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Insight into Genaveh 11-29 Runway Geometric Redesign Based on Meteorological Synoptic Data

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Abstract

Wind information can provide an optimal estimate of the runway orientation by minimizing the crosswind component of the wind at airports, which severely affects aircraft take-off and landing performance. Additionally, a systematic geometric design requires information on wind speed, direction, duration, and specific information about latitude and longitude, temperature variation, and altitude of the airport site. In the present research, meteorological synoptic data has been precisely measured and collected over Genaveh unconstructed airport for a period of five years. Investigation of the gathered data leads to the selection of an optimal runway orientation using wind rose representation and other data analysis. Additionally, the required runway length has been estimated in order to be compatible with the standards and aircraft types considered to apply the Genaveh site. All analyses are executed for variation of temperature, altitude, landing, and take-off situations. The results demonstrate that the previously considered orientation of the runway is considerably different from the optimal direction by at least 10 degrees. Moreover, a longer runway length is required to cope with the standards to reduce the risk of accidents in the presence of crosswinds.

Keywords: Genaveh airport, Runway orientation, Runway length, Meteorological synoptic data, Wind rose diagram

Genaveh 11-29 Pistinin Meteorolojik Sinoptik Verilerini Temel Alan Geometrik Yeniden Tasarımı

Öz

Rüzgâr bilgisi, havalimanlarında rüzgârın uçağın kalkış ve iniş performansını ciddi şekilde etkileyen yan rüzgâr bileşenini en aza indirerek pist oryantasyonunun optimal bir tahminini sağlayabilmektedir. Ek olarak, sistematik bir geometrik tasarım ise rüzgâr hızı, yönü, süresi hakkında bilgi ve havalimanı sahasının enlem ve boylamı, sıcaklık değişimi ve rakımı hakkında özel bilgiler gerektirmektedir. Mevcut araştırmada, meteorolojik sinoptik veriler hassas bir şekilde ölçülmüş ve beş yıllık bir süre boyunca Genaveh'in yapılmamış havalimanı üzerinden ilgili veriler toplanmıştır. Toplanan verilerin temel amacı, rüzgâr gülü gösterimi ve diğer veri analizleri kullanılarak optimal bir pist oryantasyonunun seçilmesine yardımcı olmasıdır. Ek olarak, Genaveh sahasını uyguladığı düşünülen standartlar ve uçak tipleri ile uyumlu olması için gerekli pist uzunluğu tahmin edilmesidir. Tüm analizler sıcaklık, irtifa, iniş ve kalkış durumlarının değişimini temel almaktadır. Sonuçlar, pistin önceden dikkate alınan yönünün, optimum yönden en az 10 derece önemli ölçüde farklı olduğunu göstermektedir. Ayrıca, yan rüzgarların varlığında kaza riskini azaltmak için standartlarla başa çıkmak için daha uzun bir pist uzunluğu gereklidir.

Anahtar kelimeler: Genaveh havaalanı, Pist oryantasyonu, Pist uzunluğu, Meteorolojik sinoptik veriler, Rüzgâr gülü diyagramı

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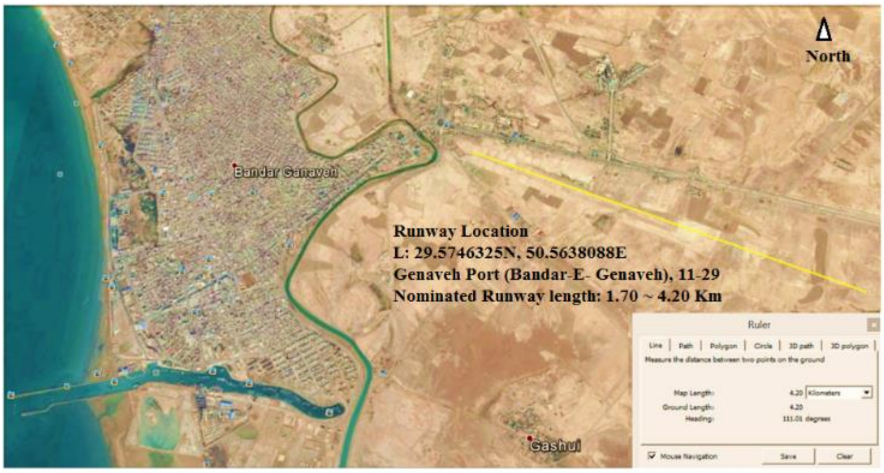
INTRODUCTION

The necessity of transportation development was forced by rapid growth of oil fields discoveries in the south of Iran which led to plans adoption for the construction of the airports of Abadan, Ahvaz, Molasani, Kot Abdullah, Dorkein, Hindijan, and Genaveh in 1934 by the council of ministers. Despite dedicating a land site to the Genaveh Airport in 1934, several parts of the embankment and even buildings for the flight tower, security, apron, and airport facilities were set up several times before and after the Islamic revolution in 1979. The airport was not operational and from the stage of the embankment, parts of the leveling and runway marking did not go further. Given the abundant capability of Genaveh Airport in the region's economic prosperity, and the fact unscientific considerations in the design phase and ignoring some standards regarding the runway design, this article redesigns the site based on the local five-year meteorological synoptic data (wind speed and its direction) and the new requirements of the runway for the airplanes' types expected to use the runway. Figure 1 illustrates the data and satellite view of Genaveh airport runway which was planned to be 4.20 *km* long with heading orientation of 110-290 degrees (11-29). According to the local wind data and the airplanes' types, the capability of the runway is investigated, and the corrected orientation and length are calculated. The requirements of the airport runway are analyzed for its ability to meet the requirements of users throughout the planning period. The main objective of this effort is to provide specifications that satisfy the Federal Aviation Administration (FAA) and International Civil Aviation Organization (ICAO) standards. For the operational safety and efficiency of an airport, it is desirable for the runway to be oriented towards the direction of the prevailing wind. This reduces the impact of the wind perpendicular to the runway (crosswinds) as well as relaxing the take-off and landing performance in the presence of headwind. The recommended length of runways is determined by considering either the family of airplanes having similar performance characteristics, or the longest runway required by an available aircraft. Additional important factors include critical aircraft approach speed, its maximum certificated take-off weight, useful load and length of haul, runway inclination, the airport's field elevation above sea level, and the mean daily maximum temperature at the airfield, and the typical runway surface conditions, such as wetness and slippery



Runway Location
L: 29.5746325N, 50.5638088E
Genaveh Port (Bandar-E- Genaveh), 11-29
Nominated Runway length: 1.70 ~ 4.20 Km

Measure the distance between two points on the ground

Map Length: 4.20 Kilometers
Ground Length: 4.20
Heading: 111.01 degrees

Figure 1. Genaveh runway satellite view, heading direction 11-29 (110-290 degrees), Lon: 29.5746325N, Lat: 50.5638088E, nominated runway length (yellow line) =1.70 ~ 4.20 km

