HEDGE: Helicopters Deploy GNSS in Europe

Financial benefit assessment

Implementing APV SBAS (LPV) at Katowice

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SEVENTH FRAMEWORK PROGRAMME

European GNSS Supervisory Authority

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DOCUMENT CHANGE RECORD

The following table gives the history of the successive editions of the present document.

EDITION	DATE	REASON FOR CHANGE	PAGES AFFECTED
0.1	19/08/10	Document outline	All
0.5	19/08/10	Initial draft for internal comment	All
0.6	26/10/10	Initial draft for stakeholder comment	All
0.7	10/11/10	Addition of the Executive Summary	pgs 2, 3

EXECUTIVE SUMMARY

This paper presents a financial benefit assessment of the introduction of APV SBAS (LPV) approach procedures at Katowice airport in Poland. The runway at Katowice has an ILS approach at one end (RWY27) and NDB based approach procedures to both runway ends (RWY27 and RWY09).

The analysis provides an assessment of the impact of new APV SBAS (LPV) procedures to reduce the number of disrupted movements at the airfield by examining the impact of meteorological conditions on approach operations. APV SBAS (LPV) allow operations in lower visibility than non-precision approaches such as those based on NDB. So in some meteorological conditions, using APV SBAS (LPV) approach procedures would allow continued operations at Katowice where using NDB would not.

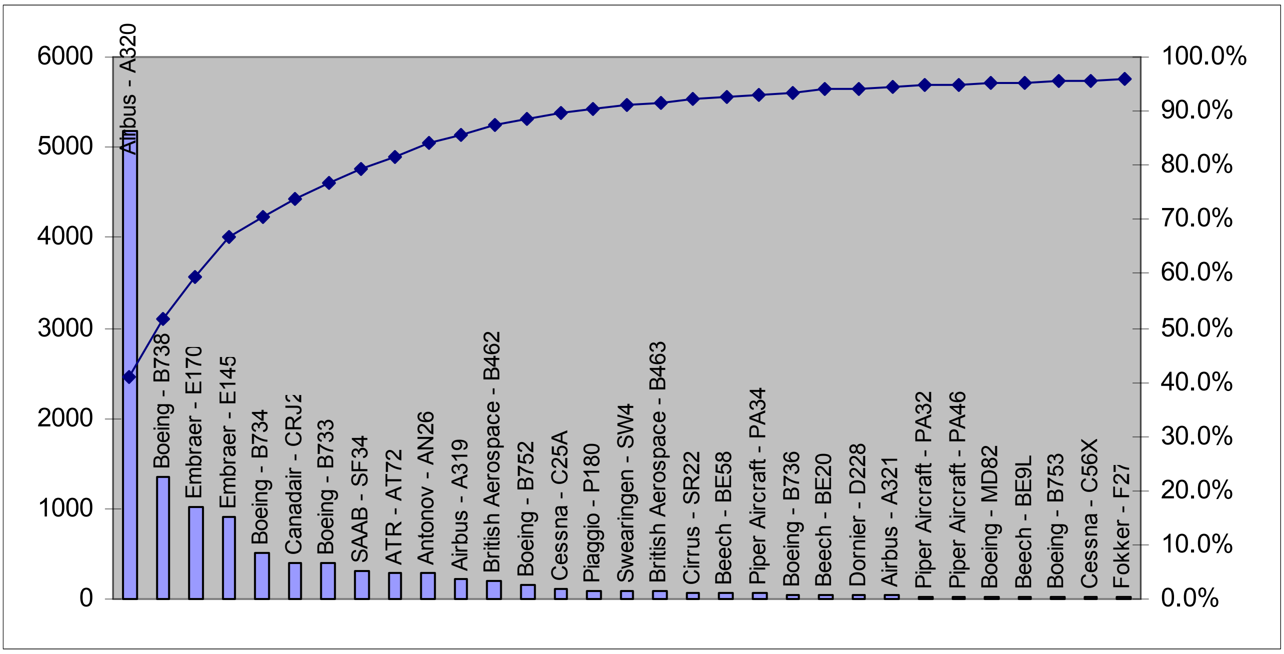
The study:

1. examined the planned aircraft movements for the year 2009;
2. examined the historical meteorological data for the year 2009;
3. correlated each planned aircraft movement against the corresponding meteorological conditions at the time;
4. determined whether the available minima at the aerodrome meet the prevailing limits for visibility, cloud base and tail wind for each movement.

To examine the level of benefit the following scenarios were defined:

1. Baseline: Considered the current implementations as available today;
2. Scenario 1: Considered the introduction of an APV SBAS (LPV) approach to the ILS runway end (RWY27);
3. Scenario 2: Considered the introduction of an APV SBAS (LPV) approach to the non-ILS runway end (RWY09).

The analysis showed that aircraft movements were predominantly by western-manufactured aircraft where aircraft types with more than 20 movements per year accounted for approximately 96% of all IFR movements. This is illustrated in the following figure which compares the number of movements per aircraft type to the cumulative percentage of arrival movements.



Distribution of arrival traffic for types with >20 landings vs contribution to total IFR arrivals

Analysis of the meteorological data provided an estimation of the probability of a disruption of an arrival movement due either to wind direction and strength, cloud base or visibility. This was performed on a quarterly basis split as follows:

- Q1: winter season, including December, January, February;
- Q2: spring season, including March, April, May;
- Q3: summer season, including June, July, August;
- Q4: autumn season, including September, October and November.

This analysis confirmed the choice of RWY27 as the primary runway due to the prevailing wind conditions. The analysis further showed that the disruptions at either runway end increased during the winter months (Q1). However, compared to the baseline, the minima available through either Scenario 1 or 2 reduce the number of likely disruptions. For 2009, the estimated number of disruptions avoided compared to the baseline is summarised as follows.

	Scenario 1	Scenario 2
Q1	1.2	49.8
Q2	0.2	17.7
Q3	0.2	7.1
Q4	0.6	21.3
Total	**2.2**	**96.0**

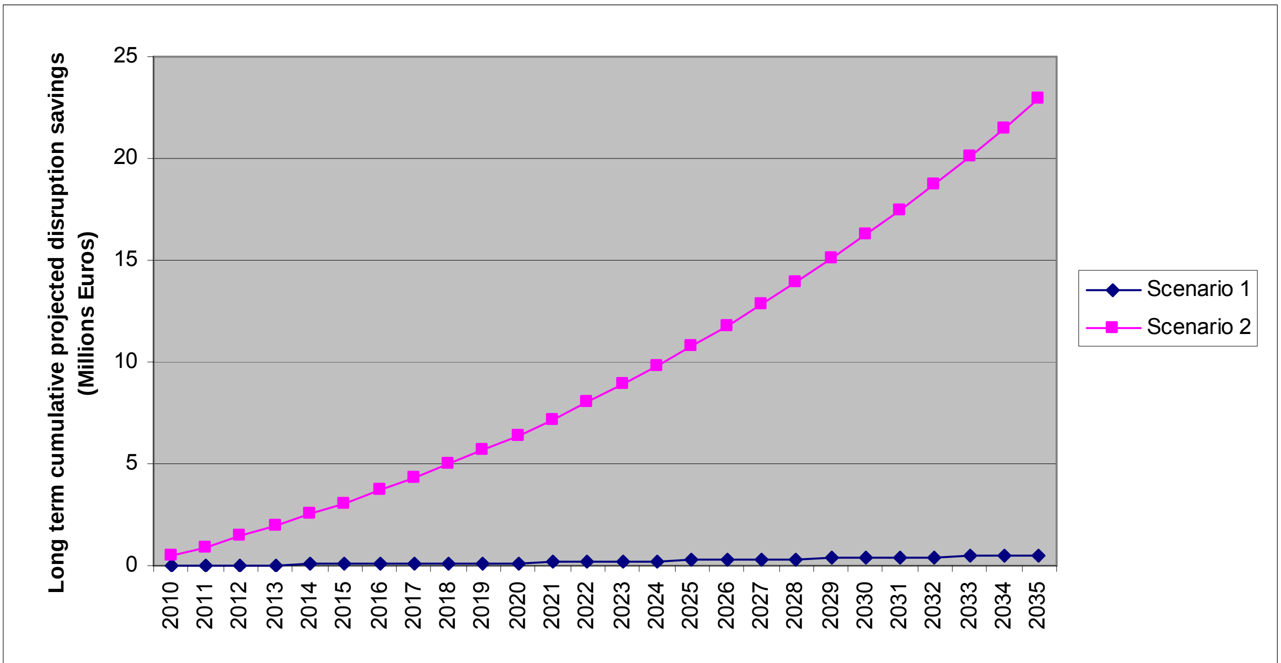
Estimated average avoided disruptions for scenarios compared to baseline

The significant difference between the two scenarios was expected as under Scenario 1 the ILS minima is the lowest available. Any disruptions under Scenario 1 would result from the ILS being unavailable for approach due to either equipment failure or meteorological limitations. Using EUROCONTROL cost benefit analysis standard input data, the cost per disruption was estimated at approximately € 4 660. This translates into an annual benefit compared to the baseline of € 446 000 under Scenario 2 as shown in the following table.

	Scenario 1	Scenario 2
Q1	€ 5,000	€ 232,000
Q2	€ 1,000	€ 82,000
Q3	€ -	€ 33,000
Q4	€ 2,000	€ 99,000
Total	**€ 8,000**	**€ 446,000**

Estimated average savings for scenarios compared to baseline

Using available traffic growth forecasts, the analysis was then extended to cover the short, mid and long term. The following chart illustrates the expected level of benefit from Scenarios 1 and 2 out to the year 2035.



