

The impact of natural geographical factors on the operational efficiency of Al-Abraq International Airport in eastern Libya: An applied analytical study

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أثر العوامل الجغرافية الطبيعية على الكفاءة التشغيلية لمطار الأبرق الدولي في شرق ليبيا:
دراسة تحليلية تطبيقية

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الملخص:

تهدف هذه الدراسة إلى تحليل تأثير العوامل الجغرافية الطبيعية على الكفاءة التشغيلية لمطار الأبرق الدولي، الواقع شرق ليبيا، وذلك من خلال تقييم خصائصه المناخية والطبوغرافية ومدى توافقه مع متطلبات تشغيل النقل الجوي، وقد اعتمدت الدراسة منهجاً تحليلياً مكانياً باستخدام بيانات مناخية وجغرافية متنوعة، تشمل درجة الحرارة والرياح والأمطار والرؤية، بالإضافة إلى تحليل الخصائص الطبوغرافية للموقع، ثم رُبطت هذه العوامل بمحددات تشغيل المطار، مثل سلامة الإقلاع والهبوط، ودقة مواعيد الرحلات، وكفاءة الأداء التشغيلي العام. أظهرت النتائج أن الموقع الجغرافي للمطار يتمتع بخصائص طبيعية ملائمة نسبياً للعمليات الجوية. ويساهم انخفاض وتيرة الظواهر الجوية المتطرفة في استقرار حركة الطيران على مدار معظم أيام السنة، في حين تُعد درجات الحرارة المرتفعة خلال فصل الصيف وأنماط الرياح السائدة من أهم العوامل المؤثرة على كفاءة العمليات، كما أشارت الدراسة إلى أن التضاريس المحيطة بالمطار توفر ظروفاً ملائمة للتوسع المستقبلي، شريطة مراعاة الاعتبارات المناخية في عملية التخطيط. توصي الدراسة بضرورة دمج التحليل الجغرافي الطبيعي في عمليات التخطيط والتطوير المستقبلي للمطارات الليبية، وتعزيز أنظمة الرصد الجوي واستخدام تقنيات نظم المعلومات الجغرافية لدعم عملية صنع القرار في قطاع النقل الجوي، مما يساهم في تحسين الكفاءة التشغيلية وتحقيق الاستدامة في البنية التحتية للمطارات.

الكلمات الدالة: الجغرافيا الطبيعية، الكفاءة التشغيلية للمطارات، جغرافية النقل الجوي، العوامل المناخية، شرق ليبيا.

Abstract

This study aims to analyze the impact of natural geographical factors on the operational efficiency of Al-Abraq International Airport, located in eastern Libya, by evaluating its climatic and topographical characteristics and their compatibility with air transport operational requirements. The study employed a spatial analytical approach using diverse climatic and geographical data, including temperature, wind, rainfall, and visibility, in addition to analyzing the site's topographical features. These factors were then correlated with airport operational determinants such as takeoff and landing safety, flight punctuality, and overall operational performance efficiency.

The results showed that the airport's geographical location possesses relatively favorable natural characteristics for air operations. The limited occurrence of extreme weather events contributes to the stability of air traffic throughout most of the year, while high temperatures during the summer and prevailing wind patterns are among the most significant factors affecting operational efficiency. The study also indicated that the airport's surrounding topography provides suitable conditions for future expansion, provided that climatic considerations are taken into account in the planning process.

The study recommends the need to integrate natural geographic analysis into the planning and future development processes of Libyan airports, and to enhance meteorological monitoring systems and use geographic information systems technologies to support decision-making in the air transport sector, thereby contributing to improving operational efficiency and achieving sustainability in airport infrastructure.

Keywords: Physical geography, operational efficiency of airports, air transport geography, climatic factors, eastern Libya.

introduction:

The air transport sector has witnessed rapid development in recent decades as a cornerstone of regional and international connectivity and a supporter of economic and spatial development. Airports have become pivotal elements in modern transport networks, playing a vital role in facilitating the movement of people and goods and connecting regions to centers of economic activity. The success of airport operations depends not only on technical and administrative aspects but is also significantly linked to the natural geographical characteristics of the locations where they are situated, as these factors directly impact the safety and efficiency of air operations.

The air transport sector has witnessed rapid development in recent decades as a cornerstone of regional and international connectivity and a supporter of economic and spatial development. Airports have become pivotal elements in modern transport networks, playing a vital role in facilitating the movement of people and goods and connecting regions to centers of economic activity. The success of airport operations depends not only on technical and administrative aspects but is also significantly linked to the natural geographical characteristics of the locations where they are situated, as these factors directly impact the safety and efficiency of air operations.