The wind data analysis is essential in different application such as meteorology and climate, air quality evaluation, architecture, energy production, agriculture, etc. The wind could be a definite threat if not adequately considered in some specific fields especially in designing airport runways. The concepts of crosswinds and tailwinds are of particular importance in the correct design of runways. A crosswind is a wind that blows perpendicular to a specific direction of a runway which makes a landing more difficult. If a crosswind is strong enough it may exceed the allowable aircraft’s crosswind limit and an attempt to land under such conditions could cause an accident. Crosswinds may cause serious accidents during landing, especially for small and light airplanes. The investigation about different accidents has proved that the accident probability increases as crosswind rises (Van, Geest and Nieuwpoort, 2001). Statistics on historic aerial accidents demonstrate that the risk of accidents grows exponentially when the airplane operates in conditions with crosswind exceeding 20 knots (10.29 m/s). Tangential wind (tailwind) causes an overrun type of events during landing and also is important in accident analysis (Fala, Nicoletta, and Marais 2016).

There are several researches concerning runway design and its challenges (Ashford and Wright, 1992). Daggubati, Nazneen and Raj (2014), investigates the runway design and the structural design of airfield pavement applying the topographical, meteorological, and geological data in the airport site. The structural design of airport runway and pavement thickness were examined in Ref (Khoemarga and Tajudin, 2019) using the Airplane Reference Field Length (ARFL) method for calculating the length of the runway, and Federal Aviation Administration (FAA) regulations for calculating the pavement thickness. Regarding the runway orientation, Jia, et al. (2004) presents a geographic information system (GIS) based strategy called airport runway optimization (ARO) that determines the best runway orientation for the effective layout of airport facilities. The method uses customized GIS technology and spatial database management tools to optimize the runway orientation based on given wind data. Mousa and Mumayiz, (2000) presents a computer model which is based on a mathematical formulation, for optimizing the runway orientation based on given wind data. Ong and Fwa, (2005), presents an up-to-date model for the optimization of multiple runway orientations by combining it with geographic information.

Runway orientation is the main focus of many researches in the airport design phase. Therefore, apart from the above researches, in this paper, an effective method is introduced to determine the orientation of the existing runway based on local metrological investigations (five-year meteorological synoptic data), wind rose method, and the allowable crosswind limit according to the FAA regulations. It is noted that our proposed approach concentrates simultaneously on two important parameters in runway design, which is the determination/evaluation of the correct orientation and minimum required length of the runway. This current study imposes the methodology into the runway essential design parameters by considering the wind data. Designing a runway entails multifactorial engineering considerations (e.g. land cover, soil texture, and geology). If the study goes beyond the construction codes, a list of assumptions is crucial.

1. Dominant Data

The investigations tend to define the runway orientation that maximizes the possible use of the runway throughout the year accounting for a wide variety of wind conditions as well as considering the regulations about runway orientation and their expected coverage. Generally, all operations on a runway must be managed according to the wind; therefore, a careful examination of prevailing wind conditions at the airport site is required. Falls and Brown presented two methods (empirical and theoretical) for determining the optimum runway orientation relative to minimizing a specific crosswind (Falls, and Brown 1972). The empirical procedure requires only hand calculation on an ordinary prevailing wind direction, while the theoretical method utilizes wind statistics computed after the bivariate normal elliptical distribution (Grewe *et al*., 2017).

The runway orientation should provide 95% wind coverage. This means that for 95% of the yearly time, the crosswind component must be smaller than the Allowable Crosswind Component (ACC). Thus, the goal here is to achieve 95% or higher coverage. The FAA considers wind analysis as fundamental processing for determining runway orientation. The runway orientation is determined by a specific number between 01 (for 10 degrees) and 36 (for 360 degrees), indicating its heading with respect to the North in sectors of 10 degrees. For example, during take-off and landing on a runway labeled as 09, an aircraft points to the East, while on runway 18, it points to the South. This definition of the orientation is not coherent with the one of wind direction since a wind direction of 180 degrees indicates a wind blowing from the South. If a runway is used in the opposite direction, it is named by adding/subtracting 18 (180 degrees). For instance, runway 09 becomes 27 when is used in the opposite direction. Then the runway orientations are often determined as *XX*-*YY*, where the absolute difference between *XX* and *YY* is 18 (for example Genaveh 11-29). Therefore, the runway direction does not change the results, the only difference is that headwinds become tailwinds, and crosswinds from left become right-hand side crosswinds (and vice versa). Since only the absolute values of the crosswind are of interest, the runway can be considered with its orientation. For this reason, in the rest of the document headwind and tailwind are considered interchangeable.

As previously mentioned, according to the FAA, a runway orientation must satisfy 95% wind coverage considering yearly wind conditions. For each wind speed $W(x,y)$, the crosswind (w_c) and tailwind (w_t) components are calculated using equations (1) to (3), where δ is the difference between the wind direction and the runway orientation. Once the ACC is known, the analysis of the wind data allows to determine the runway coverage or to determine the best runway orientation for a given site during the airport design. In order to determine the best orientation of a future runway, the calculations must be performed for all possible directions.

$$W(x,y) = \sqrt{{w_x}^2 + {w_y}^2} \tag{1}$$

$$W_c = W(x,y)\, sin(\delta) \tag{2}$$

$$W_t = W(x,y)\,cos(\delta) \tag{3}$$

Considering wind currents (w), the motion of the airplane is defined as follows:

$$x(t) = \int \big(V_a\, sin(\chi) + w_x(x,y)\big)dt \tag{4}$$

$$y(t) = \int \Big(V_a\, cos(\chi) + w_y(x,y)\Big)\,dt \tag{5}$$

where (x,y) is the airplane position, χ is the airplane heading angle relative to North direction, V_a is the velocity of the airplane, $w_x(x,y)$ is the east component of the wind, and $w_y(x,y)$ is the north component of the wind. The motion equations apparently describe the required runway length and orientation as well as the dependency of wind and airplane motion.

Every aircraft is tested according to the regulations prior to certification. The aircraft is tested by a pilot with average piloting skills in 90° crosswinds with a velocity up to 0.2 of the aircraft's stall speed in power off, gear down, and flaps down flight condition. This means that if the stall speed of the aircraft is 45 knots, it must be capable of landing in a 9-knot, 90° crosswinds. The crosswind and headwind component chart allows for figuring the headwind and crosswind component for any given wind direction and velocity. Referring to figure 2, the degrees determine the difference between the runway orientation and the wind direction while parallel quadrants denote the specific crosswind or headwind. Dimensions straight down and straight across specifies the headwind and the crosswind component at specific differences. This information is important during take-off and landing so that the appropriate runway can be picked if more than one direction exists at a particular airport.

The decision about applying a special method mainly depends on the type of input data available. Both FAA and ICAO standards employ the most critical aircraft expected to operate in the runway for allowable crosswind calculation. Hence, the most critical airplane is considered as the largest with the highest approach speed.