Cumulative avoided disruption savings per scenario compared to the baseline over a 25 year period (not discounted)

This financial benefit assessment has therefore shown a clear benefit of implementing an APV SBAS (LPV) approach to both runway ends. For Scenario 2 there is an annual saving of approximately € 446,000 from avoided disruptions and, taking into account traffic growth, the cumulative estimated disruption saving up to 2014 is approximately € 2.5M and in the 25 year period € 22M. This contrasts markedly with Scenario 1 where the annual benefit is approximately € 8,000, up to 2014 € 57,000 and in the 25 year period € 522,000. The difference between the two scenarios quite clearly illustrates the significant incremental benefits between providing APV SBAS (LPV) minima as a backup to an ILS approach (as in Scenario 1) or as an alternative to an NDB approach (as in Scenario 2) – which has larger benefits due to lower than NDB operational minima.

This financial benefit assessment provides aircraft operators the basis from which to develop a complete business case that takes into account their aircraft equipage capabilities and the potential network benefits of utilising APV SBAS (LPV) procedures at other aerodromes.

Likewise, for the airport operator this report provides the basis from which to undertake a more detailed analysis on the costs benefit case for the implementation of one or more procedures in line with the recommendations from ICAO for the replacement of NPA approaches. Indicative costs associated with the implementation of the procedures proposed in the scenarios within this report are also provided.

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1 INTRODUCTION

1.1 General

This document is a deliverable prepared under Work Package 1 (Common Developments) of the HEDGE project. The report is prepared by Helios and presents a financial impact assessment of the implementation of APV SBAS procedures at Katowice airport in Poland.

1.2 Background

Helicopters Deploy GNSS in Europe (HEDGE) is a project commissioned by the European GNSS Supervisory Authority (GSA) and part-funded under the EU's Seventh Framework Programme. The aim of the project is to develop and demonstrate new helicopter procedures as well as other EGNOS applications for general aviation.

The APV SBAS procedures provide an appreciable benefit to the low visibility operations of general aviation users. A TEN-T project being supervised by Eurocontrol has focused on the implementation of a procedure at Mielec. In tandem with this, HEDGE has developed and will be trialling the APV SBAS (LPV) procedures at Katowice. The trial will be an operational trial using the EGNOS MT2 signal when available.

1.3 Objectives and scope

HEDGE addresses three types IAPs:

- Approach procedure with vertical guidance provided by SBAS (APV SBAS);
- Point-in-Space with vertical guidance provided by SBAS (Pins);
- SBAS Offshore Approach Procedure (SOAP).

The objective of this document is to perform a financial impact assessment of the implementation of the APV SBAS (LPV) procedures at Mielec. It provides an indication of the possible benefits that could be accrued by aircraft operators at an aerodrome.

1.4 Document structure

This initial safety assessment is structured as follows:

- Section 2 contains the document references;
- Section 3 presents a list of the acronyms used;
- Section 4 discusses the operations and current implementation at Katowice;
- Section 5 presents the analysis of the financial impact of the APV SBAS (LPV) procedures at Katowice;
- Section 6 presents a summary of the financial impact assessment

2 REFERENCES

The following table shows the associated documentation referenced in this document.

#	Title	Reference	Issue	Date
[1]	Business Case: Implementation of LPV approaches in Mielec AD - EGNOS Introduction in European Eastern Region	Mielec TEN-T project	V2.0	06/08/2010
[2]	RNAV Approach Benefits Analysis – Final Report	P723D003	V2.0	16/02/2009
[3]	The development of the infrastructure of air navigation services agency	Study for PANSA by Ernst & Young and Helios	V1.0	2010

Table 2-1: Associated documentation

3 ABBREVIATIONS AND ACRONYMS

The following table shows the abbreviations and acronyms used in this document.

Acronym	Meaning
APV	APproach with Vertical guidance
SOAP	SBAS Offshore Approach Procedure
HEDGE	HElicopters Deploy GNSS in Europe
GSA	GNSS Supervisory Authority
PinS	Point-in-Space
CBA	Cost Benefit Analysis
TEN-T	Trans-European Transport Network
EU	European Union
LPV	Localiser Performance Vertical
MET	Meteorological
RWY	Runway
IFR	Instrument Flight Rules
VFR	Visual Flight Rules
ILS	Instrument Landing Systems
DME	Distance Measureing Equipment
VOR	VHF Omni-directional Radio
NDB	Non-Directional Beacon
OCH/A	Obstacle Clearance Height / Altitude
AIP	Aeronautical Information Publication
LOC	Localiser
LNAV	Lateral Navigation
PANSA	Polish Air Navigation Services Authority
METAR	MÉTéorologique Aviation Régulière (Aviation routine weather observation message)
DH / DA	Decision Height / Altitude
MDH / MDA	Minimum Descent Height / Altitude
NOAA	National Oceanic and Atmospheric Administration
ICAO	International Civil Aviation Organisation
SWY	Stopway
TODA	Take Off Distance Available
TORA	Take Off Run Available
ASDA	Accelerated Stop Distance Available

Acronym	Meaning
LDA	Landing Distance Available
GEO	Geometric (True) (of bearing)
MAG	Magnetic (of bearing)
BRG	Bearing (of track)
ATC	Air Traffic Control

Table 3-1: Abbreviations and Acronyms

4 KATOWICE OPERATIONS

4.1 General

This section describes the operations and capabilities at Katowice. This is the baseline supporting infrastructure within which any new APV SBAS (LPV) procedure will be operated.

4.2 Geographical location

Katowice is a city located within the Silesian metropolitan area in the south of Poland. As of December 2008, this region had one of joint highest population density in Poland of >170 persons per square kilometre[1], the total population of the Silesian metropolitan area being approximately 4.7 million. It is known as a centre of science, culture, industry, business and transportation. It is the seat of the Katowice Special Economic Zone (Katowicka Specjalna Strefa Ekonomiczna).

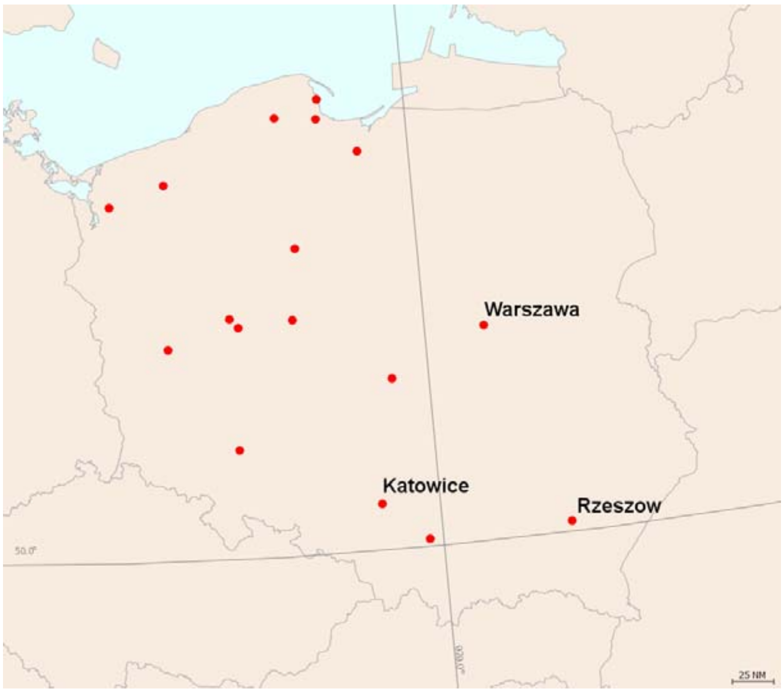

Figure 4-1: Location of Katowice relative to other aerodromes within Poland

4.3 Traffic statistics

In 2009, Katowice airport was the fourth busiest airport in Poland with a total of 25,324 movements consisting of 12,680 arrivals and 12,644 departures. Since the introduction of the APV SBAS (LPV) affects arriving traffic, these are further broken down as illustrated in the following table:

[1] http://www.stat.gov.pl/cps/rde/xbcr/gus/PUBL_demographic_yearbook_2009.pdf

Number of arrivals	Flown under flight rules
12509	IFR
58	VFR
17	IFR and then VFR
96	VFR and then IFR

Table 4-1: Arrival statistics at EPKT

These statistics show that the majority of the operations were IFR operations: 99.4% IFR compared to 0.6% VFR. This is quite clearly indicated in a hourly block assessment as shown by Figure 4-2.

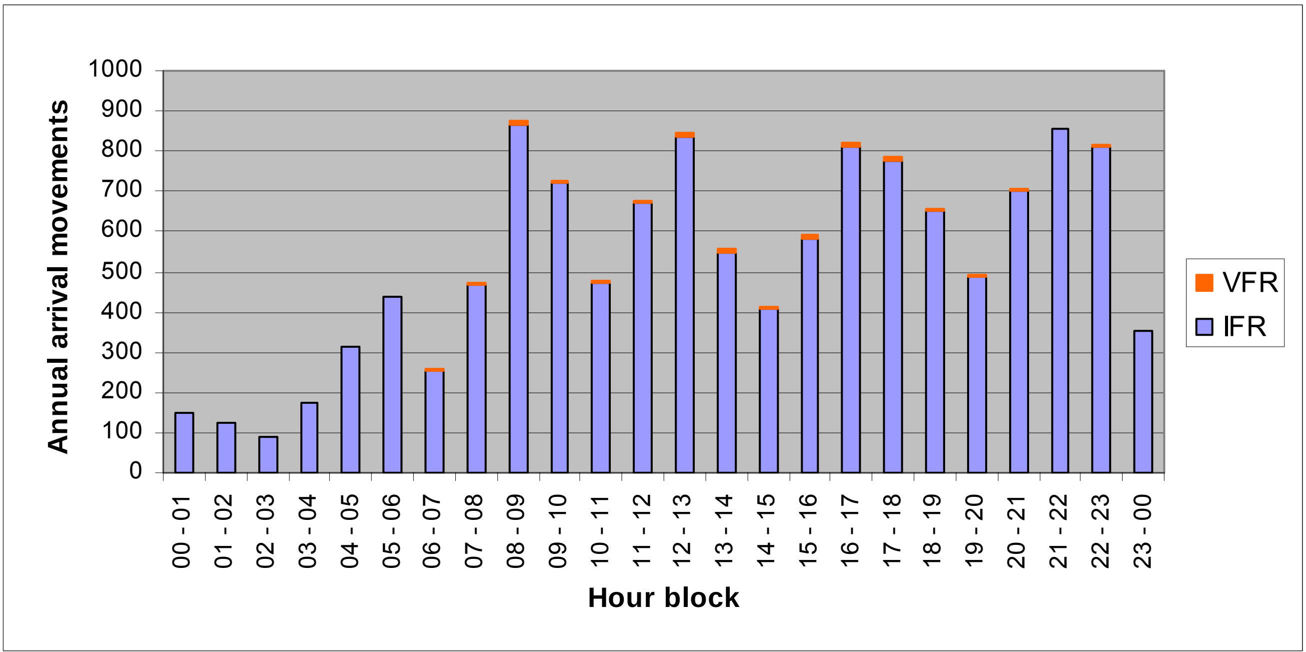

Figure 4-2: IFR and VFR arrival movements by hour

Comparing the size of traffic it is found that 94.6% of the traffic is classified as CS25 with 5.4% classified as CS23[2]. Breaking this down to aircraft types, the majority of the arrival traffic comes from western type aircraft characterised primarily by the Airbus A320, Boeing B737 and Embraer families. Ignoring aircraft types that had fewer than 20 landings throughout the year, the following graph illustrates the distribution.