In this context, Al-Abraq International Airport in eastern Libya serves as an important case study for examining the impact of natural factors on air operations. Its geographical location within a transitional environment, combining coastal and inland characteristics, results in varying climatic and topographical conditions that can affect the airport's operational efficiency. Despite its importance in serving the Green Mountain region and surrounding areas, studies assessing the impact of natural geographical factors on its operation remain limited, particularly from a spatial analysis perspective that links environmental characteristics to air transport requirements.

Based on this, this study seeks to analyze the impact of natural geographical factors on the operational efficiency of Al-Abraq International Airport, by studying climatic elements and topographical characteristics and assessing their compatibility with air operation requirements, in order to support future airport planning and improve the efficiency of air transport management in Libya.

- Previous studies and theoretical framework:

Recent studies in the field of air transport geography have shown increasing interest in analyzing the relationship between natural geographical factors and the operational efficiency of airports. Airport planning is no longer based solely on engineering or economic considerations, but is now closely linked to the climatic and topographical characteristics of the geographical location. Many studies have confirmed that climatic elements, such as temperatures, wind directions, and air visibility levels, directly affect the safety of takeoff and landing operations and the regularity of air traffic.

Specialized research in aviation geography has indicated that high temperatures lead to a decrease in air density, which affects aircraft performance during takeoff, especially at airports located in semi-arid environments. Other studies have shown that prevailing wind directions are a crucial factor in runway design and determining operational efficiency, while the topographical characteristics of the areas surrounding the airport contribute to determining air safety levels and reducing operational risks.

Within the framework of airport spatial planning, some studies have focused on employing Geographic Information Systems (GIS) in analyzing the suitability of airport sites. The results of these studies have demonstrated the importance of spatial analysis in assessing the impact of the natural environment on the performance of air transport infrastructure and improving planning decisions. These studies also confirmed that integrating natural geographic analysis into airport development policies contributes to increased operational efficiency and sustainability in the aviation sector.

Despite the variety of international studies that have addressed the impact of natural factors on airport operations, applied studies that address this relationship in the Libyan environment are still limited, especially those that rely on applied geographical analysis linking natural characteristics and operational efficiency of airports. Hence, this study comes to fill this research gap by analyzing the impact of natural geographical factors on the operational efficiency of Al-Abraq International Airport in eastern Libya.

- 1- The study conducted by (Ahmed Mahmoud Ahmed Hassanein), which is a scientific paper entitled (Analysis of the Air Traffic Map on the Air Route Network in the Cairo Aviation Region, 2025). The study aims to determine the volume of aircraft traffic at entry and exit points on transit air routes, as well as to determine the volume of aircraft on international routes. The study adopted the regional approach in determining the Cairo aviation region, and the thematic approach that is concerned with analyzing and interpreting the distribution of the phenomenon in the region. It used the quantitative method that enabled dealing with and analyzing the data on the volume of traffic on air routes, and the cartographic method in drawing and classifying maps using the Geographic Information Systems program.
- 2- The study conducted by (Ashraf Abdel Wahab Rateb Mohamed), which is a scientific paper entitled (The Current and Future Status of Air Transport in Egypt, 2023), aims to provide a general picture of the performance of air transport in Egypt in terms of the extent of economic exploitation of available capabilities and the competitive position of the sector. This is in addition to studying the challenges facing the air transport sector in Egypt. The study used the inductive method in reaching its results, the comparative historical method, and statistical

analysis to analyze a set of historical time series of the volume of air transport in Egypt to reach a general judgment on the efficiency of the air transport sector in Egypt.

