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DATA ANALYSIS APPLIED TO AIRPORT PAVEMENT DESIGN

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Abstract

Designing an airport pavement is a complex engineering task. Thus, one of the first steps is to create scenarios for the operation of the airport. In this sense, the use of data analysis techniques can extract insights for this phase. Among the various parameters that characterize a runway, the most relevant is the structural capacity of the pavement and the length. For aviation, the standard for indicating the resistance of pavement is its Pavement Classification Number (PCN). Therefore, an application was developed in Python programming language [1], having as inputs the PCN and the runway length. Outputs are the aircraft supported by the pavement and the routes served (coverage). The development of this study follows the steps: a collection of real raw data about airports and aircrafts, data processing and cleaning, model development, model testing and application, result analysis, visualization, and final report. To test the model, the Viseu Aerodrome, located in the Center of Portugal region, was used. Several combinations have been created for PCN and runway length. Of all scenarios, three of them stood out, namely: maintain current characteristics (PCN 6 and length of 1160 m); an intermediate (PCN 23 and length of 1800 m); and a more robust scenario (PCN 83 and length of 2500 m). Finally, in the first scenario, it was possible to serve mainland Portugal, Spain, and a small portion of southern France. However, the operation was limited to small aircraft of up to 20 passengers. In the intermediate scenario, it was possible to serve much of the Schengen space with aircraft of up to 70 passengers. For the robust scenario, all Schengen space was served, with aircraft of up to 200 passengers. Therefore, based on two simple parameters, such as PCN and runway length, it was possible to visualize the coverage of an airport.

Keywords: airport, data analysis, pavement design, Python programming

1 Introduction

The opening of the aviation market to private operators, as well as regional aviation, reduced costs and popularized the use of aircraft. Consequently, in recent years this demand has pushed for the creation of new routes and the construction of more infrastructure [2; 3; 4]. Likewise, in this period, Portugal had notable growth in tourism. However, the airport infrastructure is not keeping up with demand, as the two main Portuguese airports, Lisbon and Porto, operate almost to the limit. Observing a small country like Portugal, the Central and Interior zones are in a gap about air transport [5]. In this scenario, small airports and regional airports appear as alternatives to operate low-cost regional flights in places where the critical mass does not yet support large infrastructures [6]. On the other hand, at regional airports, operating costs pressure the viability of the operation, and subsidies are required [6; 7; 8]. Another relevant point in the operation of regional airports is the use of smaller

aircraft, which end up having higher fuel consumption per seat, losing competitiveness [2]. Also, it must be assessed that air transport competes with other modes of transport, such as rail and road [3].
Therefore, there are many variables when proposing new routes. When the expansion or construction of infrastructure accompanies this analysis, this study becomes even more complex. In response to this demand, this research was developed to evaluate the construction of a new runway for the Viseu Municipal Aerodrome. This airport is interested in serving larger aircraft, which allow more extended range and carry more passengers per aircraft [5]. Requiring a runway with higher structural resistance of the pavement and with a longer length [9]. To design an airport pavement, it is necessary to know two main characteristics, namely, the Pavement Classification Number (PCN) and the runway extension. Thus, the proposed challenge is to design a pavement with capacity (PCN) and extension to serve a desired group of routes. A Python application was developed to accomplish this task [1], which processes information related to aircraft and airports and presents theoretical coverage for flights from the Viseu aerodrome.

2 Data and methods

2.1 Methods

The proposed methodology (Figure 1) for the research is based on the understanding of the problem, which is the interest of the Director of the Viseu Aerodrome to increase its number of passengers and coverage of flights. Based on this problem, the research question is to operate larger aircraft. In this sense, it is necessary to increase the resistance and the length of the runway.

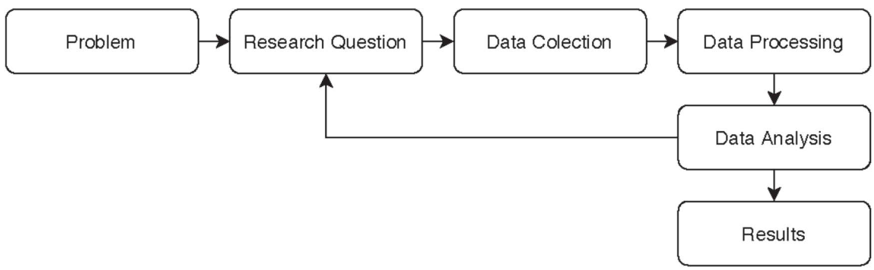

Figure 1 The methodology used in the research

After understanding the problem, the data collection and processing step begins. Finally, the last step is to analyze the data and visualize the results. In the data analysis stage, it is crucial to understand whether the problem has been answered. At this point, it may be necessary to reformulate or adjust the research question, restarting the process.