[2] CS25 and CS23 refer to the EASA designation of aircraft that replaces the definitions from the JAA of JAR 25 and JAR 23. CS25 (Certification Specifications for Large Aeroplanes) applies to large turbine powered aircraft typical of aircraft used for commercial passenger operations. CS23 (Certification Specifications for Normal, Utility, Aerobatic, and Commuter Category Aeroplanes) applies to aircraft that when used for commuter (passenger) operations have 19 or fewer passengers and a MTOW of less than 8618 kg.

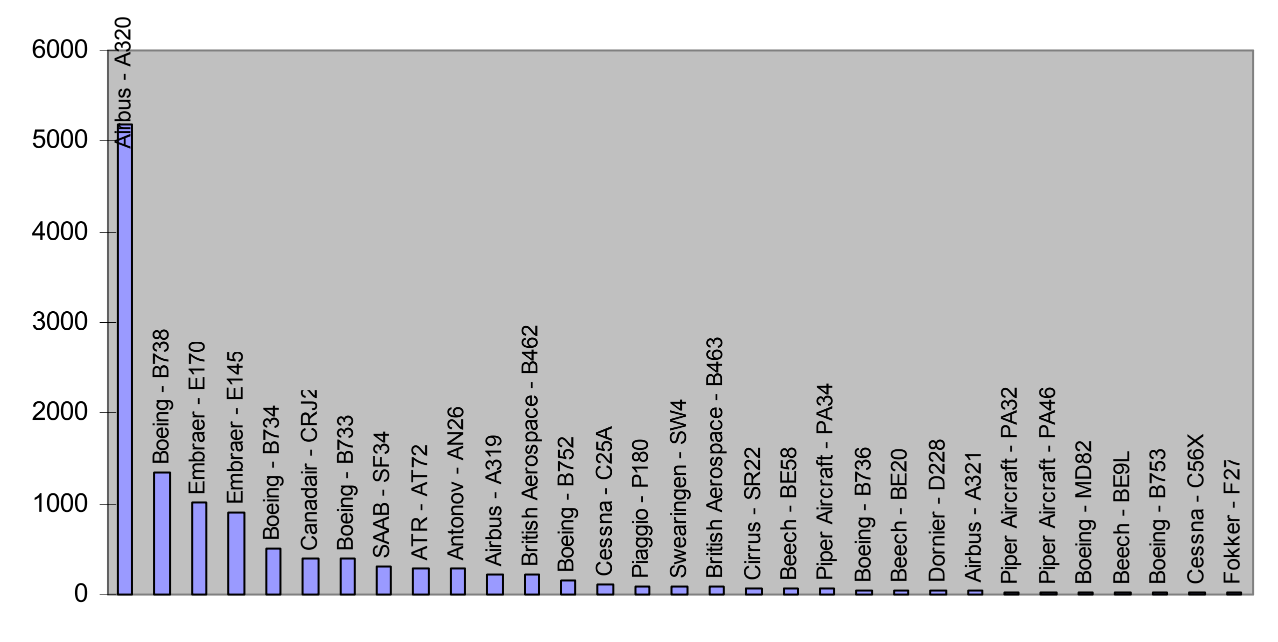

Figure 4-3: Distribution of arrival traffic for types with >20 landings

Further analysis is undertaken on a quarterly basis as follows:

- Q1: winter season, including December, January, February;
- Q2: spring season, including March, April, May;
- Q3: summer season, including June, July, August;
- Q4: autumn season, including September, October and November.

The number of movements summarised on a quarterly basis over a 24 hour period is illustrated in Figure 4-4.

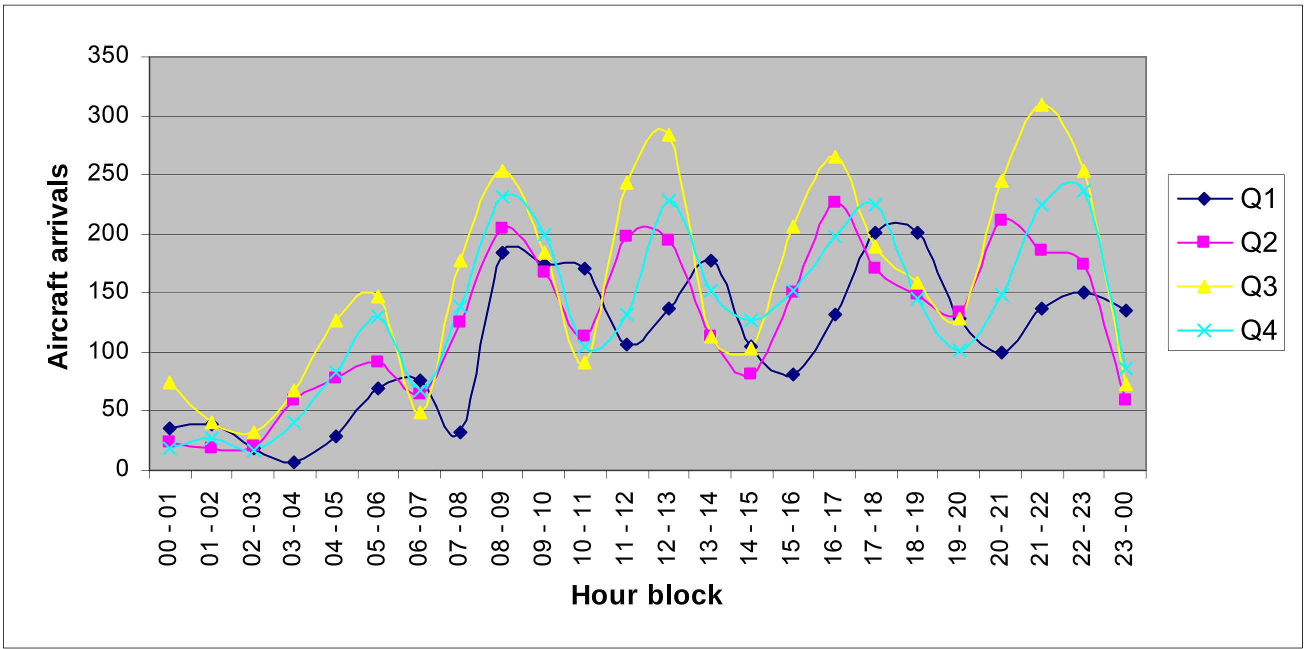

Figure 4-4: Quarterly arrival analysis by hour

Figure 4-4 illustrates that the highest number of arrivals are experienced during the summer months (Q3). On average, the winter months (Q1) see a 20% reduction in arrival numbers with a notable shift to the right resulting from the change to winter daylight saving time. Generally, arrival movements reach a consistent peak during the morning (~08-09) and early evening (~17-18) hours.

4.4 Supporting navigation infrastructure

The navigation infrastructure available within the aerodrome CTR is summarised in the following table derived from the AIP. It is noted that the available DME is an approach DME only and collocated with the ILS Glide Path.

ID	Frequency	Hours of operation	Navigation Aid	Position of transmitting antenna coordinates (WGS-84)
KTC	285 kHz	H24	Approach NDB	50°28'26.67"N 019°09'01.21"E
KTW	326 kHz	H24	Approach NDB	50°28'27.08"N 019°06'27.19"E
KAT	109.900 MHz	H24	ILS Localiser	50°28'27.53"N 019°02'56.43"E
-	333.800 MHz	H24	ILS Glide Path	50°28'32.08"N 019°05'20.93"E
KAT	109.900 MHz	H24	DME (collocated with ILS GP)	50°28'32.08"N 019°05'20.93"E

Table 4-2: Supporting navigation infrastructure at EPKT

4.5 Runway capabilities

The runway at Katowice is an instrument runway available for flights 24 hours per day. The limitation to flight operations is the availability of approach control which is only available on a fixed schedule varying with the days of the week. ATC is available at Katowice 24 hours per day.

The runway is suitable for all types of aircraft and has the characteristics shown in Table 4-3.

Characteristic \ Runway	09	27
TRUE&MAG BRG	090º GEO 086º MAG	270º GEO 266º MAG
Dimensions (m)	2800 x 60	2800 x 60
Strength (PCN) and surface of RWY and SWY	PCN 50/R/A/W/T beton/concrete	PCN 50/R/A/W/T beton/concrete
THR coordinates (WGS-84) / THR geoid undulation (m)	50º28'27.50"N 019º03'16.71"E 40.4	50º28'27.19"N 019º05'38.65"E 40.4
THR elevation /highest elevation	295.6 296.8	303.2 301.7
TORA (m)	2800	2800
TODA (m)	2800	2800
ASDA (m)	2800	2800
LDA (m)	2800	2800

Table 4-3: Runway characteristics at EPKT

Figure 4-5: Illustrated position of approach obstacles relative to the ARP

An ILS precision approach is only available from the runway end of RWY27 with RWY 09 providing a non-precision approach. The approach types that are currently available at EPKT are shown in the following tables extracted from the AIP.

