A Comparative Study between ILS and GBAS Approaches: The Case of Viseu Airfield

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Abstract

Purpose: The article aims to show a comparative study between two precision approach systems and check the viability of installing one of them in a specific regional airfield, using Viseu airfield, in Portugal, as a case study. This work looks to evidence to what extent the implementation of ILS (Instrument Landing System) or GBAS (Ground Based Augmentation System) in these types of airfields is viable, and how to choose between them for this case, from a technical and economic view and as a way to increase safety levels.

Design/methodology: The article analyses the airfield’s evolution over time and forecasts its movements for the future, over a 6-year period, by utilising IATA traffic forecast models. The different types of airfield taxes were reviewed and their values were estimated for the following years. The equipment's technical aspects and individual prices were compared and analysed to accurately determine the time needed for the airfield to recover the investment done, allied with 80% funding from a European investment project.

Findings: Approach systems are being modernized, and throughout the years more airports and airfields are starting to replace old approach systems for satellite-based new ones. When compared to ILS, GBAS offers more advantages at a technical and economic level, and even for smaller airfields with a low traffic volume, sometimes it can be technically and economically possible to have such systems implemented.

Originality/value: Studies about the implementation of new radio aids are usually prepared for big airports by airport operators or ANSPs before major investment projects. However, for most small regional airports in the country, where traffic is not near as big, such studies don’t exist, and for that reason, investigating the possibility of installing such kind of equipment is
very important, especially taking into consideration the safety they provide and other benefits that naturally come up with it. Knowing which system performs the best and at what cost is extremely valuable when installing a new approach system.

Keywords: Regional airfield, regional development, radio aids, approach systems, ILS, GBAS, safety

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1. Introduction

Despite all the efforts made by various institutions towards aeronautical safety, accidents and incidents are likely to happen at any time and under any circumstance. At a commercial level, and according to statistics from Airbus and Boeing, around half of these accidents occur during the approach and landing phases (Airbus S.A.S., 2020; Boeing, 2019). Radio aids were developed to provide pilots increased safety during flight, being requisite in modern aviation. Inside this equipment, we can find the approach systems, which operate in the approaching and landing phases of flight.

Regional airfields take a very important role in the aviation industry. Despite primarily serving short and medium-range routes inside a country, they're essential at working as congestion relievers to other nearby airports with heavy traffic. The search for regional airports and airfields has been significantly increasing over the last few decades. A 173% growth in passengers has been registered from 1993 to 2015 in European regional airports (ACI, 2017). By 2017, global traffic surpassed the 8.2 billion mark and WATF (World Airport Traffic Forecasts) studies expect this number to double by 2034, based on a projected growth of 4.3% per year (ACI, 2018). In the case of Portugal, regional air transportation isn't so significant when compared to the global scene, however, the growth is still verified, and the airfields’ importance to the development of their regions is inevitable.

2. Approach Systems

Approach systems were developed with the main objective of increasing the safety indices in the approaching and landing phases of flight, reducing the risks inherent to its complexity. These systems can be divided into precision (course guidance and glidepath provided) and non-precision (only course guidance provided). As mitigation against CFIT (Controlled Flight into Terrain) on approach to landing, APV (Approach Procedure with Vertical guidance) systems were also adopted. Despite utilising lateral and vertical guidance, these systems don’t meet the ICAO (International Civil Aviation Organization) and FAA (Federal Aviation Administration) precision approach definitions, which apply mostly to localizer and glideslope transmitters (Administration, 2017). The most recent classification method utilised since 2017 is shown in Figure 1.

Precision approach and landing operations are instrument approaches using lateral and vertical guidance with minima as determined by the category of operation. Lateral and vertical guidance can be provided either by a ground-based navigation aid or a computer-generated navigation data (ICAO, 2018a).

