a high probability of shrapnel should also be avoided. Durable materials with natural flexibility should be used.

The outer shell of the building is the most vulnerable part against explosion hazards. This is because the outer shell of the building is the first surface to be contacted by bombs, and since fragile materials such as glass are generally used, the risk of damage can be high. Therefore, the number of windows on the facade should be minimized and the ratio of openness to facade should be limited to a maximum of 15%. In addition, the transparency of the façade should be greatly reduced with the use of interior courtyards and atriums where light can be received. Thus, the glass surfaces on the facade, which have a high risk of damage in an explosion, will be reduced. The glass used in these buildings should be resistant to explosions and tempered and laminated glass should be used. Prestressed glasses do not shatter in the event of an explosion and cause less damage. In addition to the use of non-explosive glass, window films should also be used as a protective measure (The American Institute of Architects, 2001).

Material

Building materials must have passed bomb resistance tests to take precautions against possible terrorist attacks and must have achieved successful results in “high security – no damage” protection classes. In airport buildings, “steel” is generally preferred as a building material due to its advantages. Therefore, the structures should be well insulated against fires that may occur in possible explosions. Since steel is a material that heats up quickly, load-bearing columns and floors should be insulated to withstand fire for at least 2 hours [18]. In addition, materials that have natural flexibility and can respond better to load reversals should be used in material selection. Building materials with a high probability of shrapnel formation should not be used. Ductile materials with plastic deformation should be used, especially on facades. Composite materials are the most preferred facade materials in this context.

Orientation

Environmental conditions should also be taken into account for the orientation of buildings. The building façade should be oriented toward safe points. In uncontrolled areas, the building surface should be reduced and surface openings should be kept to a minimum (Figure 7). Narrow sides of buildings should be related to uncontrolled areas. Transparent surfaces should be avoided or minimized as much as possible in uncontrolled areas on building facades.

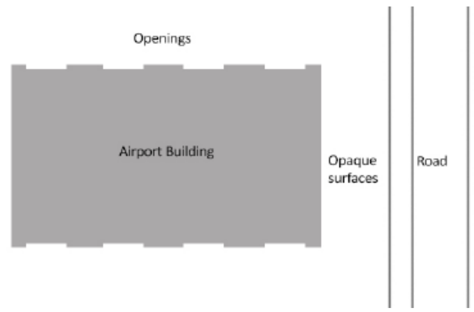

Figure 7.
Shaping facades according to risk areas at airports (drawn by the authors based on FEMA 427)

Location

Explosion risks should be taken into consideration when placing structures on the land. Structures should be positioned in the center of the terrain as much as possible. Moving closer to one edge reduces the defense of that area against external threats. Areas of particular risk should not be close to the outer periphery of the terrain but should be located in a central and controllable location. In addition, a standoff distance should be maintained between the structure and a potential explosive threat. One of the most effective protection solutions is to increase the distance between the structure and the threat as much as possible. Although there is no ideal distance, measures should be taken depending on the importance of the structure and the intensity of use.

Internal Planning

In the internal planning of the building, unsafe areas should be located as far away from the building as possible. Controlled and uncontrolled areas inside the building should be kept separate from each other. Horizontal and vertical zones should be created, and zones should not overlap each other. Buffer zones, reinforced walls, and floors should be left between them to separate.

Functionally unsafe areas such as the lobby, conveyor belt, and sales points should be kept away from the safe areas of the building. Waiting areas and emergency functions within the airport should be separated from busy circulation areas. Especially insecure areas such as parking areas should be away from the main walkways.

In the interior planning of buildings, the use of non-structural elements such as suspended ceilings, louvers, metal blinds, etc. that can cause heavy damage in possible explosions should be restricted. Placing heavy equipment such as air conditioners near the floors instead of the ceiling can reduce the damage in possible explosions. For interior facades, fabric curtains and plastic blinds should be used instead of metal blinds and shades. In addition, the joinery used on the facades should be explosion-proof and bullet-proof joinery. Interior lighting should be fixed to the ceiling, and work areas and offices should be located as far away from windows as possible [8].