EPKT27 present day approach capabilities				
Approach Type	**CAT A**	**CAT B**	**CAT C**	**CAT D**
ILS CATI	200	210	220	230
LOC-DME	328			
LPV(*)	390(*)	400(*)	410(*)	420(*)
LNAV(*)	430(*)			
NDB	492		574	
NDB_z	426			

Note: *only currently available for the purposes of the flight trial within the context of the HEDGE project.*

Table 4-4: EPKT RWY27 available IAPs and associated minima

EPKT09 present day approach capabilities				
Approach Type	**CAT A**	**CAT B**	**CAT C**	**CAT D**
NDB	689			

Table 4-5: EPKT RWY 09 available IAPs and associated minima

The default operational runway end is RWY 27. This is supported by analysis of the tailwind at each runway end which confirms RWY 27 as the preferred operational runway end throughout the year. This is described in Section 4.6.

4.6 Meteorological limitations

This section examines the runway utilisation at EPKT. The preferred runway given the availability of ILS is RWY 27. Analysis of the tailwind conditions at both runway ends reveals few instances during which high tailwind conditions prevent the use of RWY 27.

The charts below present the number of times per hour (on a quarterly basis) during which the tailwind strength exceeds a threshold value of 5 knots for each runway end.

It is assumed that an aircraft will not execute an approach to a runway end if the tailwind strength exceeds this value.

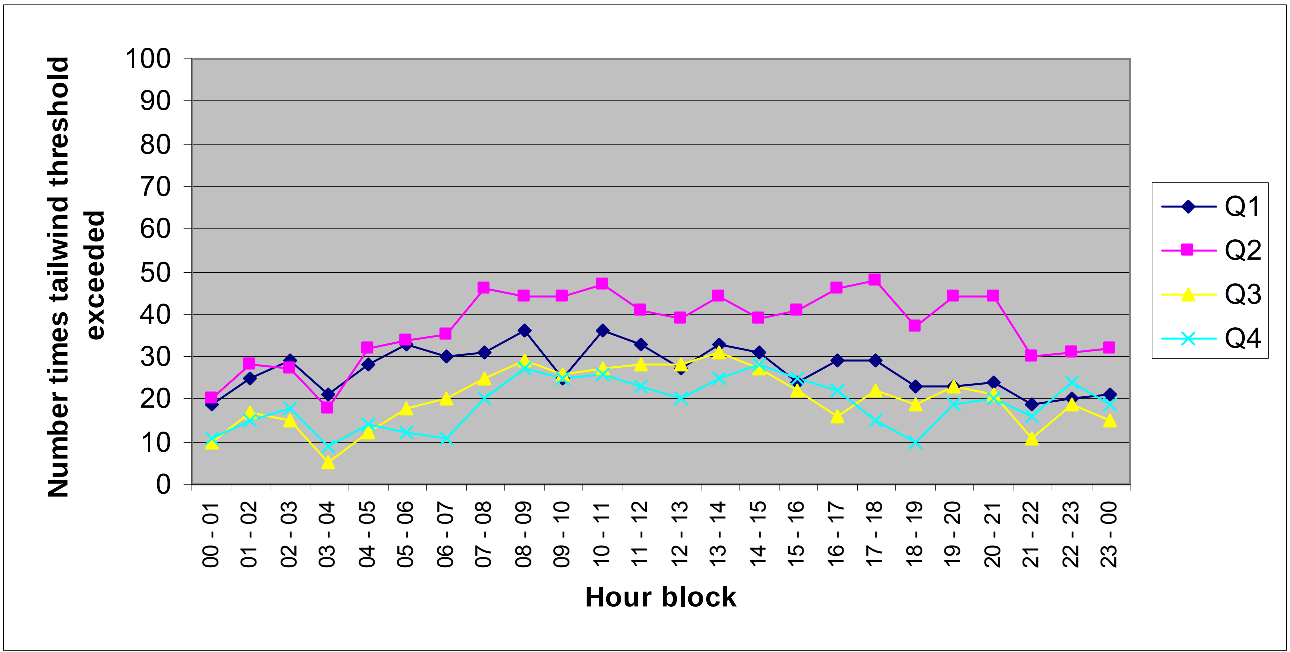

Figure 4-6: Quarterly analysis of instances of excessive tailwind component on RWY 27

The number of times that the tailwind component exceeds RWY 27 limits remains below 50 for each quarter. This is in contrast with Figure 4-7 illustrating that the instances in which the tailwind component exceeds RWY 09 limits is approximately double that of RWY 27. This analysis supports the current runway configuration in which RWY 27 is the primary runway and there is no basis to suggest a regular change in the default operational runway end, either on a daily (during selected hour blocks) or quarterly basis.

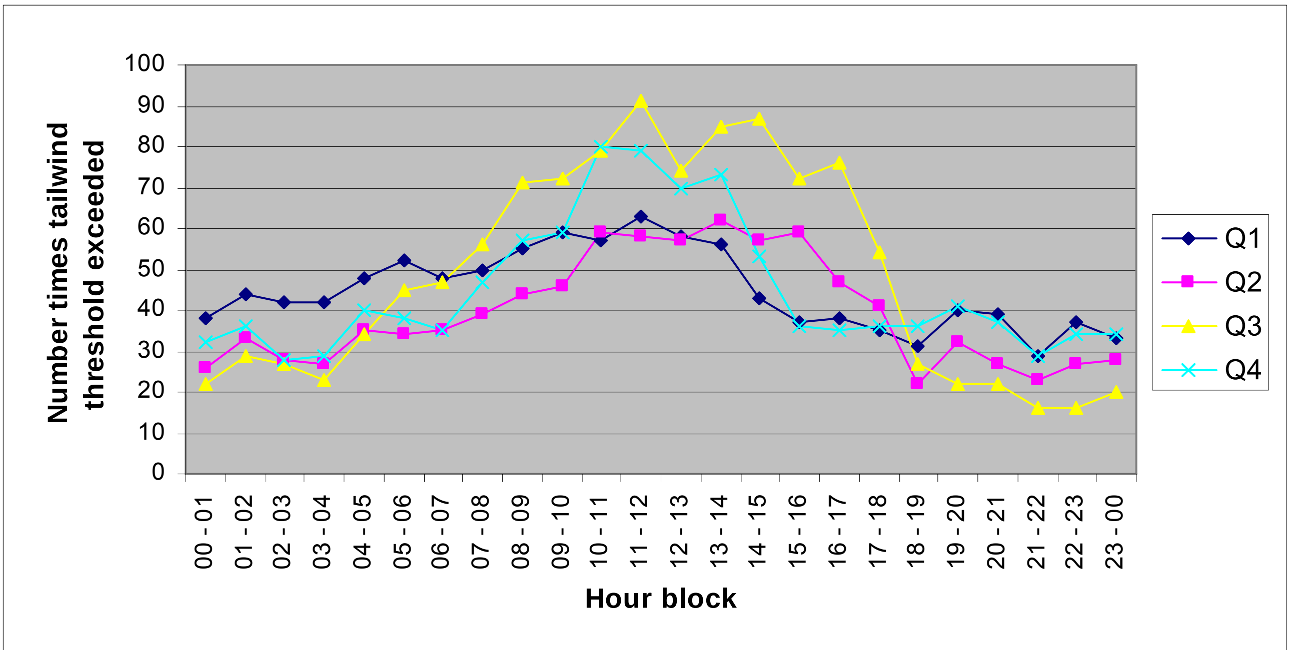

Figure 4-7: Quarterly analysis of instances of excessive tailwind component on RWY 09

5 FINANCIAL ANALYSIS

5.1 General

This section describes an assessment of the operational capacity of EPKT based on the use of different available approach types.

Each approach type allows an aircraft to execute an approach according to a specific Obstacle Clearance Height (OCH). The aircraft may be prevented from following the approach if at the time the meteorological conditions (i.e. runway visibility, cloud ceiling level, high tailwind component) exceed the limits of the procedure or the navigation aid supporting the procedure (i.e. ILS - either due to planned or unplanned service outage) is unavailable. In such circumstances the aircraft will most likely experience a disruption, defined as an aircraft delay, diversion or cancellation.

The analysis assesses the varying number of hours of disruption experienced at EPKT depending on the available approach capabilities.

5.2 Scenario definition

The following three scenarios are defined for this financial assessment:

- **Baseline scenario:** This is the current day situation. RWY 09 has an NDB approach and RWY 27 has an ILS CATI, LOC-DME and NDB approach.
- **Scenario 1: LPV implementation at RWY 27:** This is an investigated alternative to the Baseline with the current trial LPV and LNAV approach also implemented. This will provide an indication of any benefits or financial impact on the implementation of LPV as a back-up to the ILS implementation.
- **Scenario 2: LPV implementation at RWY 09:** This is an investigated alternative with the implementation of LPV approach capabilities for RWY 09 to enable near precision approach operations at both runway ends without the deployment and annual maintenance costs of an additional ILS.

The benefits of Scenario 1 and Scenario 2 are investigated in terms of their respective estimated annual number of avoided disruptions.

It is assumed that the implementation of LPV at RWY 09 will provide LPV procedures with similar OCH values to those of the proposed LPV procedure at RWY 27. The estimated approach capabilities for RWY 09 under Scenario 2 are summarised in Table 5-1. This is assumed because the obstacle environment surrounding the approach to RWY 09 is similar to that of RWY 27 (defined by the number, height and/or location of significant obstacles in the surrounding area).