These systems, just like other precision-based ones, can be divided into different categories, as shown in Table 1.
Figure 1. ICAO approach classification model (ICAO, Eurocontrol, & EASA, 2017)

| Category of Operation | Decision Height [ft] | Runway Visual Range [m] |
|-----------------------|----------------------|-------------------------|
| CAT I                 | 200                  | >550                    |
| CAT II                | 100-200              | >300                    |
| CAT III A             | 0-100                | >175                    |
| CAT III B             | 0-50                 | 50-175                  |
| CAT III C             | 0                    | 0                       |

Table 1. Precision approach categories (IVAO, 2017)

From the aerodrome's perspective, CAT II and CAT III instrument approaches should not be authorized unless RVR information is provided (ICAO, 2018a).

CAT III C takes place in no DH (Decision Height and RVR (Runway Visual Range) conditions, meaning that an aircraft can approach and land under non-visual conditions. This reason, along with the difficulty of ground manoeuvring after landing, makes this category not operational and rarely used in most airports (IVAO, 2017; Skybrary, 2014). For this work, only precision-based approaches are going to be studied: the conventional procedure ILS and GLS (GBAS Landing System), both for CAT I operations.

3. Case Study

The article leans over Viseu airfield, in Portugal. Just like many of the airfields in the country, Viseu airfield plays a very important role in the development of its region, located in the north-centre side of the country. It takes part in a regional air transportation network that connects the city of Bragança to Portimão every day and 6 days per week, performed by SevenAir. The airfield holds its own Aeroclub, as well as firefighting and health care services for its region. A training centre to produce commercial pilots, as well as cabin assistants and maintenance technicians have also just got installed. For these and many other reasons, it is considered one of the most important airport infrastructures in the country, following the international airports of Oporto, Lisbon, and Faro. An example of its verified growth can be observed in Figure 2.

The movement’s increase since 2014 is very significant. From 2016 on, they have stabilized with the only annual decrease being verified in 2018, which is explained by the really bad weather conditions in that year, preventing a lot of aircraft from landing safely. In 2019, and as expected, the movements increased again, surpassing the values of the previous year. A survey delivered to local companies also showed that the majority agreed on the importance of the airfield for them and the region, at a business level. In the following subsection, a prediction
forecast for the airfield movements in future years was performed, by using a forecast model and IATA (International Air Transport Association) data.

3.1. Forecast Method

To predict the airfield movements’ evolution for the following years, a forecast model was used. It was about reviewing IATA forecasts and applying its percentage annual growth to the airfield. For this method, only the number of movements from the years 2016, 2017, 2018 and 2019 were utilised, taking into consideration the huge discrepancy with the previous two years where the air traffic in the aerodrome was very scarce. The model is shown next.

- IATA forecast

It is easily observed that the number of movements is expected to increase in the following years, hovering close to 14000 movements, 5 years from now.

However, during the Covid-19 pandemic, which we all are part of, IATA traffic forecasts for airports and regional airports point to a significant decrease of over 56%, from 2019 to 2020 and look at 2024 as the year where the air traffic will finally resume the previous pre-Covid-19 numbers (IATA, 2020), considering the best possible scenario (if a vaccine is made available in 2021), as can be seen in Figure 4.
4. ILS vs GBAS

4.1. Technical analysis

The first system considered was an ILS. The needed equipment consists of a localizer (for lateral guidance) and a glideslope (for vertical guidance). An ILS receiver in the aircraft is also essential. For Viseu airfield, knowing that one ILS installation for each of the two runways wouldn’t be efficient, the preferential choice for this case would be runway 36, because there aren’t any obstacles near. The same principle applies to other similar airfields (ICAO, 2018).

The second system analysed was a GBAS. The equipment needed for this system consists of 2 to 4 GNSS (Global Navigation Satellite System) reference receivers and their respective geographically separated antennas; a VHF (Very High Frequency) data broadcast transmitter, a monitor system, approach database, and ground processing functions. For the inboard equipment, the essential elements are an Aircraft GNSS receiver function, a VHF data broadcast receiver function, and an aircraft navigation processing function (ICAO, 2013).