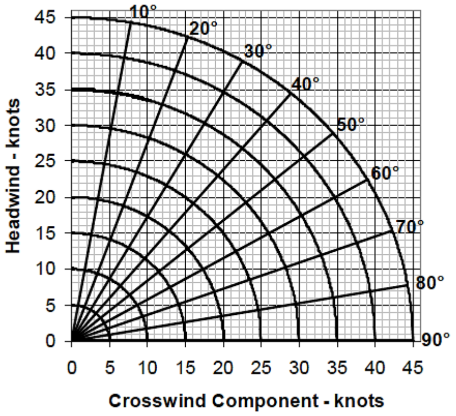


Figure 2. Wind component according to the difference between the runway orientation and the wind direction

According to the safety terms, it is also recommended to provide an orientation that satisfies crosswinds below the critical value. Each aircraft has a maximum allowable crosswind component derived from flight test experiments. The crosswind component increases with the size of the aircraft, for example, it is 33 *knots* (16.98 *m/s*) for an Airbus A320, and 17 *knots* (8.75) for a Cessna 172. The FAA coding system is employed to relate airport design criteria to the operational and physical characteristics of the aircraft projected to use the airport, while ICAO standards consider take-off weight, airport altitude, and the required take-off length (Silva, 2011). According to the FAA, an allowable crosswind component (ACC) depends on the Runway Design Code (RDC). The RDC is a string composed of a letter and a Roman numeral; the letter, from *A* to *E*, is related to the aircraft approach speed (*A* low speed, *E* high speed), while the Roman numeral, from *I* to *VI*, is related to the wingspan or tail height (*I* small size, *VI* great size). Actually, the RDC includes also third information which is related to visibility, but it is not considered in determining the ACC.

The ACC for some different airplanes (average value of different models of an airplane type) is reported in Table 1. Both the ICAO and EASA (the European Aviation Safety Agency) establish the ACC as a function of the minimum required take-off length: 10 knots (5.1 *m/s*) for lengths smaller than 1200 *m*, 13 knots (6.7 *m/s*) for lengths smaller than 1500 *m*, and 20 *knots* (10.3 *m/s*) for lengths greater than 1500 *m* (Corleisen, 2012). These dimensions about ACC refer to a dry runway surface. When the runway surface is wet with the risk of hydroplaning or covered with slush or snow, the ACC decreases. For example, the ICAO and EASA ACC of 20 knots reduce to 13 knots when the runway is characterized by poor braking conditions. According to mentioned items, 15 knots (7.7 *m/s*) is considered as the ACC threshold in the following analysis. An important aspect of airport runway geometric design is ensuring the prompt removal of water from the runway to reduce hydroplaning and skidding risks of aircraft operating under wet-weather conditions (Ong and Fwa, 2016). Skid resistance of asphalt pavement on rainy days is an essential element for improving highway safety. Hydroplaning of an aircraft refers to the condition when water on a wet runway is not displaced at a rate fast enough from the tire–pavement contact area of a rolling or a locked sliding tire, resulting in the tire not making contact with the pavement surface over its complete footprint area (Horne, and Joyner, (1965)). Although hydroplaning risk has not been explicitly taken into consideration in current geometric runway designs as well as this research, there all several valuable researches which analyze the hydroplaning phenomena by modeling or deriving the related key parameters to incorporate it in the future modern runway designs. Runway cross-slope is the main runway geometric element affected by the hydroplaning consideration. According to past studies on hydroplaning Ong and Fwa (2005) and Yu, Wu, Kong and Tang, (2017), the parameters that affect the hydroplaning speed of an aircraft on a wet pavement include the thickness of water film on the pavement, tire inflation pressure, wheel load, and aircraft speed.

The required take-off and landing field lengths depend on tailwind, therefore the minimum length of the runway for safe take-off and landing must be determined by tailwinds. Often the same aircraft has equal tailwind limits for the take-off and landing operations, but sometimes the limit is different for the two phases. Tailwind as one of the most important landing components which mostly contributes to overrun during landing and its effect is amplified when the runway surface is wet or contaminated. Moreover, many of the accidents happened for tailwinds greater than 10 *knots* (5.1 *m/s*).

Table1. Design data allowable crosswind (ACC) and tailwind-Knots

Aircraft Type		**B747**	**B737**	**B727**	**Airbus A300**	**Airbus A310**	**Cessna 172**	**Bell 212**
Take-off	Dry	33	30	29	32	28	15	30
ACC	Wet	27	15	29	32	28	15	30
Landing	Dry	33	30	29	32	28	15	30
ACC	Wet	30	25	29	32	28	15	30
Take-off	Dry	10-15	15	10	10	10	10	10
Tailwind	Wet	10-15	10	10	10	10	10	10
Landing	Dry	10-15	10	10	10	10	10	10
Tailwind	Wet	10-15	10	10	10	10	10	10

1.1. Wind Rose Diagram

The main operation in determining the orientation of a runway is the preparation of the wind rose diagram, which gives an explicit view on how wind speed and direction are distributed at a particular location over a specific period of time. It is a very useful representation because a large quantity of data can be summarized in a single plot. The importance of the information given by wind roses is known for more than half a century (Crutcher, 1954). Wind roses applied for runway design are composed of 36 wind sectors, each one spanning 10 degrees. Typically, each wind sector represents four to six wind classes. A possible variant of the wind rose consists of representing each direction, the average and/or the maximum wind speed, or any percentile of the wind speed along each direction. The wind rose template has a polar coordinate system that is made of circles and radial lines. Circles on the template represent the wind speed, while the radial lines illustrate the angles or the wind blowing directions. Each cell bounded by two circle segments and two radial lines stores the percentage of times that the winds correspond to a given direction and velocity range (frequent winds). The template is rotated around the center of the wind rose in order to search for an optimal runway orientation. At each rotating angle, the total percentage of allowable crosswinds that is covered by the template is calculated, and the best angle for the maximum percentage of coverage is determined.