RWY 09 Scenario 1: LPV implementation				
	LPV estimated OCH (ft)			
Approach Type	**CAT A**	**CAT B**	**CAT C**	**CAT D**
LPV	390	400	410	420
LNAV	430			
NDB	689			

Table 5-1: RWY 09 OCH using LPV approach (Scenario 1)

5.3 Analysis methodology

The analysis employs a modular approach calculating in turn:

- the total number of aircraft landings at the airport;
- the number of non-ILS landings from these;
- the disruption probability per approach type;
- the subsequent number of disrupted NPA landings;
- the total cost of these disruptions.

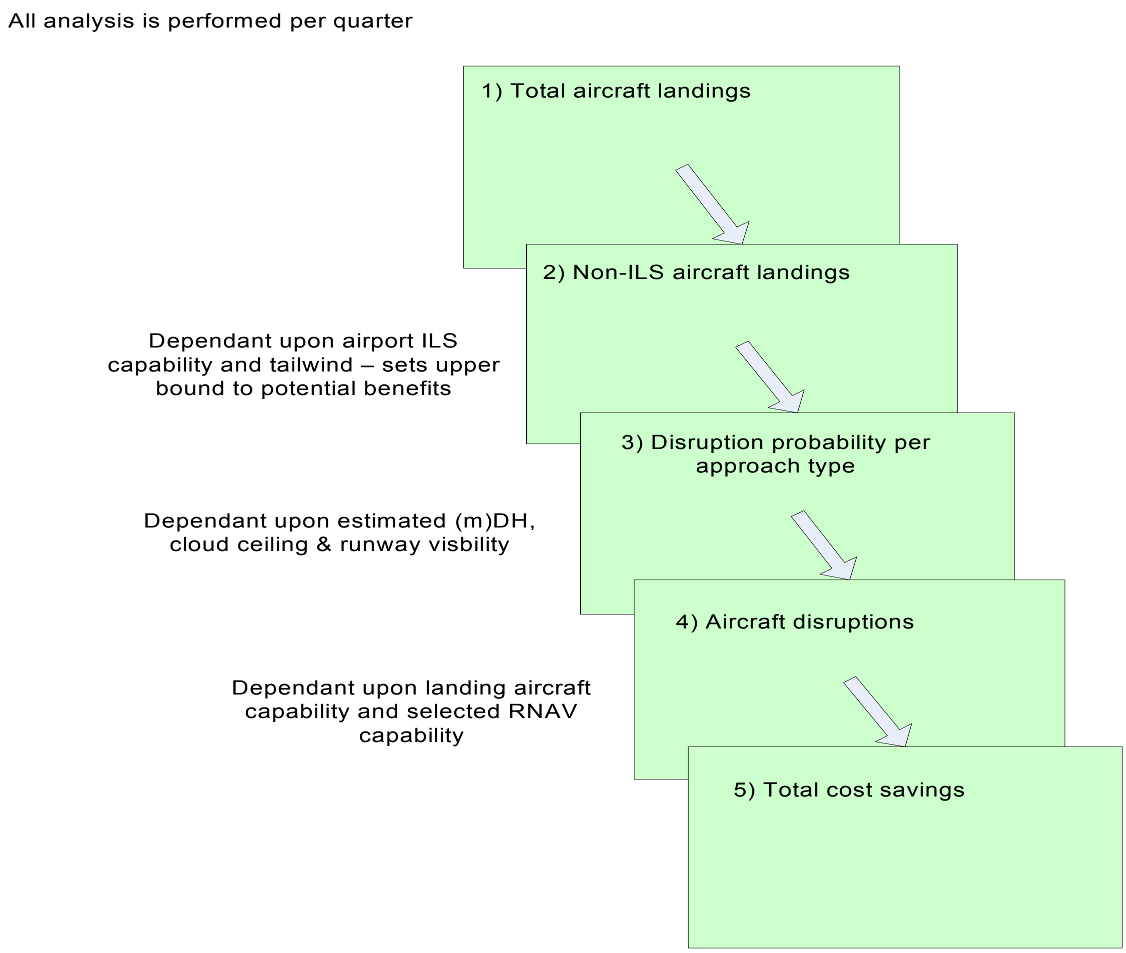

Figure 5-1: Analysis methodology

The individual analysis steps are described below:

<u>Step 1) Total aircraft landings</u>

The total number of aircraft landings is derived from data provided by PANSA. The analysis only considers Instrument Flight Rule (IFR) movements and not Visual Flight Rule (VFR) movements.

An annual increase in movements is applied from a previous study [3] as presented in the table below.

Year	2011	2012	2013	2014
% annual increase	6.20%	5.80%	4.50%	4.90%

Table 5-2: Traffic growth forecasts up to 2014

Step 2) Non-ILS aircraft landings

The number of landings where an ILS approach is not possible (non-ILS aircraft landings) is calculated based upon:

- an ILS annual outage probability of one week per year (either planned as part of maintenance or unplanned);
- a tailwind strength probability (when the tailwind strength exceeds the threshold, an approach must be made to the opposite runway end).

All weather data are derived from meteorological statistics provided by the National Oceanic and Atmospheric Administration (NOAA). These annual statistics include hourly, if not half hourly, observations of local meteorological conditions and are often the source for airport METARS.

Step 3) Disruption probability per approach type

The disruption probability per approach type is calculated based upon a combination of the approach OCH and meteorological conditions at the time of approach.

It is assumed that, given a particular OCH or (Minimum) Decision Altitude/Height or (M)DA/DH, two dominant weather types will result in a disruption; poor runway visibility or low cloud ceiling.

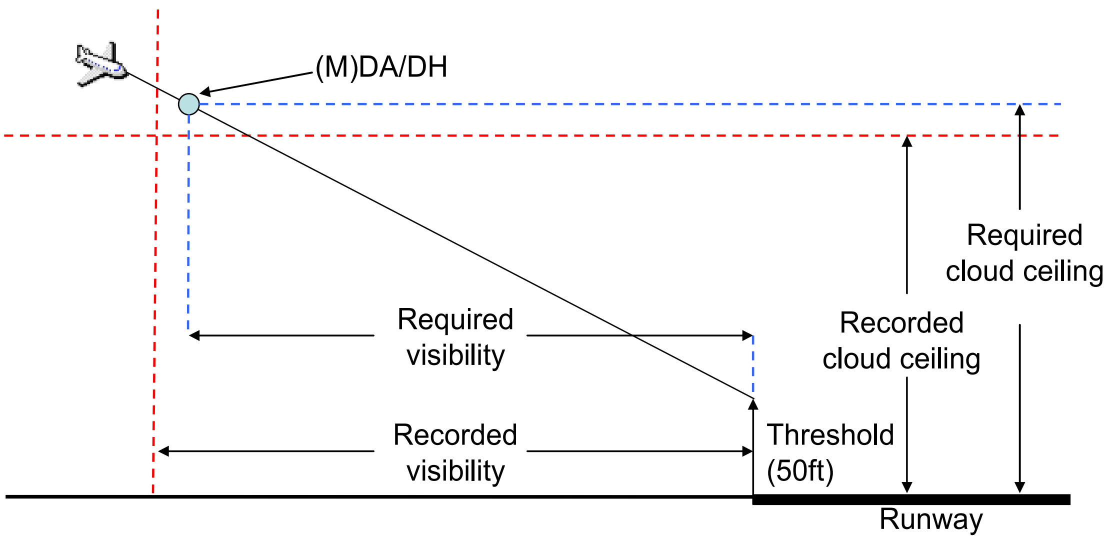

Figure 5-2: NPA landing conditions

If the decision height of an approach meant that the (M)DA/DH was greater than the required cloud ceiling or the recorded visibility exceeded the required level, then a disruption will ensue. The specific formulation of this follows.

Applying a 3° glide slope, an aircraft descends at a rate of 300 feet/NM in the final approach. Hence, for a given DH:

A) For the cloud ceiling, landings are not possible when:

Recorded cloud ceiling (feet) < DH

B) For visibility:

Tan θ = descent rate

= 300ft/NM (1 NM = 1.852 km), where θ is the descent angle.

Tan θ = (DH - 50) / Required visibility, for a given (M)DA/DH (Descent to threshold, hence DH - 50)

Since the descent angles are the same:

300/1.852 = (DH - 50) / Required visibility

Required visibility (km) = (1.852*(DH - 50)) / 300

Hence, for visibility, landings are not possible when Recorded visibility < Required visibility

Recorded visibility (km) < (1.852*(DH – 50)) / 300

Therefore, landings are not possible if:

Recorded cloud ceiling < DH **OR** recorded visibility < (1.852*(DH – 50)) / 300

This formula is evaluated for all hours over each quarter providing a specific probability factor to be applied at all times. This is then applied to the estimated non-ILS landings per quarter.

Step 4) Aircraft disruptions

The number of aircraft disruptions is calculated by applying the estimated disruption probability factors to the estimated number of non-ILS landings.

As seen from the aircraft movements analysis, 85% of all aircraft landings are accounted for by the A320 aircraft. This is a category C aircraft (according to ICAO aircraft landing speed categorisation) and as a large commercial aircraft can be expected to have high-end avionics on board. It is likely that all of these can be upgraded to LPV capability.

It is therefore assumed that all aircraft operate to category C OCH values as published in the AIP and that all aircraft are LPV capable.

Step 5) Total cost savings

The subsequent cost of aircraft disruptions and potential cost savings between the various scenarios are calculated by applying a standard operator cost per disruption.

This is assumed to be €4,660[3] based upon an average of 50 minutes of time lost per diversion and 43 passengers per flight. The recommended cost figures for each are €66 per minute of delay and €38 per hour for the passenger value of time.

[3] Standard Inputs for Eurocontrol Cost Benefit Analysis'

5.4 Improvement in serviceability

This section presents the results of the analysis undertaken as described above.

The *potential* number of disruption hours per approach type is calculated employing the above formula relating OCH, recorded cloud ceiling and runway visibility.