It is also important to note that the introduction of GNSS-based operations will allow the decommissioning of some traditional navigation aids, as seen in Figure 5.

Both systems have specific technical characteristics and operation capabilities. These characteristics are described next, for each system (Böck & Schubert, 2015; Guenter & Dennis, 2015; Guillet, 2019; ICAO, 2020; Reines, 2015).
Instrument Landing System:

- Each runway requires an ILS and a frequency assignment for that ILS, which can be a problem due to the limited numbers of available frequencies;
- Only permits one single user per approach;
- Beam bends caused by reflective interference (from buildings and vehicles) produce noise in the guidance signal and may affect the approach procedure;
- Siting requires level ground and clear areas on the runway;
- Higher size of critical protection areas;
- Existence of critical areas.

Ground Based Augmentation System:

- Approach and takeoff guidance procedures to multiple runways from a single GBAS facility, with the same VHF frequency, leading to a more efficient use of the frequency spectrum and more GBAS channels for each approach;
- Multiple and more flexible approaches from a single ground station - multiple glide slopes, thresholds, and offsets can lead to a shorter final approach, reducing flying time and fuel consumption and thus reducing environmental impact;
- More stable approach, (much less noise in the guidance signal due to the inexistence of beam bends);
- More flexible and simpler siting, since GBAS receivers do not need to be placed near a runway in a specific geometry, providing more flexible taxiway or hold line placement choices;
- Reduced size of critical protection areas, optimizing runway use;
- Inexistence of critical areas, virtually eliminating the requirements for critical protection areas against signal interference.

In addition to ILS, GBAS can also:

- Provide an alternate GNSS precision landing system, reducing the number of flights disruptions in a terminal area and weather delays;
- Provide precision approach procedures and improve capacity at airports unable to have precision approaches due to ILS siting constraints.

The reduction of the operational impact of critical and sensitive areas is probably the most important factor, allowing not only to increase an airport operational capability but also to reduce possible risks of accidents in these areas (ICAO, 2013). In some ILS scenarios, meeting the restrictions of the equipment obstruction criteria may not be sufficient to protect the system from multipath effects caused by large, fixed ground structures (ICAO, 2012). The main disadvantage of GBAS is its full dependence on GPS, where some unwanted interferences in the signal could end up disabling the whole system, and possibly the runways of an airport.

After comparing both systems, when it comes to safety, GBAS is no doubt the best option. The benefits of a GBAS performance, especially in safety terms, as well as its compliance with ICAO manuals, can't be overlooked and make this system the preferable choice, knowing also that from a pilot perspective, flying a GLS is basically the same as flying an ILS. The procedure, displays, and warnings are all the same, keeping GLS training to a minimum. The only situations where ILS should be chosen over a GBAS CAT I system are in airfields with a high traffic volume, where the meteorological conditions are so bad that it would justify an ILS CAT II installation, or at places where the GNNS signal is very unstable and thus the safety risks would not justify the
implementation of GBAS since it is dependent on the satellites that are part of the space segment of the system. For this case, ILS should be installed since it is an autonomous system.

Another option and the most effective one from a safety point of view would be the joint of both systems: ILS and GBAS, which we can already find in some airports since most moderns aircraft can easily operate with both systems simultaneously. Although this would be the desired choice for any airport or airfield, for most regional airports it would be too expensive, and for that reason, the joint cost of both types of equipment wasn’t analysed.

**Reported incidents from the use of the systems**

As we are aware, nothing is 100% safe. The same happens in aviation. Even though systems are being created and updated every year, failures are bound to happen at any time. It is known that about half of all aeronautical incidents are due to human factors, and in this kind of approaches, human judgment takes a huge part in all the reported incidents, happening a lot more often in ILS approaches when compared to the newly GLS approaches, where accidents are close to non-existent.