Several works with different methodologies were performed in accordance with the wind rose to determine runway orientation. Jia *et al.* presented a geographic information systems (GIS)-based wind rose method called Airport Runway Optimization (ARO) to determine the orientation of a runway for the effective layout of airport facilities (Jia, Chung, Huang and Petrilli, 2004). This method uses a set of customized GIS operators and the database management tools to solve both the partial coverage problem and runway orientation optimization based on given wind data and allowable crosswinds. Similar work was performed by Chung using wind rose analysis (Chang, 2015). Mousa and Mumayiz (2000) and Oktal and Yildirim, (2013) presented a computer model for optimizing the runway orientation based on a given wind data and ACC. Most computer models, as the interpretation of wind rose, are based on a mathematical formulation that transfers circles and radial lines of the wind rose method into points with numeric coordinates. The considered airport for wind data analysis is the Genaveh runway which is an under-construction abandoned runway. It is concerned to be 11-29 oriented with a nominated length of 1.70 *km* to 4.20 *km*. The runway is located at latitude and longitude of 29.57 *N* and 50.56 *E*, respectively, east of the Persian Gulf near the sea (less than 4 *km*) in a flat area (less than 5-meter altitude above sea level) and has not been dedicated an ICAO code yet. The METAR (Meteorological Aerodrome Report) data of this airport have been collected for a period of 5 years (2014-2018) with a 10-minute time resolution. Obviously, the vast collected data bank agrees with the EASA requirements, which states that a minimum of five years of observation with at least eight ones per day (while 144 daily observations were used in this study) must exist (Silva, 2011). The METAR data contain information about average wind speed and direction, temperature, visibility, cloud cover, etc. A time processing allows analyzing the data to produce the wind roses diagram.

2. Simulation and Result

Airport data collection is really challenging and time taking procedure. A huge database must be provided and examine for runway design. Based on meteorological synoptic data, the wind speed and direction, pressure, temperature, time and date of occurrence were collected with a 10-minute time resolution for five years (over 200000-time intervals and more than 1.2 ×106 data). The results of the data analysis are presented in the following.

2.1. Orientation Analysis

According to the classified wind data, the wind roses diagram of the Genaveh airport in the period of 2014-2018 has been illustrated in Figures 3, 4 and 5 for the total period and different seasons. These diagrams include both the measured average speeds and directions. In summer the spectrum of winds is more western and in winter is more northern. Although different winds are observed in the hot and cold seasons, the overall wind spectrum indicates a dominant northwest (*NW*) wind. According to the results, the dominant wind direction of the Genaveh airport greater than 6 m/s occurs in 300 degrees, followed by 310, 290, and 280 degrees, and then the most frequent winds blow from *NW*. Winds blow mostly from the arcs ENE and WNW (near the *NW*) where the *NW* winds are stronger than others. Therefore, they are roughly aligned with the imaginary axis along the *NW*, which is approximately the runway orientation.

Figure 6 illustrates the average hourly wind speed distribution during the five years of examined data. The horizontal axis depicts the hours of the day, while the vertical axis presents the percentage of occurrence of a specific velocity. It is concluded that the high-speed frequent winds occurred between the hours 06:00 and 14:00 of the daytime while the lower speeds blow at other times. Figure 7 illustrates the average hourly wind direction distribution, using a different color spectrum indicating the runway orientation. According to figure 7, it is observed that between the hours of 06:00 and 14:00, the frequent prevailing wind directions vary from 250 degrees to 310 degrees as approaching the noon and the 300 degrees is the prevailing wind blow direction. Accordingly, the lower speed winds are very frequent during the night and in the morning.