- 3- The study conducted by (Bahaa El-Din Abdel-Hamid Askar, Aida Mohamed Allam, Ashraf Abdel-Hamid Zahran, and Khaled Mohamed Hanafi) is a scientific paper entitled (A Statistical Study of the Environmental Dimension at Cairo Airport, 2017). The study aims to explain the phenomenon of pollution and its negative effects on the environment as a result of emissions, noise, and waste emitted from aircraft. It is the responsibility of the environmental management to take effective measures to reduce environmental pollution. The study adopted the case study approach of "Cairo International Airport" and included observation, questionnaires, and personal interviews in order to obtain information directly, allowing for the selection of what is related to the case under investigation based on in-depth study. The study also used the statistical method and the analytical method.
- 4- The study conducted by (Tahia Talal Nasr Farhat and Tariq Muhammad Saba'i Muhammad Al-Azzazi) is a scientific paper entitled (The Role of the Green Economy in Creating Sustainable Communities: A Study of Egyptian Airports, 2024). The study aims to identify the role of the green economy in creating sustainable communities in Egyptian airports by achieving a set of objectives, the most important of which is identifying the requirements for transitioning to the green economy in Egyptian airports and analyzing the most important challenges that limit the effectiveness of applying the requirements of the green economy in these airports. The study used the descriptive analytical method in analyzing and collecting data from its primary sources. It also used the statistical analysis program in analyzing the questionnaire forms distributed to employees in Egyptian airports (Marsa Alam Airport, Sphinx Airport, Sohag Airport).
- 5- The study conducted by (Jamila Salem Al-Labbad), which is a scientific paper entitled (The Impact of Dust Storms on Air Transport in Northwest Libya, 2024), aims to highlight the impact of dust storms and the resulting environmental problems, and to determine the times of dust storms, their locations, and the extent of their impact on air transport. The study used the historical method, through which the historical development of Mitiga Airport was traced, and it also used the analytical method to analyze the data collected on the problem of the study, such as official reports, and the descriptive method to interpret the current situation of the phenomenon of dust storms.
- 6- The study conducted by (Shrouq Naeem Jassim Al-Jubouri), which is a scientific paper entitled (Spatial Analysis of Air Cargo Flights in Iraq for the year 2020, 2022), aims to find out what air cargo flights include, how these flights were distributed in the country of Iraq for the year 2020, and to clarify the most important international destinations with the highest implementation of air cargo flights in the country of Iraq. The study used the descriptive method and the statistical method in analyzing air cargo data.
- 7- The study conducted by (Abdulaziz Saad Amaiziq Suleiman), a scientific paper entitled (The Emergence and Development of Air Transport in Eastern Libya, 2018), aims to identify the initial features of the emergence of aviation in Libyan airspace in general and the east in particular, and its impact on the many factors and variables that led to these airports and landing strips taking a specific pattern in their geographical distribution on the Libyan map, which made them different from the rest of the airports in the Libyan state. In addition, the study addresses the important role that this sector plays in economic and spatial development and its contribution to the distribution of urban centers and economic and service institutions in the east. The study used the descriptive method in describing the political and security events, regional and international conflicts, and military tendencies, which in turn affected the performance of the air transport industry in Libya in general and the east in particular. It also

used the historical method by tracing the historical stages of the emergence and development of the air transport industry in eastern Libya.

- 8- The study conducted by (Mohammed Al-Mahdi Al-Asta) is a scientific paper entitled (Spatial Analysis of the Location of Misrata International Airport - An Applied Study in Transport Geography, 2017). The study aims to conduct an analytical study of the location of Misrata Airport, identify the most important planning considerations that must be available at the location of Misrata Airport, and study the most important spatial factors affecting the selection of the location of this airport. The study used the descriptive method in collecting information, identifying the characteristics of the phenomenon, describing its nature and the type of relationship between its variables, its causes and trends, in addition to using the analytical or inductive method to compare the data and information in order to reach results that achieve the goal of the study.
- 9- The study conducted by (Manal Saleh Al-Ansari), which is a scientific paper entitled (Domestic Air Traffic of Saudi Arabian Airlines Passengers: A Case Study of King Abdulaziz Airport in Jeddah, 2021), aims to estimate the volume of air traffic and identify the most busy domestic routes. The study relied on the descriptive analytical method to describe the phenomenon, identify its characteristics, and find the relationship between its elements. It also used the quantitative method by collecting data on the studied phenomenon, then classifying and tabulating it to reach accurate objective results.
- 10- The study they conducted (Nancy Mohamed Fawzy, Islam Elsayed Hussein, and Shaimaa Mamdouh Abdelwahab) is a scientific paper entitled (Measuring the impact of providing ground services at airports on passenger satisfaction “with application to Cairo International Airport”, 2018). The study aims to identify the viewpoint of arriving and departing passengers through Cairo International Airport in order to determine the ground services provided by Cairo International Airport to passengers. The study adopted the descriptive analytical method.

Despite the importance of these studies, the application of this type of analysis to Libyan airports, especially Al-Abraq International Airport, remains limited.

- Research problem:

Despite the growing importance of air transport in supporting regional development and enhancing spatial connectivity between cities and regions, the operational efficiency of airports depends not only on technical and administrative equipment but is also significantly affected by the natural geographical characteristics of their locations. Climatic elements and topographical features are influential factors in the safety of air operations, flight punctuality, and operational efficiency, as they directly impact takeoff and landing procedures and the suitability of the natural environment for air activity.

Al-Abraq International Airport is one of the most important airports in eastern Libya. However, the impact of natural geographical factors on its operational efficiency has not been assessed through a specialized analytical study that links natural characteristics to the requirements of air transport operations from an applied geographical perspective.

Hence, the research problem lies in the absence of a scientific analytical assessment that clarifies the nature of the impact of natural geographical factors on the operational efficiency of Al-Abraq International Airport, and the extent to which these factors are compatible with modern air operation requirements, which limits the possibility of employing geographical analysis in supporting the future planning and development of the airport.

- Study questions:

The study begins with the following main question:

How do natural geographical factors affect the operational efficiency of Al Abraq International Airport in eastern Libya?

This main question gives rise to a set of sub-questions:

- 1- What are the prevailing climatic characteristics in the Al-Abraq International Airport area, and what is the nature of their temporal and spatial variation?
- 2- How do climatic elements, especially temperature, wind direction and air visibility, affect takeoff and landing operations and the regularity of flights?
- 3- What role do the topographical characteristics of the site play in supporting or limiting the operational efficiency of the airport?
- 4- To what extent do the airport's natural geographical factors align with modern air operations requirements and future expansion?