One of the most recent incidents involving instrument approaches was the flight Air India AI 101 (from Delhi to New York), in September 2018, where all three ILS receivers in the aircraft (Boeing 777-300) malfunctioned as well as two altimeters, meaning that the pilot had to manually land the aircraft in a nearby airport with better visibility conditions (Times, 2018). Another incident occurred in 2008: A Delta Connection flight 6448, an Embraer ERJ-170 landing at Cleveland-Hopkins International Airport struck the airport’s perimeters fence. The flight crewmembers executed the approach to ILS minimums, even though they were advised that the glideslope was unusable and for that reason, they should have accomplished the approach to localizer minimums (Board, 2008).

After analysing these and a lot of other incidents, it’s safe to say that most of the incident reports happen during ILS approaches with failures in inboard equipment and not in the ground facilities at the airports. The flight crew judgment also takes a huge part in avoiding those incidents, especially when flying at the equipment's approach minimums. The absence of GBAS reported incidents also contribute to making this system look like the best option in safety terms, even though a heavy majority of incidents during ILS approaches can't be attributed to the equipment but rather to human error.

**4.2. Economic analysis**

| Type                          | Taxes       |
|-------------------------------|-------------|
| Day/ton                       | 12,38€      |
| Night/ton                     | 18,46€      |
| Parking (>2hours)             |             |
| Inside Platform               | 11,73€      |
| Outside Platform              | 6,52€       |
| For services offered (luggage)| 0,87€       |

Table 2. Airfield charged fees

For this case, the economic study was based on analysing the past and the current number of movements in the aerodrome and to estimate its corresponding taxes for the following years. Considering that 60% of all the movements in the airfield were paying the fixed taxes values, presented in Table 2, it was determined an average cost of 7,62€ per movement. Parking, night movements, and luggage taxes weren’t considered, given their very low amount.

After the installation of the equipment, the taxes were estimated to increase by 15%. Thus, Figure 6 was obtained.
By summing up the values obtained after the installation from 2021 to 2026, a total value of 401 429,30 € from the taxes was estimated, as depicted in Table 3.

| Year | Total Movements | Paying Movements (60%) | Taxes [€] | Total (cumulative) [€] |
|------|-----------------|------------------------|----------|------------------------|
| 2021 | 11574           | 6944                   | 60831,01 | 60831,01               |
| 2022 | 12025           | 7215                   | 63203,42 | 124034,43              |
| 2023 | 12494           | 7496                   | 65668,35 | 189 702,78             |
| 2024 | 12981           | 7789                   | 68229,42 | 257 932,19             |
| 2025 | 13423           | 8054                   | 70549,22 | 328 481,41             |
| 2026 | 13879           | 8327                   | 72947,89 | 401 429,30             |

Table 3. Total taxes value after equipment installation

After estimating the total revenue from the charged fees in the airfield, ILS, and GBAS equipment costs were analysed, as shown in Table 4.

| ILS CAT I installation costs | Price [€] | GBAS Cat I Installation costs | Price [€] |
|------------------------------|----------|--------------------------------|----------|
| DME and ILS CAT I infrastructure | 336 000 | Infrastructure              | 500 000 |
| Installation and commissioning | 175 000 | Installation and commissioning | 120 000 |
| Civil works                   | 195 000 | Civil works                  | 44 000  |
| Calibration                   | 30 000  | Initial flight certification | 30 000  |
| Operation costs (per year)    | 79 000  | Operating costs (per year)    | 43 000  |

Table 4. ILS and GBAS associated costs (Ferreira Esteves, 2007; Džunda, Dzurovcin & Ondruš, 2019; Kraemer, 2013; Reines, 2015; Xiao, 2008)

By analysing the table, we can notice that the equipment acquisition cost of ILS is slightly higher than GBAS (only the GBAS infrastructure cost is higher than ILS). However, the biggest difference is in the operation (maintenance) costs. ILS operation costs are very high every year when compared to GBAS. By calculating, it is easily noticed that a GLS is more cost-efficient than ILS, saving up to 42000€ in the equipment acquisition and...
402 000€ over 10 years. For that reason, and in economic terms, GBAS should always be chosen over ILS, if the conditions are available.