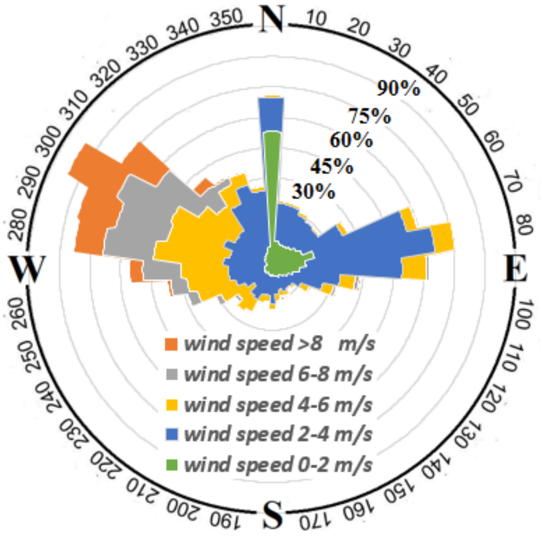


Figure 3. Genaveh airport wind roses diagram 2014-2018

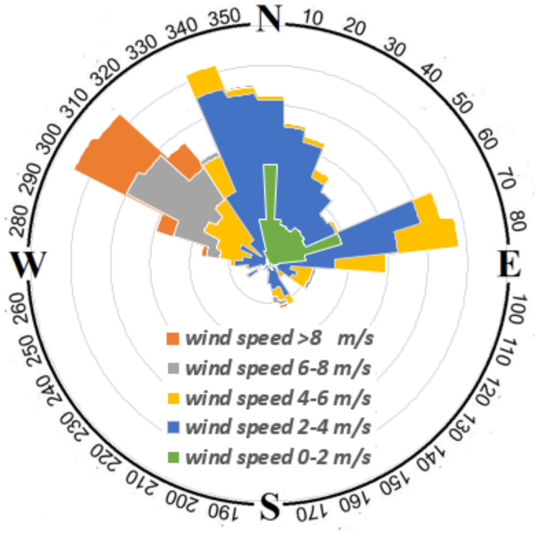


Figure 4. Genaveh airport wind roses diagram based on winter data, 2014-2018

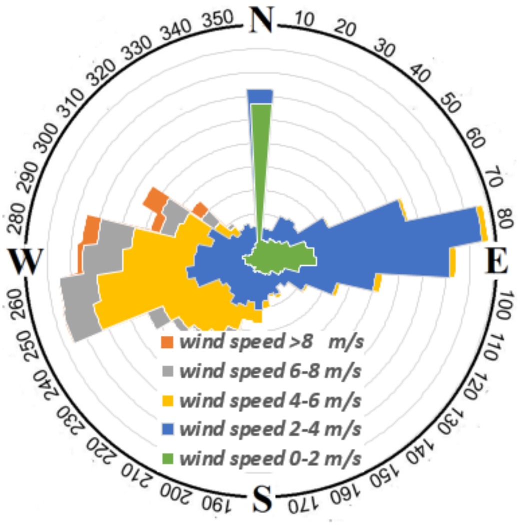


Figure 5. Genaveh airport wind roses diagram based on summer data, 2014-2018

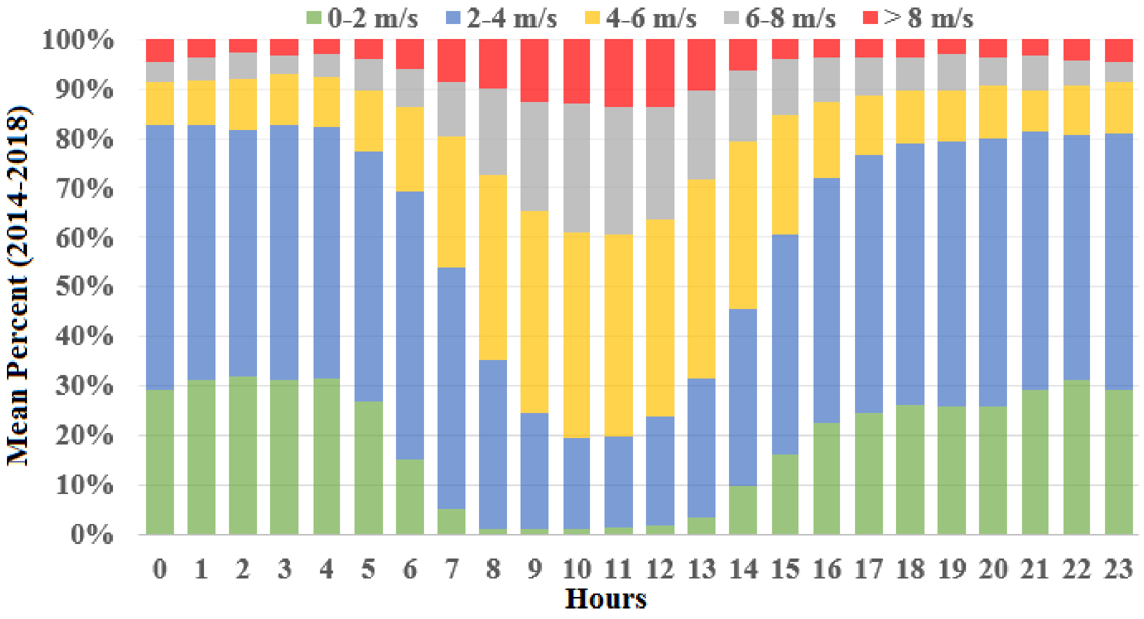


Figure 6. Average hourly wind speed distribution from 2014 to 2018 for the Genaveh airport

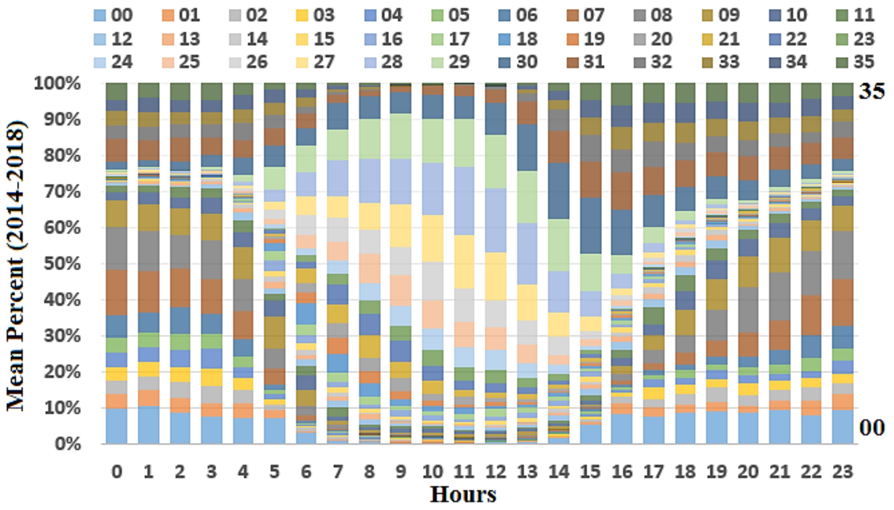


Figure 7. Average hourly wind direction distribution from 2014 to 2018 for the Genaveh airport (00 from the bottom to 35 in top of each bar)

According to figure 8 of the hourly wind, in an interval of 250 -320 degrees, the hourly wind distribution presents that the high frequent winds occur from 06:00 to 15:00. Figure 9 verifies these results and illustrates that the critical high-speed winds (>6 *m/s*) are more frequent from 09:00 to 12:00. Therefore, the design orientation must be around this critical condition while covering all strong winds in the daytime.

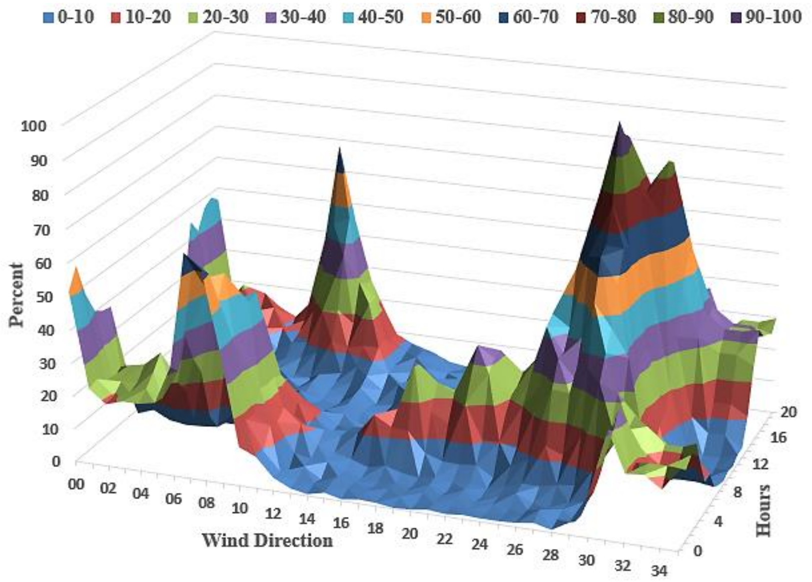


Figure 8. Average wind hour distribution from 2014 to 2018 for the Genaveh airport

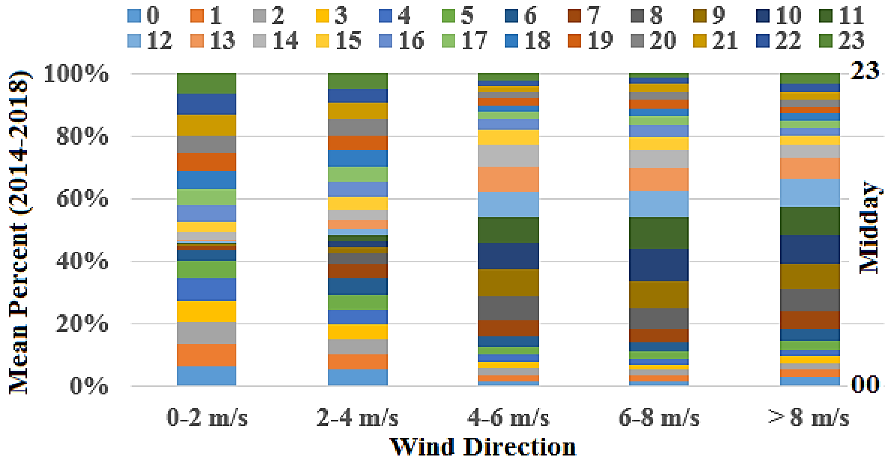


Figure 9. Average hourly wind speed distribution from 2014 to 2018 for the Genaveh airport

2.2. Crosswind-Tailwind Analysis

Regarding three critical values of crosswind, Figure 10 illustrates Genaveh peak crosswind components percentage of exceedance versus runway orientation. The distribution of the absolute values of 11-29 Genaveh airport crosswind and tailwind are shown in Figure 11. Absolute values mean that crosswinds from left and right are considered similarly, and the same is true regarding headwinds and tailwinds. The crosswind distribution plot helps to estimate graphically the wind coverage once the ACC of the runway has been defined. Similarly, the plot of tailwinds distributions allows estimating how frequently the threshold of 10 knots or 5.1 m/s, is exceeded. The distribution of absolute crosswind is illustrated in figure 12 for all orientations of Genaveh airport. The influence of orientation on wind coverage is apparently observed. The resulting calculated wind coverage values are reported in Table 2 for all the runway orientations of the Genaveh airport. The highest wind coverage established by the FAA has obtained form 12-30 and 13-31 orientations while the 12-30 orientation demonstrates a lower wind speed in 100% coverage and a higher percentage of the tailwind. These results support the initial results according to wind rose analysis.