This is termed the potential number of disruption hours as actual disruptions only occur in the absence of ILS availability. The actual number of disruptions depends upon the correlation of weather conditions and actual aircraft landing movements as well as the service availability of ILS and tailwind conditions at the time of landing.

Nevertheless, this is a valuable exercise to perform as it provides an illustration of the potential effect of varying the OCH in accordance with the available runway approach capabilities. In general, the higher the OCH, the likelihood of a potential disruption is increased. However, this relationship between potential disruption and OCH is not linear. The critical value at which a reduction in OCH will enable dramatic reduction in potential disruption depends upon the average and variance of the cloud ceiling and runway visibility at the airport.

Figure 5-3 and Figure 5-4 below present the potential disruption hours as calculated for both RWY 27 and RWY 09 for each quarter. The potential disruption hours are shown for each approach procedure (both current and potential) and for each ICAO aircraft approach category (A-D).

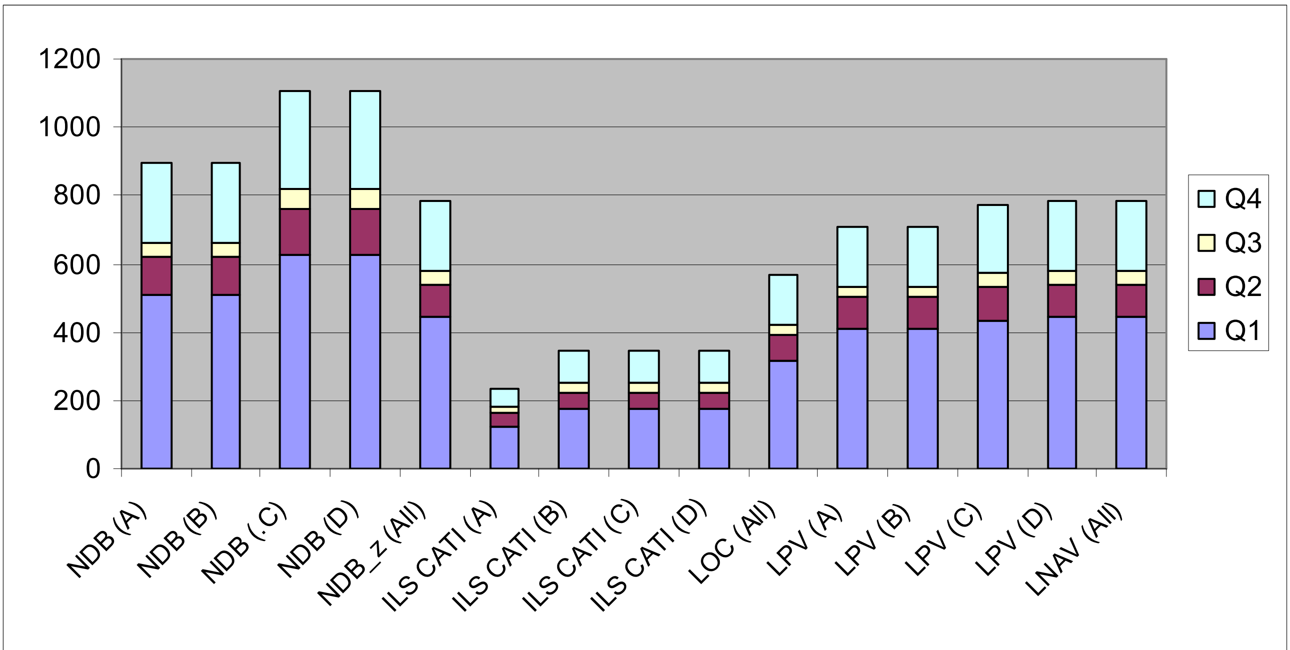

Figure 5-3: Estimated number of disruption hours per approach type per quarter (RWY 27)

For RWY 27, ILS demonstrates the lowest number of potential disruption hours as expected. A slight variance is seen with respect to the different ICAO aircraft approach categories, in line with the slightly varying OCH values. LPV and/or LNAV approach procedures show a significant improvement with respect to the NDB procedures although still suffer from almost double the number of potential disruptions compared to ILS.

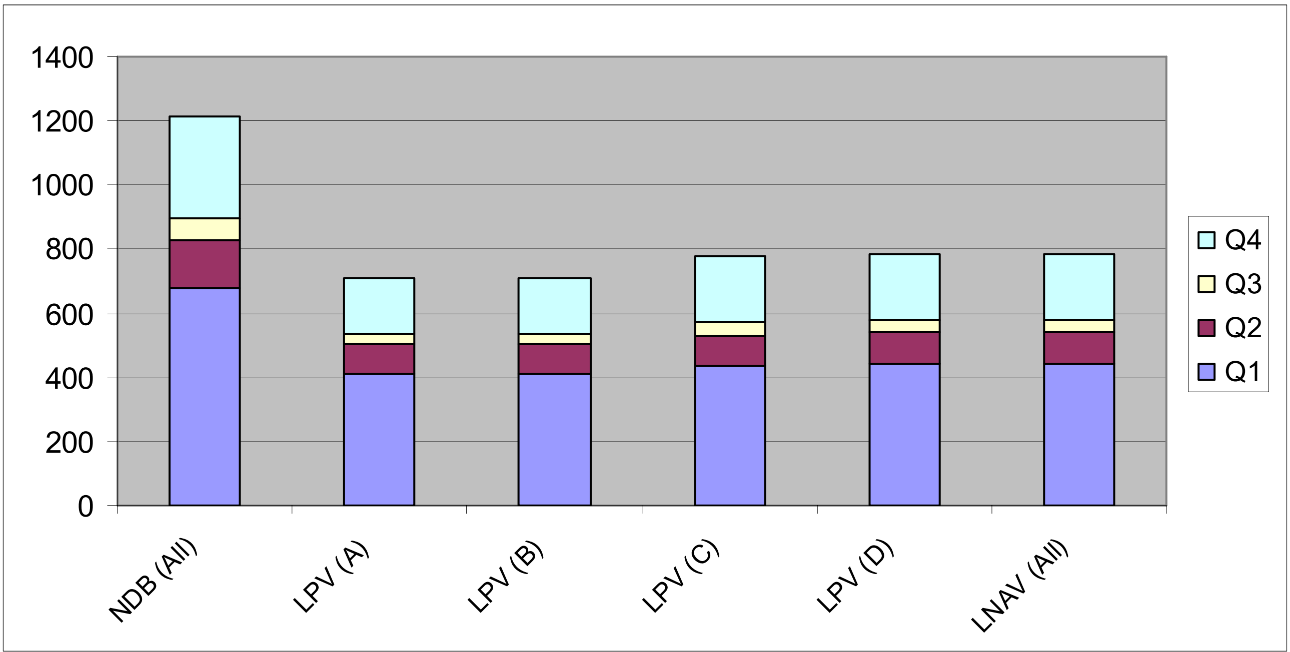

Figure 5-4: Estimated number of disruption hours per approach type per quarter (RWY 09)

For RWY 09, there is significant opportunity to reduce the potential disruption hours through LPV implementation. LPV approaches enable an annual reduction of the order of 400 – 500 hours compared to the current NDB procedures at RWY 09.

From the total number of potential disruptions per navigation aid, a comparison to the baseline scenario can be made. This comparison can be made with respect to:

1. the number of disruptions saved by the introduction of LPV, and
2. the financial benefit in reduced disruption costs as a result of the benefit.

The level of disruptions needs to be based on the availability of the approach to arriving aircraft considering the meteorological conditions and the state of the navigation aids. The following figure illustrates the logic applied to determining whether, for each of the scenarios, a disruption occurred. The level of benefit afforded by LPV procedures within Scenarios 1 and 2 is then compared to the Baseline.