Due to the dynamic effect created by the pressure during the explosion, the slabs and beams are translated upwards, which causes the slab to crumble and the structural elements (beams and columns) to articulate. For this reason, the thickness of the slab and the amount of reinforcement are important and thick slabs should be selected. Stub beams, hollow beams, and joistless slabs should be avoided as they are particularly vulnerable to earthquake and blast loads. In addition, prestressed slabs should not be preferred because they will show brittle behavior during an explosion [31].

Method

Qualitative research method was used in the study. Qualitative research generally includes three types of data sets: data sets that focus on nature and the environment, data sets that emphasize the research process, and data sets that emphasize the way in which the event or phenomenon being researched is perceived [27]. In this study, the data set emphasizing nature and environment was used. Descriptive analysis method was used to analyze the data set. The data were classified according to the criteria determined according to the theoretical framework. Findings related to the classified data were summarized and summaries were interpreted. Cause-effect relationships between the findings were determined. At the same time, the differences between the findings are presented in a comparative table.

In determining the study sample, the first five airports with the highest capacity in our country were determined. The data are from the State Airports Authority (DHMI) for the year 2022. Istanbul Airport (2018),

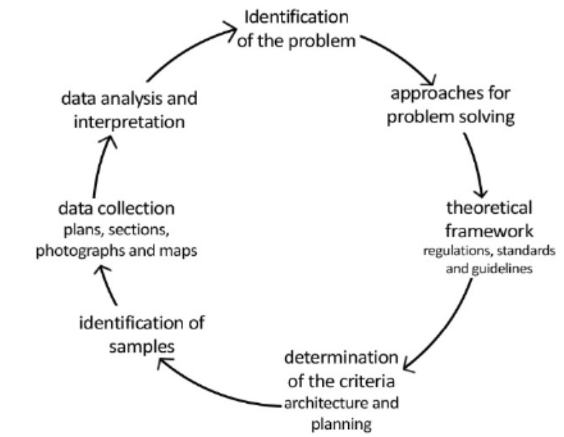

Figure 8.
Work flow chart (drawn by the authors)

Antalya Airport (1998), Istanbul Sabiha Gökçen Airport (2001), Ankara Esenboğa Airport (1955) and Izmir Adnan Menderes Airport (1987) are the buildings analyzed. The buildings were analyzed through photographs, project drawings and maps obtained from Google maps application. The buildings were evaluated according to their current conditions.

As a result of the examinations, possible problems of the buildings and their surroundings against terrorist attacks are identified and recommendations are developed. The buildings are evaluated within the scope of planning principles and architectural design criteria against terrorist attacks determined as a result of literature analysis. The building environment, vehicle and pedestrian circulation, infrastructure, landscape and urban design, access, and parking areas are evaluated within the scope of the planning of the buildings. Within the scope of the architectural design of the buildings, building form, floor area, facade, materials, orientation, location, and interior planning criteria are analyzed.

5. RESULTS

İstanbul Airport (AGİ)

The city's third airport after Sabiha Gökçen and Atatürk Airports, AGI was opened for use in 2018. The building, which has a capacity of 200 million passengers, has a T-plan form (Figure 9). A plan has been developed with the building area in the center and the aprons around it. Having sufficient access area between the building and open parking areas increases the security of the building against possible terrorist attacks. UV-filtered glasses and aluminum composite panels were used as facade materials in the building [19]. The materials used were preferred to be resistant to explosions. When the facade is evaluated in terms of opening ratio, the density of glass surfaces creates a disadvantage. In the interior planning of the building, the density of public use areas draws attention. While shopping streets increase the usage possibilities of the building, they make the interior spaces more risky areas against terrorist attacks. There is no clear distinction between controlled and uncontrolled areas. Intensive public uses negatively affects the holistic perception of the area. When the building land is evaluated, the airport is located in an area outside the urban settlement areas. This increases the safety of the building. However, the fact that the refueling units and technical service units are located on the outer perimeter of the building land puts the safety of these areas at risk. When the building area is evaluated in terms of environmental safety, wire mesh between concrete pillars is used on a concrete wall whose height varies from place to place. The perimeter wall poses a risk both visually and physically against possible attacks.