2.2 Data source

The information present in the datasets used in this research is shown in Table 1.

Table 1 Datasets used in the research

Dataset name	Fields	Source
AircraftData.csv	Aircraft identification, ACN[a], runway length required for landing and takeoff operations, autonomy, passengers[b].	[1]
AirportData.csv	Airport name, city, country, ICAO code, latitude, longitude, altitude, other fields[c].	[10]
20191227_basemap.shp	Layer file with boundaries of countries.	[11]
AirportTestExtraData.csv[d]	ICAO code, runway length, PCN.	[12]

Notes: a) Aircraft Classification Number is related to the impact of the aircraft on the pavement, and must be less than or equal to the runway PCN; b) Standard configuration; c) Other unused fields have been excluded; d) Schengen area airports only (lower airport security requirements).

2.3 Data preprocessing

The data is seldom perfect for use. Usually, they are in databases distributed in several sources, in different formats. Consequently, this information must be treated before being used. There is a pre-processing that consists of importing, formatting, and cleaning the data. Hence, in Figure 2, the pseudo-code for the data preprocessing step is presented.

```
Data preprocessing algorithm
Read input data
Merge airport data
Set ref. Airport = LPVZ (ICAO code of Viseu Aedrome)
for all airports:
        Drop unused columns
        Drop rows with PCN or Runway Length = 0
        Calculates the distance to the ref. Airport
Save results
```

Figure 2 Pseudo-code for data preprocessing step

To process the input data, the Python Pandas library is used to read, manipulate and view the data. Thus, the data are transformed into dataframes. The aircraft dataframe can be seen in Table 2.

As this base was built from scratch, it was not necessary to format and clean the data, since the dataset was created with the application in mind. On the other hand, the airport dataset had to be processed until it was usable. Initially, the file "AirportData.csv" and "AirportTestExtraData.csv" were merged. The field used as a pointer to this union was the ICAO code. Also, all unused fields were deleted. Finally, airports that had null information for runway length or PCN, were also removed. The resultant airport dataframe can be seen in Table 3.

Table 2 Aircraft dataframe

Aircraft	ACN	Required extension	Autonomy	Passengers
Dornier_228	6.4	792	1037	19
DCH-8_Q200	16.5	1000	2084	40
ATR42-600	18.6	1165	1326	48
ERJ140	21.1	1850	3058	44
ATR72-600	23.0	1175	1528	72
CRJ200	23.0	1768	2500	50
DCH-8_Q400	30.5	1425	2040	82
CRJ700	34.0	1605	2553	70
E170	38.6	1644	3982	72
E175	40.4	2244	4074	80
B737-800	79.3	2316	5436	184
B737-MAX8	82.2	2500	6570	200

Table 3 Airport dataframe (slice with the five first rows)

ICAO	Country	Latitude	Longitude	Distance to Ref[a]	RWY Length	PCN
BIKF	Iceland	63.99	-22.60	2759.7	3065	80
EBBR	Belgium	50.90	4.48	1480.6	3638	80
EBCI	Belgium	50.46	4.45	1444.6	2550	64
EDDB	Germany	52.38	13.52	2077.9	3000	140
EDDK	Germany	50.87	7.14	1617.8	3815	75

Notes: a) The Distance to ref column refers to the distance from the reference airport (Aerodrome of Viseu) to the destination airport. This field received the value zero initially. This item was calculated using the geodetic distance supported by the Python GeoPy library.

2.4 Data processing and analysis

After preparing the data for the study, the next step is to analyze the data and test hypotheses. Two datasets are formatted for processing (airports and aircrafts), and the objective is to compare the requirements for aircraft operation and the characteristics of the airports. The algorithm used to process the data can be viewed in the pseudo-code in Figure 3.