It was also previously seen that technically, GBAS offers more solutions and better performance in comparison to ILS. Knowing this, and applying the reduced costs of GBAS for the context of Viseu airfield where a European investment project could fund 80% of the costs, Table 5 was elaborated.

| GBAS CAT I | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 |
|------------|------|------|------|------|------|------|
| Equipment cost [€] | 694 000 | - | - | - | - | - |
| Equipment cost with 80% fund [€] | 138 800 | - | - | - | - | - |
| Operation costs [€] | 43 000 | 43 000 | 43 000 | 43 000 | 43 000 | 43 000 |
| Revenue [€] | 60 831,01 | 63 203,42 | 65 668,35 | 68 229,42 | 70 549,22 | 72 947,89 |
| Balance [€] | -120 968,99 | -100 765,57 | -78 097,22 | -52 867,80 | -25 318,58 | +4529,31 |

Table 5. Breakeven point (with 80% fund)

For this case, the revenue is directly related to the total capital obtained from the charged fees in the airfield, every year. When the balance reaches a positive value (in the year 2026), that's when the equipment is fully paid, and the airfield begins profiting from its installation.

Even after all this analysis, there is always the possibility of a system failure, caused by the loss of functionality of the satellite navigation system which would make the airfield not operational for this kind of approaches and would obviously lead to economic losses, delaying the payback period of the system since aircraft wouldn't be able to safely land in the airfield. However, GBAS approaches would only be necessary when pilots can't perform a visual approach to the runway, in bad weather and meteorological conditions. These conditions usually happen in the winter (Böck & Schubert, 2015), so we would have to analyse the probability of a GNSS failure during that period of the year. Exact values for these economic losses are very hard to obtain since they would also depend on the pilot's ability on whether or not they feel comfortable to perform the landing in non-ideal conditions and without any backup from navigation systems. Despite being hard to take into consideration these situations and thus to evaluate possible economic losses from it, deeper and more detailed studies on this matter should always include this possibility and try to obtain the most objective data for the number of movements available and which of them would require instrument landing procedures.

5. Conclusion

The article aims to show a comparison between two different precision-approach systems and how to choose between them to analyse the viability of its implementation in a regional airport, using Viseu airfield as a case study. The two systems analysed for this case were ILS and GBAS. As can be seen from the studies, a GBAS landing system would bring the most advantages in comparison to traditional ILS.
From a technical point of view, not only is it simpler to install but also more practical, since one single GBAS station can support multiple runways ends, allowing for more simultaneous approaches and reducing the number of systems in the airfield. For airfields that are already using GNSS procedures to approach and landing, a GBAS installation would highly increase the precision obtained in these flight phases, especially in bad weather conditions. The equipment can be easily upgraded to a CAT II/III system, which may be required and very useful for some airfields in future times. It is also expected that approach and landing systems will increasingly move to GNSS-based landing to improve airport accessibility either in CAT I conditions or CAT II/III conditions.

In economic terms, a GBAS installation also ends up as the better option in comparison with ILS, with lower equipment and operating costs. Not only this but also possible modifications to permit CAT II/III operations wouldn't increase the operating costs in the GBAS facility, as opposed to ILS. For this case, and knowing that a European investment project can fund around 80% of the equipment cost and estimating the revenue from the airfield taxes after the equipment implementation, it was determined a 6-year investment recovery forecast, from the installation of a GBAS.

Overall, a GBAS landing system looks like the better option for a precision-based equipment in these phases of flight, offering better solutions and performance at a lower cost compared to the other alternatives like ILS. There are very few situations where ILS should be chosen over GBAS, and if the GNSS signal coverage in the area is good, there shouldn't be any reason to not install a GBAS over an ILS, since the economic costs are always lower, both for short and long-time periods.

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