- Study objectives:

This study aims to analyze the impact of natural geographical factors on the operational efficiency of Al-Abraq International Airport in eastern Libya, by achieving the following objectives:

- 1-Analyzing the prevailing climatic characteristics in the Al-Abraq International Airport area, including temperatures, winds, rainfall, and air visibility.
- 2- Evaluating the impact of climatic elements on the efficiency of airport operations, especially with regard to takeoff and landing operations and the regularity of air traffic.
- 3- Studying the topographical characteristics of the airport site and determining its suitability for air operations.
- 4- Determining the degree of compatibility of natural geographical factors with modern air operation requirements and the potential for future airport expansion.
- 5- Providing planning recommendations that contribute to improving the operational efficiency of the airport based on natural geographic analysis.

- The scientific contribution of the study:

The scientific contribution of this study is to provide an integrated applied geographical analysis linking natural geographical factors and the operational efficiency of airports, through the application of the spatial analysis method to Al-Abraq International Airport in eastern Libya as a model for airports in semi-arid regions. The study contributes to filling a research gap represented by the limited number of studies that addressed the impact of natural characteristics - such as climatic conditions, topography and geological characteristics - on the operational performance of airports in Arab geographical environments, as most previous studies focused on engineering or administrative aspects without integrating the analytical geographical dimension.

The study also provides a reliable analytical framework for assessing the operational efficiency of airports based on natural geographical indicators, which supports decision-makers in future air transport planning and enhances the sustainability of airport infrastructure in areas with changing environmental conditions.

- Methodology and research methods:

This study employed a spatial analytical approach to assess the impact of natural geographical factors on the operational efficiency of Al-Abraq International Airport in eastern Libya. This was achieved by analyzing climatic and topographical characteristics and relating them to airport operational requirements. A range of quantitative and descriptive methods were utilized to achieve the study's objectives and answer its research questions.

1- Study methodology:

The study was based on:

- **The descriptive analytical approach:** to present and scientifically interpret the natural characteristics of the study area.

- **The spatial analytical approach:** to study the relationship between natural factors and the efficiency of aerial operations.
- **Comparative approach:** to analyze the temporal variation of climatic elements and their impact on operational performance.

2- Data sources:

The study relied on a set of data, which included:

- Climate data issued by weather monitoring stations near Al-Abraq International Airport.
- Topographic maps and geographic data for the study area.
- Long-term climate statistics relating to temperature, wind, rainfall and air visibility.
- Scientific references and previous studies related to the geography of air transport and airport operations.

3- Analysis tools:

A number of analytical tools were used, most notably:

- Simple statistical analysis of climate data.
- Analyzing climate trends and their impact on atmospheric processes.
- Analyzing geographical maps to assess the topographical characteristics of the site.
- Employing Geographic Information Systems (GIS) in representing and analyzing spatial data (when available).

4- Study area and its boundaries:

Al Abraq International Airport is located in eastern Libya, within the Green Mountain region, and is one of the most important regional airports serving the eastern part of the country. The airport's location is characterized by geographical features that combine coastal and inland influences, which are reflected in the prevailing climatic conditions and natural environmental elements affecting air operations.

The airport is located at geographical coordinates approximately (13', 47', 32° and 26', 48', 32° North, and longitudes 20', 55', 21° and 46', 58', 21° East), and at an altitude of approximately (657 meters) above sea level, which gives it distinctive topographical and climatic characteristics that affect takeoff and landing operations and the efficiency of air traffic.

The airport is surrounded by a topographical environment that varies between relatively high areas and open plains, which helps determine local wind patterns and air visibility levels, and makes the location suitable for studying the relationship between natural geographical factors and airport operating requirements.

- Scope of the study:

The study was based on a set of scientific limitations, which were as follows:

1- Spatial boundaries:

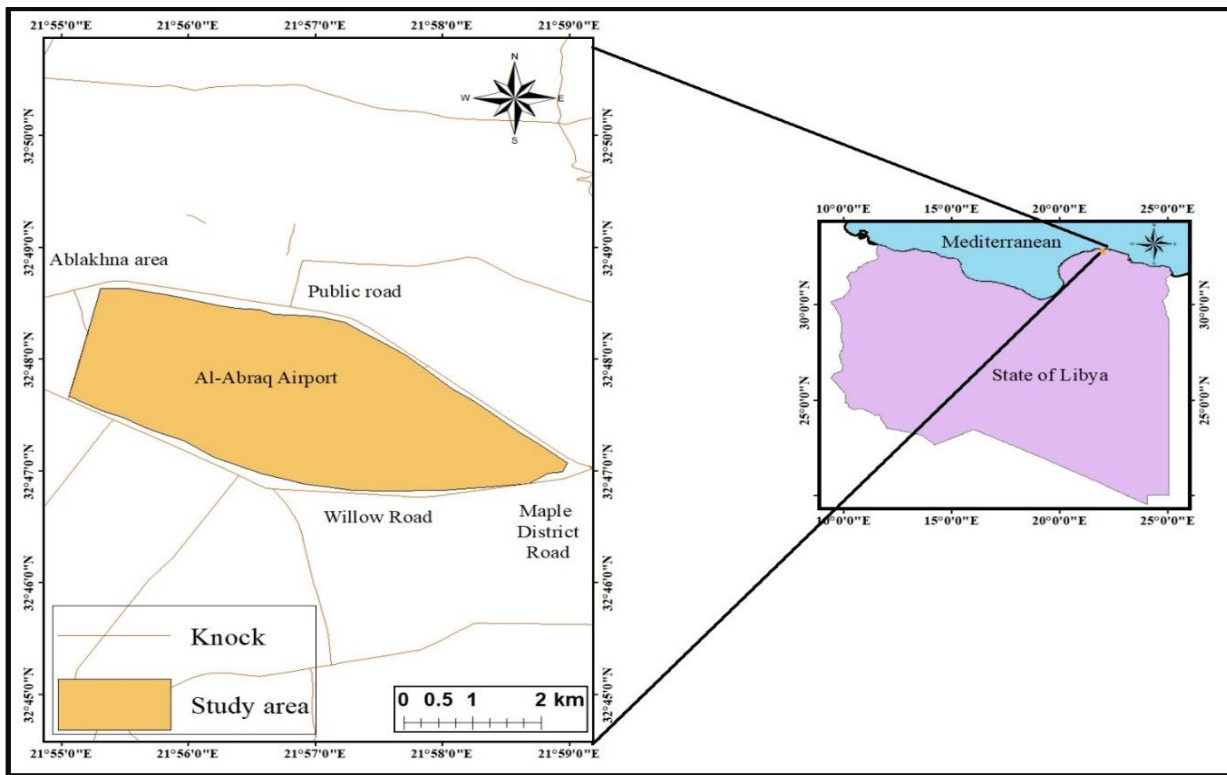
It is represented by the area of Al Abraq International Airport and the surrounding geographical area within eastern Libya.

2- Time limits:

The time period covered by the climate data used in the analysis includes (from 2015 to 2024).

3- Objective boundaries:

The study is limited to analyzing the impact of natural geographical factors on the operational efficiency of the airport without expanding on human or economic factors. Figure (1) shows the study area and its boundaries.



Source: The researcher's work was based on (Google Earth Pro) for the year 2025, using (10.4) ArcMap, based on the boundaries specified by Mr. Boubaker Miftah Bader, General Manager of Al-Abraq International Airport, on 8/31/2025.

Figure (1) Study area and its boundaries

- Results and discussion:

- Climatic characteristics of the Al-Abraq International Airport area:

The results of the analysis of climate data for the Al-Abraq International Airport area showed that the site is affected by a semi-humid Mediterranean climate characterized by a clear seasonal variation in temperatures and rainfall amounts, with temperatures recording a significant increase during the summer, while they decrease during the winter as a result of the relative elevation of the airport within the Green Mountain region.

Thermal variation is one of the factors affecting the efficiency of air operations, as high temperatures lead to a decrease in air density, which is reflected in the performance of aircraft during takeoff and affects the required takeoff distance. These results indicate the need to consider local thermal characteristics when planning airport operations, especially during the summer months.

It was also found that annual rainfall rates are relatively moderate and do not pose a major obstacle to the regularity of air traffic, with the exception of some limited weather conditions that may temporarily affect operations.

- The impact of wind and air visibility on operational efficiency:

The study results showed that prevailing wind patterns in the airport area are among the most important natural determinants affecting air traffic. Wind contributes to determining runway utilization efficiency and takeoff and landing directions, and increased wind speed during certain periods can lead to some disruption in flight schedules.

The data also showed that air visibility levels in the airport area are stable for most of the year, due to the limited occurrence of dense fog and severe storms, which enhances the continuity of air operations and reduces the likelihood of flight delays.

These results are consistent with recent studies in air transport geography that emphasize the crucial role of weather conditions in achieving operational safety at airports.

Climate:

Shahat station is located in the Green Mountain region, which is a high-altitude area with a mild to cold climate in winter and a mild climate in summer. Al-Abraq International Airport is close to this area by about (30 km) and is therefore affected by almost the same climatic conditions.

The temperature in the summer (June-September) ranges between 21.2-22.8°C, which are relatively moderate temperatures, meaning that the weather does not pose a major obstacle to air traffic. In the winter (December-February), temperatures drop to 9-11°C, which may lead to the formation of morning fog, especially at dawn, and affect flights by reducing horizontal visibility, leading to the postponement or cancellation of some flights. The drop in temperature also leads to the possibility of slight freezing on the runway or engine failure during takeoff, which affects the progress of flights at Al-Abraq International Airport.