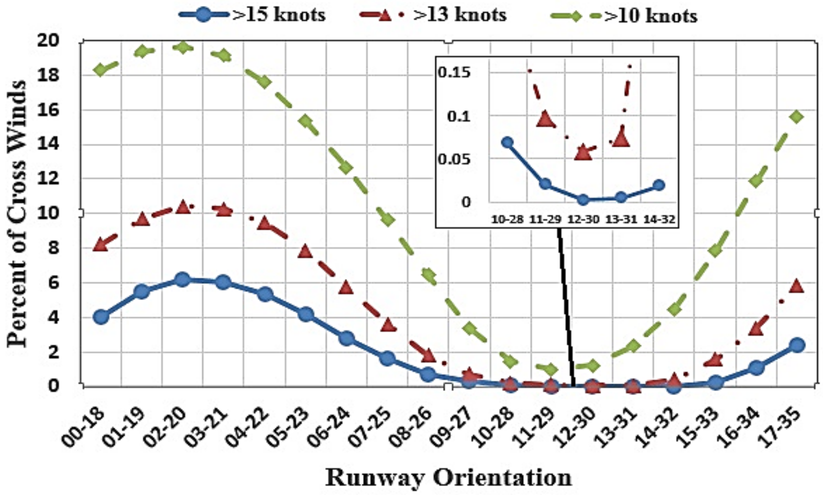


Figure 10. Crosswind components percentage of frequency of exceedance versus runway orientation

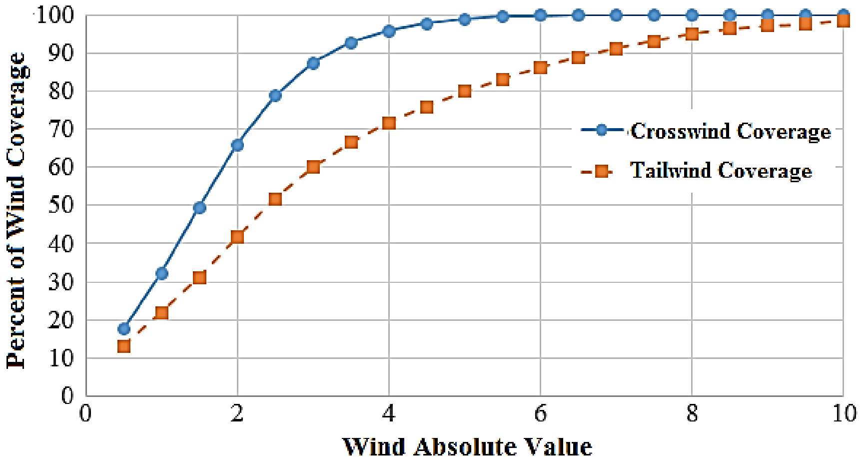


Figure 11. Distribution of the absolute values of crosswinds and tailwinds (from 2014 to 2018)

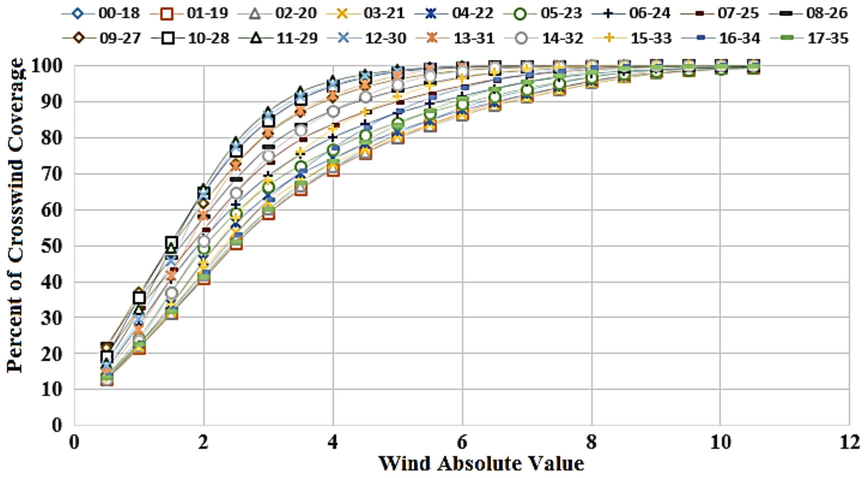


Figure 12. Crosswind coverage for all orientation of Genaveh airport from 2014 to 2018.

Table 2. Wind coverage for all orientation of Genaveh airport based on local observation.

Direction	**Wind coverage (%)**	**Wind speed at 100% coverage (*m/s*)**	**Tailwind greater than 10 Knot (5.1 *m/s*), %**
00-18	93.26	>10.5	68.14
01-19	91.77	>10.5	72.83
02-20	91.17	>10.5	73.27
03-21	91.27	>10.5	74.45
04-22	92.09	>10.5	74.99
05-23	93.56	>10.5	75.32
06-24	95.44	>10.5	76.11
07-25	97.22	>10.5	77.01
08-26	98.62	>10.5	77.98
09-27	99.45	10.50	78.74
10-28	99.85	10	79.69
11-29	99.93	9.5	80.10
12-30	99.97	8.5	80.38
13-31	99.97	8	80.21
14-32	99.83	8.5	79.53
15-33	99.06	9.5	78.28
16-34	97.54	>10.5	77.34
17-35	95.46	>10.5	76.46

According to the results, especially the wind rose and the crosswind analysis, the best orientation for Genaveh airport is concluded to be 12-30, and consequently, the previous orientation has not been considered appropriately. In order to validate our results, the nearest runways data with similar meteorological conditions are presented and compared in Table 3 and Figure 13. Based on Figure 13, eleven runways near Genaveh landing site have been selected.

Accordingly, the selected runways along with some important metrological characteristics have been presented in Table 3. Obviously, the predominant orientation is 300 degrees to 310 degrees with runway lengths of more than 2200 meters. In this statistical study, the runways local wind streaming from the south and north of the Persian Gulf as the source of wind streaming have been selected and examined. Local runway data analysis assists in understanding the coastline wind behavior while 11-29 orientation (considered orientation of Genaveh runway in the previous design) seems to be a discontinuity in the wind streaming behavior in runway design.