At this moment, the developed algorithm has the function of evaluating whether the aircraft registered in the database can operate at the reference airport (Viseu Aerodrome - LPVZ). In a second step, for all airports in the database, the capacity to receive the supported aircraft (which operate in the LPVZ) is analyzed. Also, it is observed whether the distance from the reference airport is within the autonomy of the aircraft.

As a result of the proposed algorithm, the airports served are presented. The list of aircraft with the possibility of operating at the reference airport is also informed.

```
Hypothesis testing algorithm
User input: ref PCN, ref Runway Length
Read input data (from data preprocessing results)
For all aircrafts:
        if aircraft ACN > ref PCN then:
                Drop aircraft
        if aircraft required extension > ref runway length then:
                Drop aircraft
        For all airports:
                if aircraft ACN > PCN then:
                        Drop airport
                if aircraft autonomy < airport distance to ref then:
                        Drop airport
                if aircraft required extension > runway lenght then:
                        Drop airport
Results: Airports served, list of possible aircraft
```

Figure 3 Pseudo-code algorithm used for hypothesis testing

3 Results and discussion

As a result of processing the data, the user receives a list of aircraft that can operate on LPVZ, and a list of possible airports that can function as a destination is also provided. As an example, the algorithm was used with the following inputs for Viseu Aerodrome: PCN: 23; Runway length: 1800 m. The results after processing can be seen in Figure 4.

```
Aircrafts served: ['Dornier_228' 'DCH-8_Q200' 'ATR42-600' 'ATR72-600' 'CRJ200']
Routes served: ['EBBR' 'EBCI' 'EDDB' 'EDDK' 'EDDL' 'EDDM' 'EDDN' 'EDDP' 'EDDS' 'EDDT'
 'EDDV' 'EDDW' 'EDFH' 'EDLW' 'EHAM' 'EHEH' 'EHRD' 'EKCH' 'ELLX' 'ENBR'
 'EPGD' 'EPKK' 'EPKT' 'ESGG' 'GCFV' 'GCLP' 'GCRR' 'GCTS' 'GCXO' 'GEML'
 'LEAL' 'LEAM' 'LEAS' 'LEBB' 'LEBL' 'LECO' 'LEGE' 'LEGR' 'LEIB' 'LEJR'
 'LELC' 'LEMD' 'LEMG' 'LEMH' 'LEMO' 'LERS' 'LESO' 'LEST' 'LEVC' 'LEVX'
 'LEXJ' 'LEZG' 'LFBD' 'LFBO' 'LFLL' 'LFML' 'LFMN' 'LFOB' 'LFPG' 'LFPO'
 'LFRS' 'LFSB' 'LHBP' 'LIBD' 'LICA' 'LICC' 'LICJ' 'LIEE' 'LIEO' 'LIMC'
 'LIME' 'LIMF' 'LIML' 'LIPE' 'LIPX' 'LIRN' 'LIRP' 'LIRQ' 'LKPR' 'LMML'
 'LOWW' 'LPAZ' 'LPBJ' 'LPBR' 'LPCS' 'LPEV' 'LPFR' 'LPGR' 'LPHR' 'LPLA'
 'LPPD' 'LPPI' 'LPPM' 'LPPR' 'LPPS' 'LPPT' 'LPVR' 'LPVZ' 'LSGG' 'LSZH'
 'LEPA' 'LPMA' 'LPCB' 'LPSO']
```

Figure 4 Results of the data processing algorithm

The results presented show the aircraft that can operate at LPVZ. ICAO codes are also reported for all airports within the Schengen area that can serve as a route for these aircraft. The name of each airport which corresponds to each ICAO code can be seen in [10]. An essential part of data analysis is the visualization of results. At this time, the data has been processed, and there are already valid results. However, an essential part of data analysis is the visualization of results. Thus, GIS data [11; 13] were used as a base map, on which layer the possible airports are plotted, and the countries served are highlighted (Figure 5).