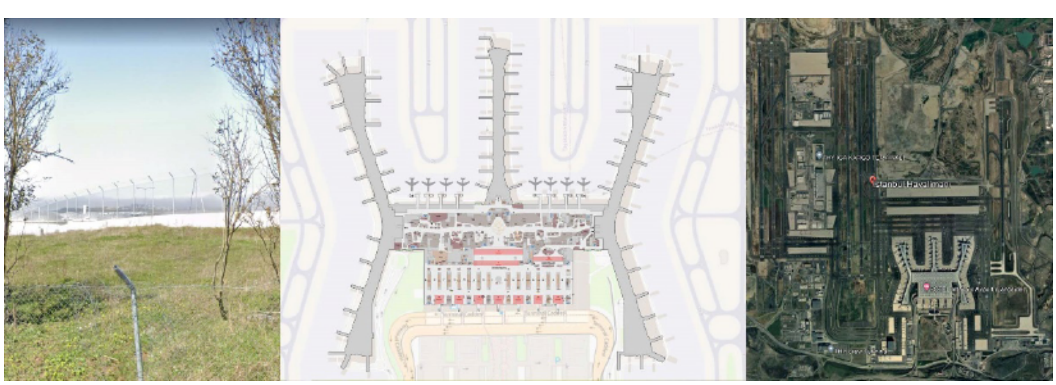

Figure 9.
İstanbul AGİ Airport (URL 1)

Esenboğa Airport

The building, which was first opened for use in 1955, was redesigned by the architect Ercan Çoban in 2006 and took its final form. The building has a construction area of 293,000 m^2 and is located 28 km from the city center. Access to the building is provided by taxi, private car, or public transportation. The building has a linear plan type that develops horizontally (Figure 10). In the two-story building, the upper floor serves the departing passengers, and the lower floor serves the arriving passengers. s. The west wing of the building is divided into domestic flights and the east wing is divided into international flights, and the middle part consists of transition halls [29]. The curvilinear form of the structure tends to reflect the shock waves generated by the explosives due to its concave structure. This creates a disadvantage for the building. In the interior planning of the building, a clear separation is provided between control points and service units, also stairs and elevators form a buffer between these spaces. Within the Esenboğa land, parking areas are designed in a separate area outside the airport. Glass and composite panels are used as materials on the facade of the building. It is not known whether the glass material is explosion-proof glass or not. But in general, it is positive that light materials are preferred on the facade. The density of the windows on the façade, that is, the opening ratio, is above the maximum 15% limit. This situation creates a handicap against possible explosion hazards. In addition, the eaves in the entrance areas can also pose a risk of explosions. On the other hand, positioning risky areas such as the oil office, flight control unit, and energy facility away from the airport building and in a central area of the land is a positive arrangement against terrorist attacks. The building site is located outside the city center, in an area where the density of construction is low. There is a concrete wall approximately 1 meter high on the outermost part of the building site. Above this wall, there is a wire fence approximately 2 meters high and barbed wire above it. The lack of high walls against the effects of explosions makes it easier to see the building site from the surrounding area and to access the area in case of a possible attack.