Figure 13. Nearest airports to Genaveh airport (star marked) with the same climate situations (airports presented in Table 3).

Table 3. Local runway near Genaveh airport (nearest runways with the almost same climate and temperature)

No	**Runway Loc.**	**Orientation**	**Loc. (LON-LAT)**	**Alt. from sea level (m)**	**Mean maximum temperature at the hottest month (*°C*)**	**Aerial distance from Genaveh (*km*)**	**Runway length (*m*)**
1	Bushehr	13-31	28.56 N,50.49 E	13	40.6	76	5000
2	Kharkisland	13-31	29.15 N,50.19 E	4	38.3	42	2340
3	Asaloyeh 1	13-31	27.28 N,52.36 E	1	41.9	308	3500
4	Asaloyeh 2	13-31	27.22 N,52,44 E	4	41.8	325	4000
5	Bahregan	15-33	29.50 N,50.16 E	14	38.6	40	2200
6	Goreh	12-30	29.54 N,50.25 E	35	40.3	38	1400
7	Mahshahr	13-31	30.33 N,49.09 E	6	42.3	173	2700
8	Omidiyeh 1	13-31	30.44 N,49.40 E	17	41.9	154	2150
9	Omidiyeh 2	12-30	30.50 N,49.31 E	21	41.5	170	4100
10	Behbahan	13-31	30.43 N,50.06 E	350	38.1	135	2500
11	Abadan	14-32	30.22 N,48.13 E	2	42.8	240	3100

2.3. Runway Length/Width Analysis

Various factors including the weight of aircraft, runway slope, weather condition, and elevation with respect to sea level affect the runway length requirements. Runway length requirements for each aircraft along with related general guidelines have been defined and published in FAA AC 150/5325-4B standards. This Advisory Circular (AC) provides guidelines for airport designers and planners to determine recommended runway lengths for new runways or extensions of existing runways. Various factors govern the suitability of available runway lengths, most notably airport elevation above mean sea level, mean maximum temperature of the hottest month, wind velocity/speed, airplane operating weights, take-off and landing flap settings, runway surface condition (dry or wet), effective runway gradient, presence of obstructions in the vicinity of the airport, and, if any, locally imposed noise abatement restrictions or other prohibitions. Among these factors, certain ones have an operational impact on available runway lengths. Hence, for a given runway the usable length made available by the airport authority may not be entirely suitable for all types of airplane operations. Fortunately, airport authorities, airport designers, and planners are able to mitigate some of these factors. Independently, airport authorities working with their local lawmakers can establish zoning laws to prohibit the introduction of natural growth and man-made structural obstructions that penetrate existing or planned runway approach and departure surfaces. Effective zoning laws avoid the displacement of runway thresholds or reduction of take-off runway lengths thereby providing airplanes with sufficient clearances over obstructions during climb outs. Airport authorities working with airport designers and planners should validate future runway demand by identifying the critical design airplanes. In particular, it is recommended that the evaluation process assess and verify the airport's ultimate development plan for real changes that could result in future operational limitations to customers. In summary, the goal is to construct an available runway length for new runways or extensions to existing runways that is suitable for the forecasted critical design airplanes.

The basic length for a primary runway at an airport is determined by considering either the family of airplanes having similar performance characteristics or a specific aircraft requiring the longest runway. Both the Advisory Circular, as well as the FAA's airport design, classify aircraft based on weight. The standards include the aircraft fleet profile designed to be representative of the small and large aircraft.

The runway length requirements in this investigation are defined in accordance with the aircraft characteristics of Airport Planning Manuals (APM) distributed by the corresponding aircraft manufacturers. These manuals provide consideration for most factors that influence the basic runway length required for aircraft operations. Figure 14 demonstrates the sample calculation worksheets to compute the basic runway length for the small airplane with fewer than 10 passenger seats, while figure 15 illustrates the worksheets for heavier type correction of basic runway length. The design table for two types of the airplane, the small airplane of 12,500 pounds (5,670 *kg*) or with less maximum certificated take-off weight, and large airplane with more than 12,500 *lbs* (5,670 *kg*) of maximum certificated take-off weight are listed in the Fig. 14 and 15.

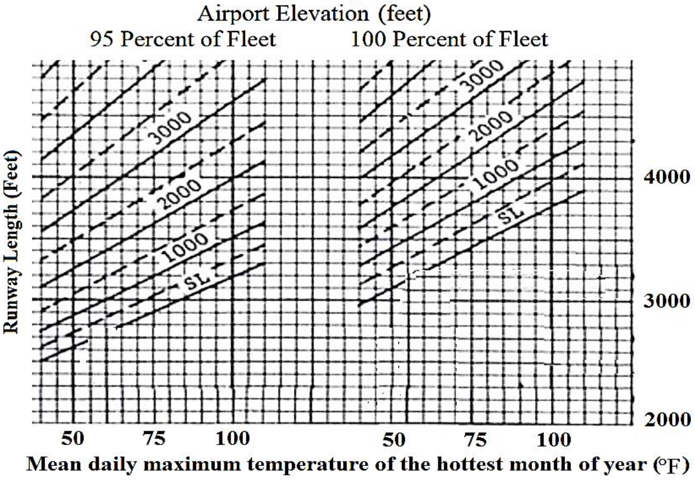


Figure 14. Small airplanes with fewer than 10 passenger seats exclude pilot and co-pilot, (FAA AC 150/5325-4B).

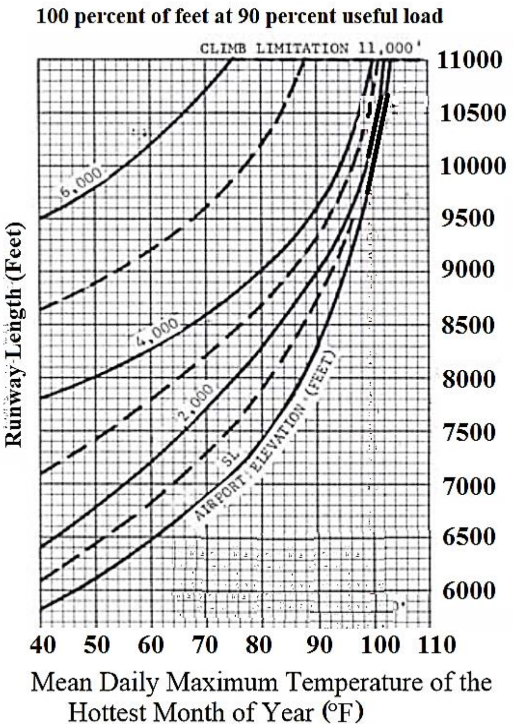


Figure 15. Runway lengths for airplanes within a maximum certified take-off weight between 12,500 *lbs* (5,670 *kg*) and 60,000 *lbs* (27,200 *kg*), (FAA AC 150/5325-4B).