The study area also experiences high humidity in winter and spring, which increases the likelihood of fog or low cloud formation. These phenomena negatively affect landing and takeoff operations and require precise navigational equipment at the airport.

As for the most common type of wind in the Green Mountain region, it is known as the monsoon wind activity, especially in the winter and spring seasons. These strong winds lead to disruption in air navigation, and may require changing the direction of takeoff and landing or delaying flights.

The direction of the runway at any airport is determined primarily by the prevailing winds in the area, because aircraft must take off and land against the wind direction as much as possible. Facing the wind provides greater wing lift, reduces takeoff and landing distances, and makes aircraft control safer. The runway is designed to be in the direction in which the winds blow most frequently during the year. For example, at Al Abraq International Airport, the most common winds are often from west-northwest directions, so takeoff is usually done in a direction of 10 (i.e., towards the east) to face the incoming wind. If the wind is in the opposite direction, 28 is used. The goal is to facilitate takeoff and landing and make them safer for aircraft.

These numbers 10 and 28 are the runway direction numbers at Al-Abraq International Airport. They do not represent random things, but rather the angle of the runway direction relative to the compass. The runway direction is measured by the compass degree (from 00 to 0360), then the number is divided by 10 and the last digit is removed. Runway 10 means that the direction of takeoff and landing is approximately 100 degrees (east-southeast), and runway 28 is the exact opposite direction to 10, i.e., 280 degrees (west-northwest). Each runway is used from two directions, so it has two opposite numbers. If you take off in the direction of 0100, you use runway 10, and if you take off in the opposite direction of 0280, you use runway 28 (Personal interview with Mr. Tariq Abdulrahman Younis, Head of the Air Operations Unit at Al-Abraq International Airport, dated 7/10/2025).

Rain also plays an important role in affecting the efficiency and operation of the airport, as rain often falls from (November to March) due to the humid winds coming from the Mediterranean Sea. Al-Abraq city is known for its relatively heavy winter rains compared to the rest of the cities of Libya. These rains may be accompanied by fog and low clouds, which leads to poor horizontal visibility and affects flights by reducing pilots' visibility during takeoff or landing, or by reducing the effectiveness of air navigation systems, or by delaying flights or

diverting them to alternative airports. It also leads to slippery runways and affects flights by reducing friction between the aircraft wheels and the runway, or the possibility of aircraft skidding during landing, or delaying flights if some parts of the runway are flooded with water.

While the impact of rain on ground equipment and machinery is evident through the accumulation of water in the aircraft yard or near the gates, which may hinder baggage loading or passenger boarding and disembarking, or the movement of fuel or maintenance vehicles, and the increase in ground rotation time due to the slow movement of ground equipment and the difficulty of operating in the rain, it also causes time to prepare the aircraft, which leads to delays in successive flights. As for thunderstorms accompanying the rain, they may pose a risk to the ground safety of workers and equipment, which requires a temporary halt to all refueling and boarding operations. Table (1).

Table (1) Monthly and annual average temperatures at Shahat station during the period (1961-1990)

months	January	February	March	April	May	June	July	August	September	October	November	December	Average Annual
Averages	9.3	9.8	11.5	14.8	18.2	21.9	22.3	22.8	21.2	18.5	14.4	11.1	16.3

Source: Fariha Issa Al-Jarari (2008) The Role of Forests in Domestic Tourism and Outdoor Recreation in the Green Mountain, Unpublished Master's Thesis, Department of Geography, Omar Al-Mukhtar University, p. 50.

- Topographical features and their impact on atmospheric processes:

Al Abraq International Airport is situated at an altitude of approximately 657 meters above sea level, giving it distinct climatic characteristics compared to the surrounding coastal areas. Topographical analysis has shown that the site features a relatively open area surrounding the airport with limited direct topographical obstacles, thus supporting the safety of takeoff and landing runways.

However, the relative elevation of an airport affects atmospheric pressure and air density, which can impact aircraft operational performance, especially under high temperatures. This data highlights the importance of incorporating topographical considerations into future airport infrastructure development planning.

- Assessing the suitability of natural geographical factors for air operations:

By linking climate elements with topographical characteristics, it was shown that the natural geographical factors of Al Abraq International Airport provide relatively favorable operating conditions for air transport, as the limited occurrence of extreme weather phenomena and stable air visibility contribute to the regularity of air traffic.

However, high temperatures and monsoon wind patterns represent the most significant natural challenges that can affect operational efficiency during specific times of the year. These findings indicate that improving operational efficiency is not solely dependent on technological development, but also requires a thorough understanding of the natural geographical environment surrounding the airport.