Antalya Airport

Opened in 1998, the building was expanded with new additions in 2005. Thus, the passenger capacity increased from 5 million to 8 million. The building has two floors, a horizontal layout, and an inverted T-shape in plan (Figure 11). Arriving and departing passengers access the building from the same level (URL 2). The concave form of the building has a tendency to reflect blast waves, which creates a disadvantage for the building. In the interior planning of the building, a clear distinction was made between controlled and uncontrolled areas. Stairs and elevators form a buffer zone between the spaces. Glass and aluminum composite panels were used as materials on the facades of the building. It is not known whether the glass material is explosion-proof glass or not. But in general, it is positive that light materials are preferred on the facade. The openness ratio of the facade meets the necessary conditions (maximum 15%). The lack of a certain distance between the entrance of the building and the open parking areas poses a risk of explosions. The building site is located in an area with intense urban use. Therefore, it is located in a risky area against terrorist attacks. Areas such as refueling areas, flight control, and energy facilities are located far away from the airport building and in a central area of the land. On the other hand, there are approximately 50 cm of concrete walls outside the building site. On top of these walls, perimeter security is provided with wire fences between concrete pillars with a height of approxi-

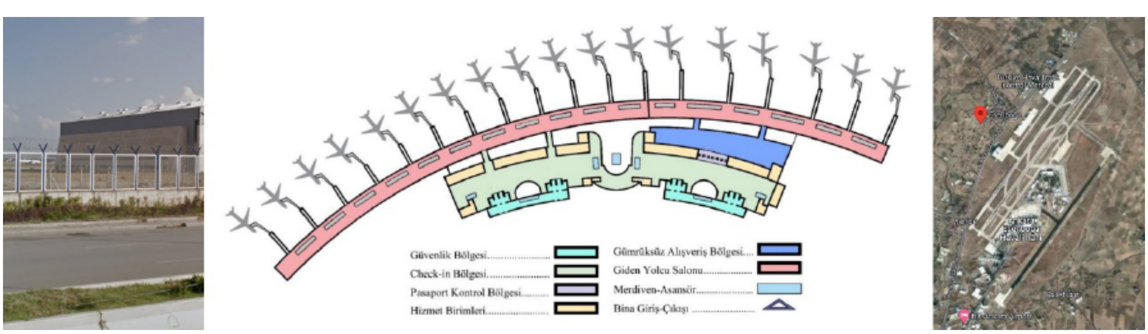

Figure 10.
Ankara Esenboğa Airport (Şahin ve Aslanöz, 2022)

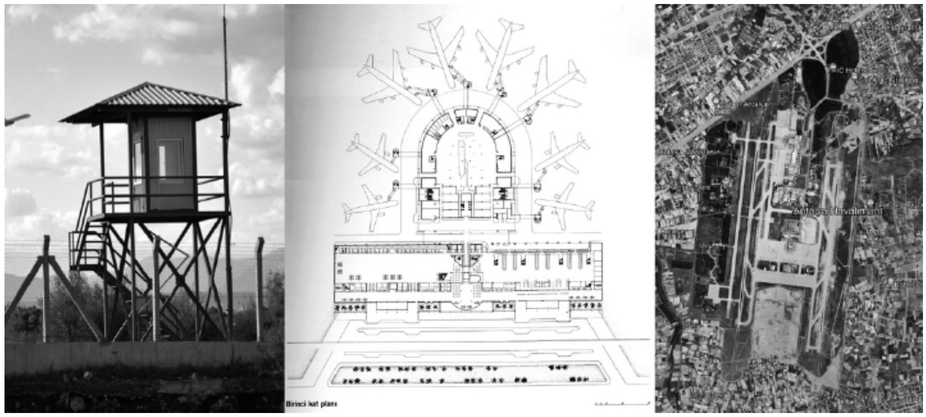

Figure 11.
Antalya Airport (URL 2)