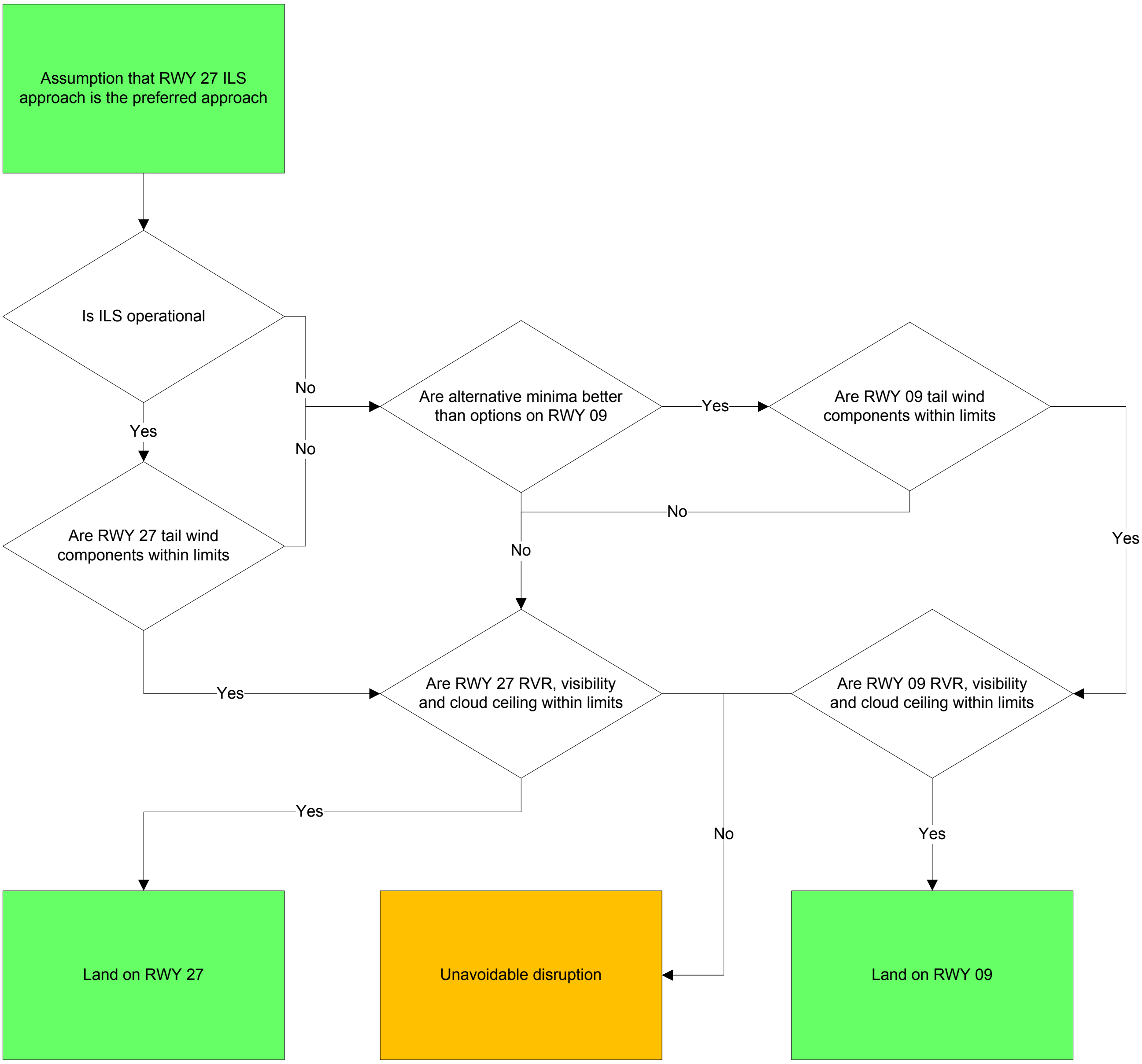

Figure 5-5: Logic used in determining likelihood of disruption

Based on this analysis, the following table shows the estimated number of disruptions avoided compared to the baseline through provision of the LPV procedures at each runway end. (Note values are expressed as fractions due to the probability effect of ILS outages and weather phenomena)

	Scenario 1	Scenario 2
Q1	1.2	49.8
Q2	0.2	17.7
Q3	0.2	7.1
Q4	0.6	21.3
Total	**2.2**	**96.0**

Figure 5-6: Estimated average avoided disruptions for scenarios compared to baseline

Scenario 1 (EPKT RWY 27 LPV deployment)

The deployment of LPV at RWY 27 could be expected to enable a reduction of approximately two disruptions per year. This small decrease is a result of the higher minima afforded by the available ILS and the small period of unavailability of the ILS that could be expected.

Scenario 2 (EPKT RWY 09 LPV implementation)

The implementation of LPV at RWY 09 can be expected to enable a reduction of approximately 96 disruptions per year. This is most notable in Q1 during the winter months (as owing to a greater frequency of unfavourable weather conditions).

Converting these disruptions into financial benefits, the corresponding quarterly and annual estimated cost corresponding to these disruptions is presented below.

	Scenario 1	Scenario 2
Q1	€ 5,000	€ 232,000
Q2	€ 1,000	€ 82,000
Q3	€ -	€ 33,000
Q4	€ 2,000	€ 99,000
Total	**€ 8,000**	**€ 446,000**

Figure 5-7: Estimated average savings for scenarios compared to baseline

This is best examined over the upcoming 5 years (short term forecast) to determine the potential cost savings and therefore trade-off in the implementation of LPV at RWY 09.

This forecast assumes the disruption probabilities remain constant (and that therefore there is no significant change in the predominant wind conditions, cloud ceiling level and runway visibility). It only assumes an increase in the annual number of aircraft arrival movements in lines with predicted traffic trends.

The chart below illustrates the estimated number of annual disruptions for each of the defined scenarios up until 2014.

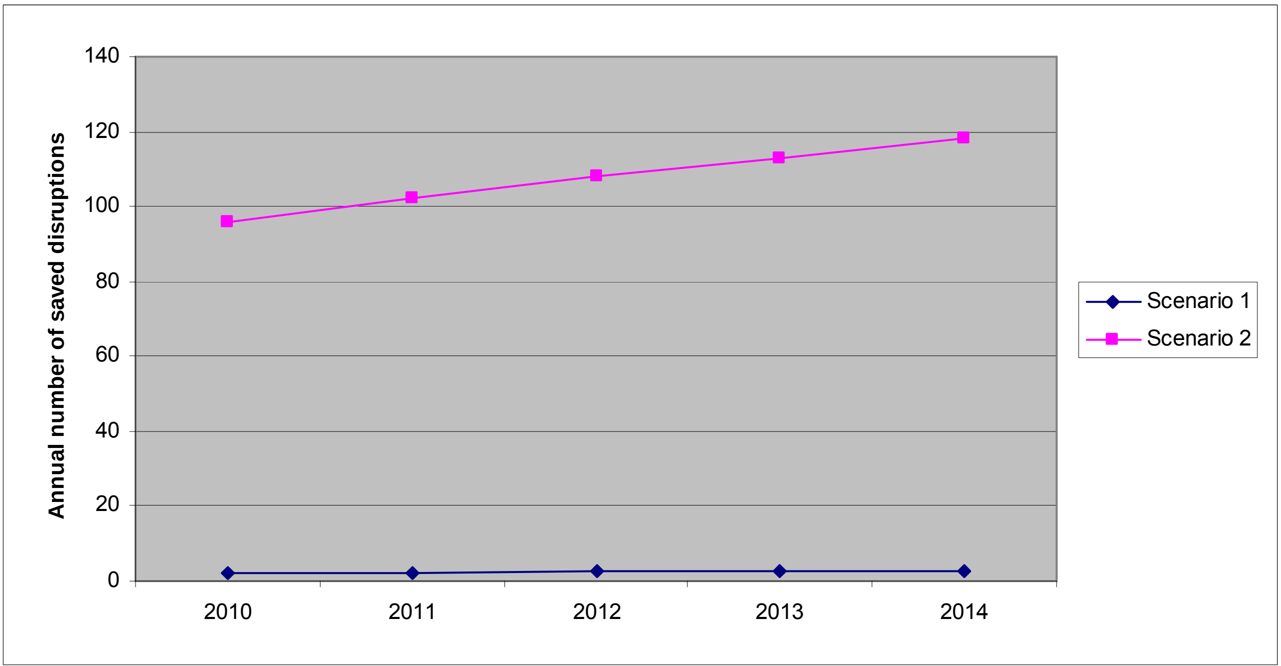

Figure 5-8: Estimated number of avoided annual disruptions per scenario compared to the baseline

This translates to the following annual disruption saving:

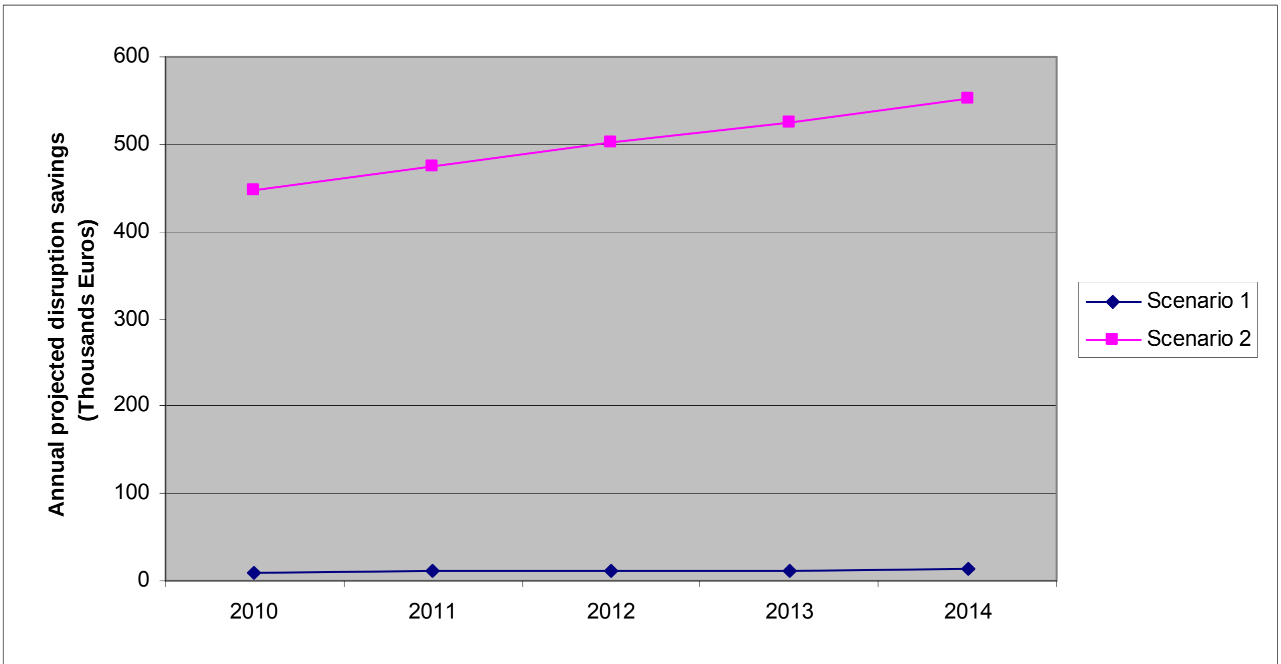

Figure 5-9: Estimated avoided annual disruption savings per scenario compared to the baseline

The cumulative disruption saving per scenario throughout this period is shown below. This is calculated for the 5 year period from 2010 to 2014 inclusive.