For Genaveh airport the mean daily maximum temperature in the hottest month of the year is 39.5 °C (103.1 °F), therefore the runway length for 95 % and 100% coverage of small airplanes are 3200 *ft* (=976 *m*), and 3800 *ft* (=1160 *m*), respectively (Fig. 14). According to a maximum temperature in the hottest month of the Genaveh, the runway length is about 9800 *ft* (=3000*m*) for 100 % coverage of airplanes within a maximum certified take-off weight of more than 12,500 *lbs* (5,670*kg*) up to and including 60,000 *lbs* (27200 *kg*) at 90 percentage of useful load (Design Table Fig. 15).

Runway lengths for regional jets and those airplanes with a maximum certified take-off weight of more than 60,000 lbs (27,200 *kg*) requires the following information: the critical design airplanes under evaluation and their APMs, the maximum certificated take-off weight or take-off operating weight for short-haul routes, maximum certificated landing weight, airport elevation above mean sea level, effective runway gradient, and the mean daily maximum temperature of the hottest month at the airport. The recommended runway length obtained for this weight category of airplanes is based on using the performance charts published by airplane manufacturers, *i.e.*, APMs, or by contacting the airplane manufacturer and/or air carriers for the information. Regardless of the approach taken by the airport designer, the design procedure described below must be applied to the information/performance charts. Both take-off and landing runway length requirements must be determined with applicable length-adjustments in order to determine the recommended runway length. The requirements for the longest take-off and landing runway for the critical airplanes under evaluation is considered as the recommended runway length. Table 4, represents the required runway length for some heavy type airplanes which have the most flight sorties in Iran, according to manufacturing APM.

The characteristics related to airport design of the most used aircraft in Iran and some types of other are shown in Table 4. Wheel track (a distance between double main/aft landing gears) and wingspan determine the runway and taxiway widths. The wheelbase (longitudinal distance between main and nose landing gears) is related to airplane turning activities in the taxiway area. Additionally, wingspan and aircraft length rule the design of the apron/Taxiway area. According to the jet blast area, the runway length must be 10% greater than the biggest wingspan of landed airplanes while pavement strength is based on the aircraft weight and the distribution of the weight between the landing gears (Barros, and Wirasinghe, 2002). Passenger terminal facilities are sized to accommodate peak hour demand, which is highly influenced by aircraft passenger capacity.

Table 4. Landing/take-off length for heavy type aircrafts

Aircraft	**Wingspan (*m*)**	**Length (*m*)**	**Wheel base (*m*)**	**Wheel track (*m*)**	**Landing distance (*m*)**	**Take-off distance (*m*)**	**Passengers**	**Maximum take-off weight (*kg*)**
A300-600	44.8	53.3	18.6	9.6	1490	2240	247-375	165000
A310-300	43.9	46.6	14.9	9.6	1490	2290	200-280	149997
A320-200	33.8	37.5	12.5	7.6	1530	2190	138-179	71998
A321-100	34.1	44.5	N/A	7.6	1577	2210	186	82200
A330-300	60.3	63.7	25.6	10.7	1750	2500	295-335	208000
A340-200	60.3	59.4	23.2	10.7	1890	2990	262-375	253511
A340-300	60.3	63.7	25.6	10.7	1926	3000	295-335	253500
B727-200	32.9	46.6	19.2	5.7	1494	3033	145-189	83823
B737-300	28.6	33.4	12.5	5.2	1396	1939	128-149	56472
B737-400	28.6	36.5	14.3	5.2	1540	2540	146-189	62822
B737-500	28.6	31.0	11.1	5.2	1360	2470	108-149	52390
B737-600[b]	34.3	31.2	N/A	N/A	1400	2500	108-132	65090
B737-700[b]	34.3	33.6	N/A	N/A	1500	2600	128-149	69626
B737-800[b]	34.3	39.5	N/A	N/A	1600	2700	162-189	78244
B747-100	59.4	70.7	25.6	11.0	2100	3200	452-480	322048
B747-300	59.4	70.7	25.6	11.0	1905	3322	565-608	322048
B747-400	64.9	70.4	25.6	11.0	2179	3018	400	362871
MD-81	32.6	45.1	22.1	5.1	1478	2210	155-172	63502
MD-87	32.6	39.7	19.2	5.1	1430	1859	130-139	67812
MD-90-30	32.6	46.5	23.5	5.1	1510	2300	158-172	70760
DC-10-30	50.3	55.5	22.1	10.7	1758	2847	255-380	259453
DC-10-40	50.3	55.5	22.1	10.7	1750	2850	255-399	251742
MD-11	51.8	61.3	24.6	10.7	2118	3115	323-410	273287
ATR-42-300	24.4	22.7	8.8	4.1	1090	1100	42-50	16699
ATR-72-201	26.8	27.1	10.8	4.1	1100	1500	64-74	21500
EMB-120 Brasilia	19.5	20.0	6.8	2.0	1400	1400	30	11500

3. Conclusion

The analysis of wind data is of fundamental importance to design a new runway. Crosswind and tailwind components must be examined in the airport area throughout a long period of time in order to determine the optimal runway orientation and required length. The FAA and EASA have legislated that the runway orientation must satisfy 95% of the wind coverage.

ACC depends on the runway features as well as the aircraft operating on it. Considering dry conditions, the ACC of 15 *knots* (7.7 *m/s*) was applied for the analysis of wind data of Genaveh unconstructed airports. Five years of METAR data have been collected for the investigation of runway orientation and length. Crosswinds and tailwinds have been calculated for each measured data and their maximum values have been determined. The developed data and the related computations are severely important for the management of airport design and provide instant information regarding the runway orientation, location, and length design. The results of our analysis are unlike what has been designed or considered to be designed. Accordingly, the results show that the best runway orientation for Genaveh airport is 12-30 (120-300 degrees) since its coverage exceeds the 95% threshold value based on the standard requirements and therefore has the best performance comparing other directions.

Additionally, this study follows the statistics data to calculate the effective runway length based on the most frequent aircraft which are considered to perform take-off and landing on Genaveh airport. For instance, runway length requirement ranges from 1,100 m (ATR-42) to over 4,400 m (DC-1040), a difference of 300 %. The passenger capacity range is even wider: from 30 seats (EMB120) to 600 seats (the intended capacity of B747-300). Finally, the maximum take-off weight ranges from 11,500 kg (EMB-120) to over 362,000 kg (B747-400). It is very important to notice these differences since they perform a high influence on airport design. Runway length is highly limited by land availability and land costs; the amount of runway required by aircraft is, therefore, determinant for the airport cost. Thus, investigating the FAA, APMs and most used intended aircraft in light and heavy categories as well as the airplanes taxiway/apron and related facilities, the Genaveh runway length must have a length of at least 3500 meters.

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