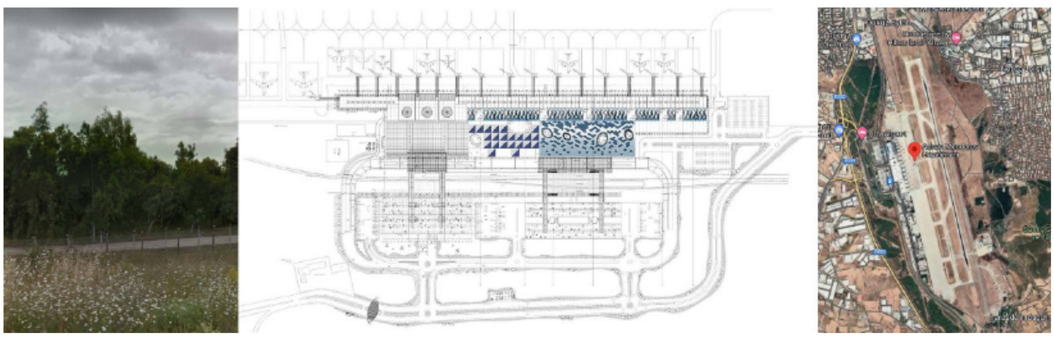

Figure 12.
İzmir Adnan Menderes Airport (URL 3)

mately 2 meters. The existing perimeter wall poses a risk against possible terrorist attacks. Both the perceptibility of the building land from the environment is high and the access to the area is facilitated through the wire fences.

İzmir Adnan Menderes Airport

The building, which was first opened for use in 1987, was renovated in 2006. Located 14 km from the city center, the airport has a construction area of 310,000 m2. It can serve 20 million passengers. In the project obtained through the competition, the project of architect Yakup Hazan was selected and implemented (URL 3). In the interior planning of the building, all visual barriers between the land side and the air side were removed and complete transparency was achieved between the two parts (Figure 12). Galleries and hanging gardens are placed between the land and air sides. This design approach creates spaces that pose a risk against terrorist attacks. The building has a linear form. The concave surfaces in the building form tend to reflect the shock waves that explosions may generate. In the entrance area of the two-story building, bridges provide access to the multi-story car park areas. The design diversity of the building has the potential to create risks against terrorist attacks. Glass and aluminum composite panels was used as materials on the exterior of the building. It is not known whether the glass material is explosion resistant or not. As in other buildings, the use of lightweight materials on the facade of this building is a positive feature. When the façade is evaluated in terms of opening ratio, it is seen that glass surfaces are dominant in the building. When the land of the building is examined; it is seen that the area where urbanization has developed towards this area has a partial density. Units such as refueling areas, flight control, and energy facilities are located far away from the airport building but close to the outer perimeters of the building site. Landscaping around this area creates potential areas for surveillance and concealment. The sloping nature of the land also increases the danger for risky areas. When the perimeter walls of the building site are examined, it is seen that border security is provided with wire fences between concrete pillars. The existing perimeter wall provides insufficient protection both visually and physically against possible terrorist attacks. Perennial trees on the building site also increase the risk potential against possible terrorist attacks.

Sabiha Gökçen Airport

The airport, which has a construction area of 320,000 square meters, was first opened for use in 2001 and was renovated in 2009. The structure, which has a passenger capacity of 25 million, was designed by Doğan Tekeli and Sami Sisa and was carried out under the consultancy of ARUP (URL 4). The building has a plan form close to a square (Figure 13). The absence of concave surfaces increases the strength of the structure against shock waves created by explosions. Glass, fiber concrete panels, and wood-like aluminum sunshades are used as materials on the exterior of the building. Information on the resistance of the glass and other materials against explosions could not be obtained. In terms of the facade openness ratio, the intensive use of glass poses a risk in terms of possible terrorist attacks. In the interior planning of the building, it is understood that clear distinctions between controlled and uncontrolled areas are not as legible as in other buildings. The compact form of the building causes the spaces to be intertwined. When the building land is evaluated, the open car park area in front of the building does not have sufficient distance. The building site is located among the areas where urban use is intense. Therefore, the surrounding of the building is in a risky position against possible terrorist attacks. Especially the airport building is located on the periphery of the land and in an area with dense urban settlement. When the perimeter walls of the building site are examined, there are concrete walls with a height of approximately 2 meters. Above these walls are wire mesh walls of the same height and barbed wires above them. The perimeter wall prevents access to the building site both visually and physically.