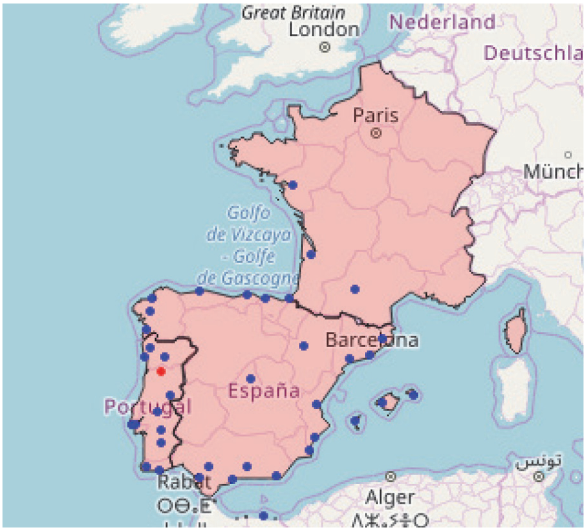

Figure 5 Results for PCN 6, and 1160 meters runway length

In this scenario, the Viseu Aerodrome (red point) maintains the pavement with PCN 6 and a runway length of 1160 m (current situation of the LPVZ infrastructure). In this situation, it was possible to serve mainland Portugal, Spain, and a portion of southern France (airports served in blue). However, the operation was limited to small aircraft of up to 20 passengers. Two other scenarios were also created, an intermediate (PCN 23 and runway length of 1800 m); and a more robust scenario (PCN 83 and runway length 2500 m). In the intermediate scenario, it was possible to serve a large part of the Schengen area with aircraft of up to 70 passengers. For the robust scenario, the entire Schengen space was served, with aircraft of up to 200 passengers. All three scenarios can be seen in Figure 6.

Therefore, based on two simple parameters, such as PCN and runway length, it was possible to visualize the coverage of an airport. This shows that the procedure developed for data analysis has the ability to provide information to decision makers.

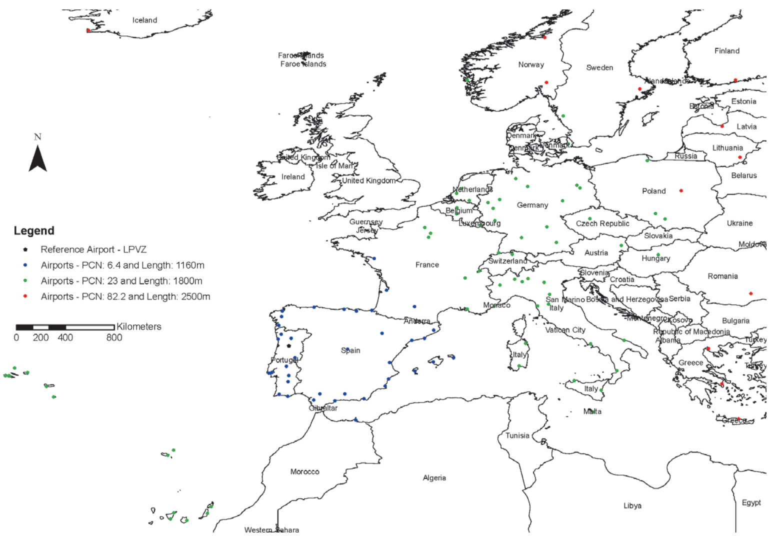

Figure 6 Results with three analysed scenarios (full resolution image)

4 Conclusions

This entire research was developed based on a problem, which is the need for the Aerodrome of Viseu to operate larger aircraft. In this sense, it is necessary to reinforce the pavement structure and increase the length of the runway. As a result, we have the following results: maintaining the current characteristics of the Viseu Aerodrome runway pavement, PCN 6 and runway length of 1160 meters, it was possible to serve mainland Portugal, Spain and southern France. Nevertheless, the aircraft in operation is limited to the use of the Dornier 228, which carries only 19 passengers. Likewise, with PCN 23 and runway length of 1800 meters, the Schengen space is almost served. However, it is limited to the use of aircrafts with higher operating costs per passenger, such as CRJ200 and ATR72-600 (these aircrafts carry between 50-70 passengers). Finally, with PCN 83 and runway length of 2500 meters, little coverage is obtained compared to the previous scenario, but larger aircraft (up to 200 passengers) can be used, with best cost/passenger ratio. For example, the low-cost airline Ryanair only operates B737-800 aircraft within these parameters. Having presented the three best scenarios, the next step is a business decision, which will be supported by the data analysis carried out in this research. Finally, in this research it was demonstrated that data analysis can be a great ally for engineers and that computational tools have evolved in this direction every day. Putting all hype aside, it is clear that data analysis can help us make better engineering decisions.

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