- Geological structure:

The Green Mountain is a series of highlands and is generally a gently undulating surface in which erosion features are evident to varying degrees, and the rock formations are mixed and covered by limestone rocks. The study area is covered by geological formations, most of which date back to the rocks of the Tertiary and Quaternary periods. The following are the most important formations of the study area, represented by Al-Abraq International Airport:

- Formation of the Oligocene epoch, which includes:

A - Al-Bayda Formation: This formation consists of yellowish-white limestone, sometimes containing a high percentage of clay and marl. It extends between Lamluda and Al-Bayda, i.e., it includes the city of Al-Abraq, including Al-Abraq International Airport.

B- Al-Abraq Formation: This formation consists of large-grained calcareous chalcarnite rocks, and limestone (dolomite marl) appears in the Ras Al-Tin area and southwest of the city of Derna (Al-Khajkhaj, 2009, 47).

Al-Abraq Airport is located in an area where Miocene and Oligocene formations overlap, and part of the airport's subsoil lies above calcareous Oligocene formations. These formations are known for their relative hardness, natural cracking, and susceptibility to erosion over time by water. We observe the effect of this formation on Al-Abraq International Airport through the relative stability of the surface soil, which makes the airport ground suitable as a base for runways and facilities. It also provides engineering leveling by allowing the limestone rocks to be easily cut and leveled during construction. The relatively low groundwater level also plays a role in reducing the risk of water saturation of the soil under the air facilities.

It is also possible that this formation at Al-Abraq International Airport may be exposed to natural cracks and fractures, which may cause water leakage or weakening in some parts of the ground under the runway over time, or hidden karst activity may occur due to the presence of cavities under the surface. This is a result of the dissolution of limestone and may lead to ground subsidence, which affects the safety of the runway or the efficiency of surface water drainage systems. Therefore, advanced monitoring devices should be used for early detection of any karst voids, as well as the use of deep foundation techniques during construction to strengthen the soil and reduce these effects.

- Miocene formation: This is represented by the Faidha formation as follows:

This formation is considered the most widespread geological formation along the Libyan coast. In its lower part, this formation begins with a layer of clay or marl that tends to be green or yellow. The upper part consists of pure limestone with medium to large grains, sometimes. In some areas, chalcarnite rocks and coral moss limestone are interspersed with this formation. The Faidiya Formation represents 90% of the rocks that appear in the eastern region, starting from the city of Derna to the eastern borders.

The city of Al-Abraq and its airport (Al-Abraq International Airport) are located above areas dominated by early and middle Miocene formations. These layers represent the main geological base under the airport's infrastructure. We note the impact of this formation on Al-Abraq International Airport through the provision of a suitable base for building runways and facilities due to the moderate hardness of the Miocene limestone rocks. This formation also led to the surface leveling of most of the Miocene areas in the city of Al-Abraq and its airport, which facilitated the construction of the airport without large excavation works. This formation is also geologically stable from seismic activity and makes the airport suitable in terms of structural safety.

The variation in the quality of Miocene rocks (limestone, marl, clayey) may lead to variations in soil bearing capacity, which may require the design of irregular foundations in some locations. The presence of weak layers also leads to uneven subsidence in some parts of the floor under the runway or buildings. The presence of old or compressible sedimentary cracks may affect ground stability. Erosion factors in this formation, especially in the unprotected upper layers, also play a role in affecting drainage systems (Omar Al-Mukhtar University, Final Report, 2005, 51).

- Surface features:

The Green Mountain (Jabal Akhdar) is characterized by topographical and geological features that make it one of the most important areas with surface drainage in Libya. The city

center of Al-Abraq is located near the airport, in a relatively low-lying position compared to the surrounding mountains. This makes Al-Abraq and its airport susceptible to runoff accumulation. Furthermore, Al-Abraq Airport is situated in an area with complex topography, between plateaus and highlands, making it vulnerable to significant topographical influences. This is evident in the surrounding slopes; Al-Abraq Airport lies on the southern edge of the Green Mountain, with valleys descending towards it. This could expose it to the risk of seasonal flooding during heavy rainfall. The rocky nature and rugged terrain of Al-Abraq (near valleys and highlands) could negatively impact the ease of future airport expansion and limit the construction of bypass roads or additional facilities without extensive engineering intervention. It could also pose challenges in stabilizing the infrastructure. Additionally, the presence of watercourses near the runway could lead to increased humidity and infrastructure erosion if not considered during the planning phase. This underscores the importance of a proper drainage network at the airport.

- Natural plants:

Natural vegetation is a double-edged element for Al-Abraq International Airport. On the one hand, it contributes to protecting the environment and improving climatic conditions, and on the other hand, it may pose a direct threat to air traffic if it is not managed properly. Therefore, the balance between environmental conservation and air safety should be a focus in the vegetation management plan around Al-Abraq International Airport.