Table 2.
Analysis of case studies against terrorist attacks in terms of planning and architectural design criteria (arranged by the authors)

Buildings	İstanbul Airport	Antalya Airport	Sabiha Gökçen Airport	Ankara Esenboğa Airport	İzmir Adnan Menderes Airport
Building Perimeter	–	–		–	–
Circulation		–	–		
Infrastructure	–		–		–
Landscape and urban design					–
Access	–	–		–	–
Parking lot			–		
Building form	–	–		–	–
Floor area					
Facade	–		–	–	–
Material					
Orientation	–	–	–	–	–
Location			–		–
Planning	–		–		–

6. CONCLUSION

In the past, terrorist organizations used weapons with low destructive power, but today, with the use of weapons of mass destruction, terrorist attacks are becoming a significant threat to world welfare. Airports are one of the areas where terrorist attacks are mostly carried out due to their international visibility, intense human circulation, and economic importance. Airports, both in our country and around the world, are heavily exposed to terrorist attacks. Therefore, it is important to take security measures against terrorist attacks in airport planning and should be carefully considered from the first stage of architectural planning. Otherwise, making the necessary changes after the construction is completed is much more costly and restrictive.

In this study, planning and architectural design criteria that can be taken against terrorist attacks in airport buildings are determined. Within the scope of

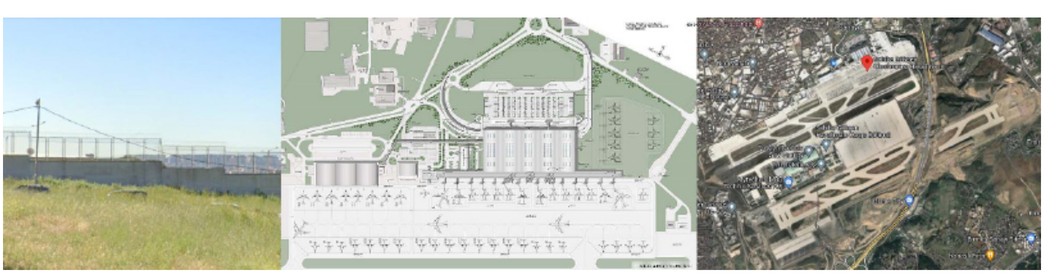

Figure 13.
Sabiha Gökçen Airport (URL 4)

these criteria, five of the largest airports in Turkey were analyzed. As a result of the evaluations in Table 2, it has been realized that the airports have strong and positive qualities in some aspects while they are lacking in others.

When evaluated in terms of building form, structures with a linear form create a more efficient usage area in terms of the separation of controlled and uncontrolled areas. Among the airports examined, except Sabiha Gökçen airport, all other buildings have a linear form. All the buildings are low-rise and horizontally developed. This is a positive feature against possible terrorist attacks. However, large surfaces are usually associated with the entrance of the buildings. This is undesirable in terms of terrorist attacks, but large surfaces are more functional in terms of the intense circulation requirements of airports and the perceptibility of the buildings.

When the buildings are evaluated in terms of interior planning, the increase in design diversity, eaves, recessed-protruding surfaces, glass covers, etc. pose a risk against terrorist attacks. In addition, the increase in mixed-use areas and public functions of buildings creates a disadvantage against terrorist attacks. The dense shopping areas at İGA Airport not only reduce the visual perceptibility and wayfinding of the spaces but also increase the uncontrolled areas within the building. As public units increase, the control of these areas becomes more difficult.

When the buildings are evaluated in terms of perimeter security, it is found that the perimeter walls defining the boundaries are inadequate in all buildings except Sabiha Gökçen Airport. The fact that the perimeter walls are not shear concrete walls at least three meters high poses a risk to the security of the building site. Due to the functional requirements, the spread of the lands to very large areas increases the cost of the perimeter walls. Therefore, these areas, which are often neglected, pose a potential danger to buildings. In most of the buildings, security is provided by transparent wire fences. These fences both provide surveillance of the building and facilitate access to the site.

At İGA, İzmir, and Sabiha Gökçen Airports, parts that pose a risk for terrorist attacks are located on the periphery of the airport land or in areas where urban use is intense. Risky areas should be located in the safest central areas of the land.

At Izmir Airport, perennial trees within the boundaries of the land create favorable areas for concealment and surveillance. Planting in airport structures should be designed with a few perennial plants in a way that does not allow camouflage and concealment. Landscaping and planting should be planned to serve the security of the structure. In addition, since the direction of urban growth and development was not accurately predicted, most of the airports are now located in areas of intensive urban use. This situation significantly affects the security of structures against terrorist attacks. As a result, the planning and design of airports against possible explosions and terrorist attacks is an important issue that should be considered as a whole with its environment. Building-specific measures are insufficient against the developing technological weapons and attack tactics today. Considering that airports are complex and sophisticated structures that increasingly incorporate a variety of functions, the scope, and dimensions of the area to be protected are quite large. Buildings should be considered as a whole with their land and planning should be realized by taking into account the direction of urban growth and development.

REFERENCES

[1] Akgün İ., (2012). Security Risk Assessment for Critical Facility Protection, İstanbul Technical University Institute of Science and Technology, Ph.D. Thesis, 15.

[2] Apostolakis G. E and Lemon D. M. (2005). A Screening Methodology for the Identification and Ranking of Infrastructure Vulnerabilities Due to Terrorism, *Risk Analysis*, 25, 361–376.

[3] Arasly, J. (2004). Terrorism and Civil Aviation Security: Problems and Trends, Working Paper, Combating Terrorism Working Group of the PfP Consortium, Sarajevo.

[4] Blow, C.J. (1996). Airport Terminals. Second Edition, Architectural Press, London, 15–25.

[5] Brandt, B. (2011). Terrorist Threats to Commercial Aviation: A Contemporary Assessment, Combatting Terrorism Center at West Point, 4, 11–12.

[6] Edward, B. (2005). The Modern Airport Terminal. Oxford: Spon Press.

[7] Eskew, E., Jang, S. (2012). Impacts and Analysis for Buildings under Terrorist Attacks. CEE Articles. 1.

[8] Federal Emergency Management Agency (FEMA). (2003b). FEMA 427. Primer for the design of commercial buildings to mitigate terrorist attacks. Washington, D.C.: U.S. Department Of Homeland Security.

[9] Federal Emergency Management Agency (FEMA). (2011). FEMA 426 BIPS 06. Reference manual to mitigate potential terrorist attacks against buildings. Washington, D.C.: U.S. Department Of Homeland Security.

[10] Federal Emergency Management Agency (FEMA). (2012). FEMA 428, BIPS-07. Primer to design safe school projects in case of terrorist attacks and school shootings. Washington, D.C.: U.S. Department Of Homeland Security.

[11] Harris, D. (2002). How to Improve Airport Security, Ergonomics in Design, Winter, 17–22.

[12] Havalimanı Planlama Kılavuzu, (2015). Uluslararası Sivil Havacılık Teşkilatı.

[13] Homeland Security Research Corp. (2015). Introduction to Tomographic Explosives Detection Systems & Baggage Handling Systems: Technologies & Market, Washington D.C.

[14] Kaya, A., Kartal, M. (2021). Havalimanı Güvenlik Yönetiminde Teknoloji ve İnsan. *Journal of Aviation. 5*(2), 298–309.

[15] Kaya, O. (2018). Turistlerin Terörist Saldırılara İlk Tepkileri: Atatürk Havalimanı Saldırısı Örneği. OPUS *Uluslararası Toplum Araştırmaları Dergisi, 9*(16), 2234–2250.

[16] Kazda, A., Caves, R.E. (2015). Airport Design and Operation, Third Edition, Emerald, Bingley.