Al-Abraq Airport is located in an area south of the Green Mountain, a region characterized by varying density of natural vegetation. It is affected by a semi-arid Mediterranean climate and by the diverse terrain, ranging from highlands to plateaus. The positive impact of natural vegetation on Al-Abraq Airport is evident in its reduction of wind and dust, particularly grasses and shrubs. It also stabilizes the soil and reduces dust storms, thus improving visibility and safety during takeoff and landing. Furthermore, it mitigates the phenomenon of dust storms that could disrupt air traffic. Natural vegetation also reduces the absorption of the sun's heat in the airport's vicinity, contributing to a cooler environment and reducing the "urban heat" phenomenon on the runways. Natural vegetation can also aid in the natural drainage of water through its roots, which absorb excess water during the rainy season, thus reducing the risk of water accumulation or flooding around the runway. Thus, it is clear that the presence of natural vegetation preserves the local ecosystem and prevents land degradation and soil erosion that could affect the stability of the ground around the airport.

Natural vegetation has negative effects on Al-Abraq International Airport by attracting birds, especially near the runways. This may be a habitat for insects and small animals, which attracts birds and poses a danger to aviation. The vegetation may also lead to a fire risk in the summer, particularly during periods of drought, as the dry vegetation turns into flammable natural fuel, exposing the airport to the risk of wildfires, especially in the vicinity of the airport. Uncontrolled growth of natural vegetation also affects air traffic. If green spaces are not maintained, tall grasses may grow around the runways and affect ground visibility, monitoring systems, or obstruct ground vehicles related to the airport. Figure (2) shows the negative impact of plants through the presence of farms inside the main wall of Al-Abraq International Airport.



Source: Field study dated 14/8/2025.

Figure (2) The negative impact of plants through the presence of farms inside the main wall of Al-Abraq International Airport.

- Conclusions:

- 1- The study showed that the geographical location of Al-Abraq International Airport represents an important strategic factor in supporting air transport in eastern Libya, given its location within a geographical area that serves several urban and economic centers.
- 2- It has been shown that the topographical characteristics of the area surrounding the airport contribute significantly to determining the patterns of air operation, as the adjacent elevations and slopes affect takeoff and landing procedures and the level of air safety.
- 3- The results revealed that climatic elements, especially wind speed and direction and seasonal weather fluctuations, are among the most prominent natural factors affecting the regularity of flights and the operational efficiency of the airport.
- 4- The study proved that horizontal visibility and accompanying weather phenomena such as fog and dust storms lead to fluctuations in operational performance, which necessitates the development of weather monitoring and early warning systems.
- 5- The results showed that the geological characteristics and soil nature in the airport area play an important role in the stability of the infrastructure and runways, especially in light of climate changes and long-term environmental factors.
- 6- The study showed a clear correlation between natural factors and the level of operational efficiency, as operational efficiency increases during stable climatic periods and decreases during unfavorable weather conditions.
- 7- The study confirmed that integrating natural geographic analysis into the planning and future development of airports is essential to improving operational performance and reducing environmental risks.
- 8- The study concluded that relying on applied geographic analysis provides a scientific basis to support decision-making in the management and operation of airports in areas with changing environmental characteristics.

The study's findings indicate that natural geographical factors are a key determinant of operational efficiency at Al-Abraq International Airport, demonstrating a clear impact of climatic and topographical elements on the regularity of air operations and operational safety levels. The

study underscores the importance of integrating applied geographic analysis into future airport planning and development policies, thereby contributing to enhanced air transport efficiency in regions with varying environmental characteristics.

- Recommendations:

- 1- The need to develop an integrated weather monitoring system within Al-Abraq International Airport that relies on modern technologies to monitor the climatic elements affecting takeoff and landing operations, in order to contribute to raising the level of air safety and operational efficiency.
- 2- Integrating natural geographic analysis into the airport's future planning and development plans, so that topographic and climatic characteristics are taken into account when implementing any expansions or infrastructure projects.
- 3- Enhancing the use of Geographic Information Systems (GIS) and remote sensing technologies in monitoring environmental changes surrounding the airport and analyzing their impact on operational performance on a regular basis.
- 4- Establishing a long-term climate and geographic database specific to the airport, to support decision-making processes and forecasting potential weather conditions that may affect air traffic.
- 5- Improve air risk management procedures by preparing flexible operating plans that adapt to changing weather conditions, especially during periods of dust storms and reduced visibility.
- 6- Supporting cooperation between airport operators, academic institutions and meteorological centers to conduct ongoing applied studies on the impact of natural factors on air transport in eastern Libya.
- 7- Taking into account the results of applied geographical studies when setting national policies related to the development of regional airports, in a way that contributes to achieving operational sustainability and reducing costs resulting from environmental factors.
- 8- Expanding the conduct of comparative studies between Al Abraq International Airport and other airports with similar environmental conditions, with the aim of developing more efficient operating models in semi-arid environments.

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