[17] Kesikbaş, E., (2006). Havaalanı Terminal İşletmeciliği Ve Konya Havaalanı Uygulaması. Dumlupınar Üniversitesi Sosyal Bilimler Enstitüsü İşletme Anabilim Dalı, Yüksek Lisans Tezi, 148, Kütahya.

[18] Kılıç, A., (2013). Betonarme ve Çelik Yapılar Yangın Güvenliği, http://www.yangin.org/dosyalar/betonarme_ve_celik_yapilar_yangin_guvenligi.pdf (20.04.2023)

[19] Kılıç, D., Turgut, M. (2019). Kentsel lojistik açısından İstanbul Havalimanı ve Atatürk Havalimanı'nın değerlendirilmesi. *KOCATEPEİİBF Dergisi*, *Aralık, 21*(2), 148–157.

[20] Lavy, S., Dixit, M. (2010). Literature Review on Design Terror Mitigation for Facility Managers in Public Access Buildings, *Emerald Publishing, 28*(11), 542–563.

[21] Little, R. G. (2007). Cost-effective strategies to address urban terrorism: A risk management approach. The economic costs and consequences of terrorism, H. W. Richardson, P. Gordon, and J. E. Moore, II, eds., Edward Elgar, U.K., 98–115.

[22] Mueller, J., Stewart, M. G. (2011). Terror, security, and money: Balancing the risks, benefits, and costs of homeland security, Oxford University Press, New York.

[23] O'Sullivan, T. (2004). Comparative Risk Analysis & Threat Adaptability: Civil Aviation and Biological Terrorism, Create Homeland Security Center, University of Southern California, California.

[24] Öğünç, G.İ. (2019). Kent Güvenliğinde Araç Bomba Saldırısı Tehdidi, Assam Uluslararası Hakemli Dergi, Uluslararası Kamu Yönetimi Sempozyumu Bildirileri Özel Sayısı, 401–416.

[25] Sönmez, S., Graefe, A.R. (1998). Influence of Terrorism Risk on Foreign Tourism Decisions. *Annals of Tourism Research, 25*(1), 112–144.

[26] Stewart, M. (2016). Risk of Progressive Collepse of Buildings from Terrorist Attacts: Are the Benefits of Protection Worth the Cost?, *Journal of Performance of Constructed Facilities, 31*(2), 1–9.

[27] Strauss, A., Corbin, J. (1990). Basics of Qualitative Research. Sage Publications.

[28] Sweet K.M., (2008), Aviation and Airport Security: Terrorism and Safety Concerns, CRC Press Taylor and Francis Group, NY, 206.

[29] Şahin, F., Aslanöz, Ö. (2022). Yapı İçinde Bir Kent Modeli: Esenboğa Havalimanı. *Mimarlık ve Yaşam Dergisi, 7*(3), 831–851.

[30] The American Institute of Architects. (2001) Building Security through Design: A Primer for Architects, Design Professionals, and their Clients, The American Institute of Architects, Washington, D.C.

[31] Topçu, A., Eskişehir Osmangazi Üniversitesi, Mayıs 2006-Eylül 2014, pdf, http://mmf2.ogu.edu.tr/atopcu/ (20.04.2023)

[32] URL1:https://www.turkishairlines.com/tr-int/istanbul-havalimani/terminal-haritalari/ (10.05.2023)

[33] https://www.dhmi.gov.tr/Lists/Istatislikler/Attachments/244/YOLCU.pdf (10.05.2023)

[34] URL2:https://www.arkitera.com/proje/antalya-havalimani-dis-hatlar-terminal-binasi/ (10.05.2023)

[35] URL3:https://galeri3.arkitera.com/var/albums/Arkiv.com.tr/Proje/yakup-hazan-mimarlik/izmir-adnan-menderes-havalimani-ic-hatlar-terminali/ (10.05.2023)

[36] URL4:https://v3.arkitera.com/tools/watermark.php?src=UserFiles/Image/ig/Yarisma_Projeleri/sabihagokcen/101.jpg (10.05.2023)