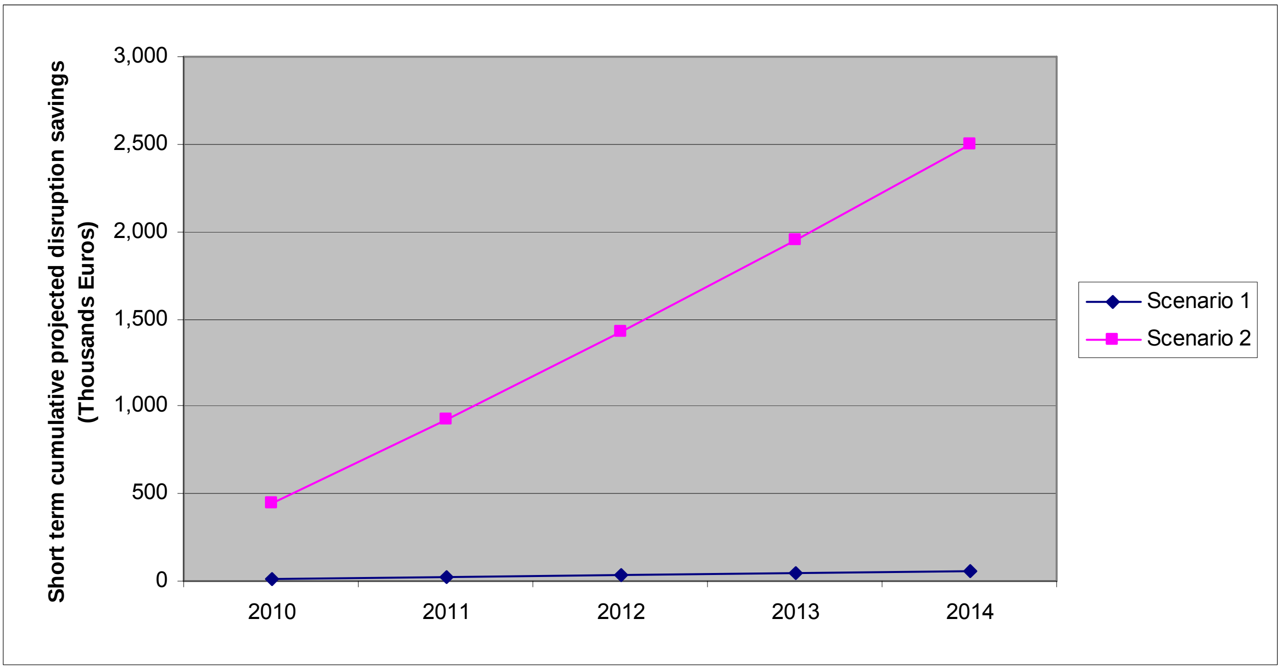

Figure 5-10: Cumulative avoided disruption savings per scenario compared to the baseline over a 5 year period

The deployment and implementation of LPV at RWY 09 can be expected to enable a cumulative cost saving of € 2.5M over the next 5 years compared to € 57,000 for the implementation of LPV on RWY 27. This is expected since the minima provided by the ILS installation on RWY 27 is lower than the available LPV procedure within Scenario 1.

With the combined cost of installation and annual maintenance of ILS, the implementation of LPV procedures at RWY 09 in its place may pose a potentially beneficial alternative.

A long term forecast illustrates the potential cumulative cost savings between Scenario 1 and Scenario 2 with respect to the baseline. Figure 5-11 demonstrates a cumulative benefit of avoided disruptions of the order of € 22M over a 25 year period between Scenario 1 and Scenario 2.

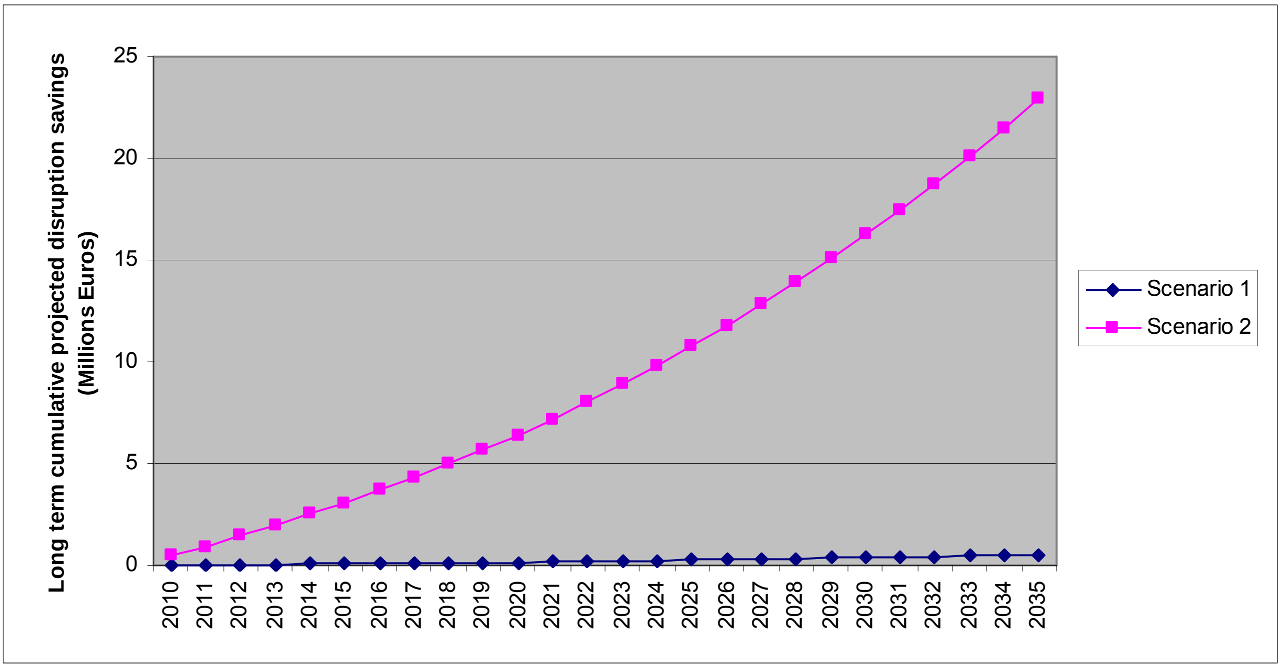

Figure 5-11 : Cumulative avoided disruption savings per scenario compared to the baseline over a 25 year period

5.5 Safety improvements

ICAO has recognised that the safety benefit provided by APV SBAS procedures is significant compared to non-precision approach procedures resulting from the vertical guidance which is provided to the aircraft on approach. Historically, the accident rates for aircraft following an NPA are because of an incorrect vertical profile, as illustrated by Figure 5-12.

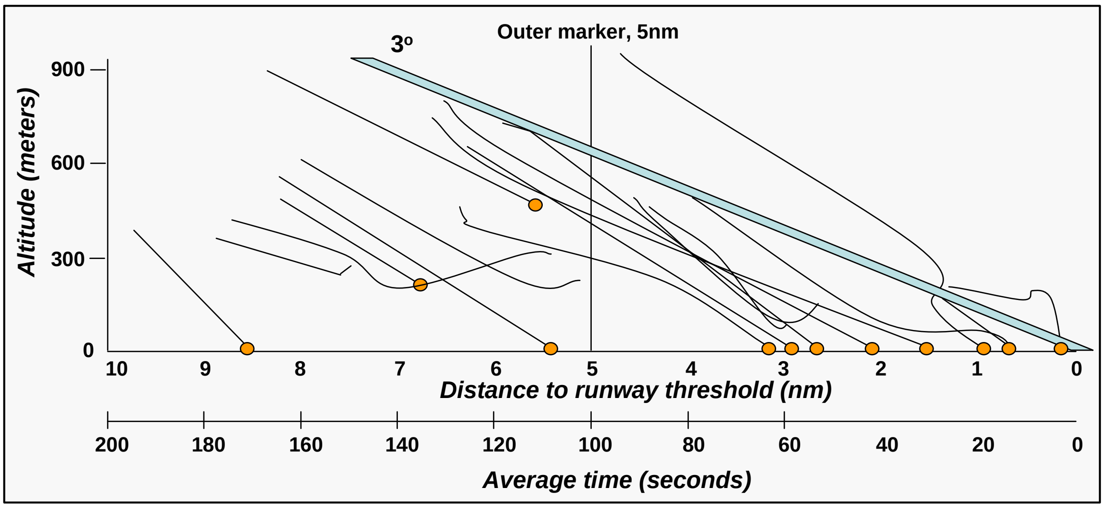

Figure 5-12: Vertical profile of recent CFIT accidents / incidents

At the 36th ICAO General Assembly a resolution was adopted that:

- *Urges all States to implement RNAV and RNP air traffic services (ATS) routes and approach procedures in accordance with the ICAO PBN concept laid down in the Performance-Based Navigation Manual (Doc 9613);*
- *Resolves that:*
    - *a) States and planning and implementation regional groups (PIRGs) complete a PBN implementation plan by 2009 to achieve:*
        - *1) implementation of RNAV and RNP operations (where required) for en route and terminal areas according to established timelines and intermediate milestones; and*
        - *2)* ***implementation of approach procedures with vertical guidance (APV) (Baro-VNAV and/or augmented GNSS) for all instrument runway ends****, either as the primary approach or as a back-up for precision approaches by 2016 with intermediate milestones as follows: 30 per cent by 2010, 70 per cent by 2014; and*
    - *b) ICAO develop a coordinated action plan to assist States in the implementation of PBN and to ensure development and/or maintenance of globally harmonized SARPs, Procedures for Air Navigation Services (PANS) and guidance material including a global harmonized safety assessment methodology to keep pace with operational demands;*

and

- *Urges that* ***States include in their PBN implementation plan provisions for implementation of approach procedures with vertical guidance (APV) to all runway ends serving aircraft with a maximum certificated take-off mass of 5 700 kg or more,*** *according to established timelines and intermediate milestones.*

On this basis, even without the savings to flight disruption there is the resolution agreed by ICAO State members for the adoption of APV procedures. In this case, the adoption of the APV SBAS (LPV) procedure for both RWY 27 and RWY 09 would be in accordance with this resolution which seeks to increase the safety of operations from aircraft having to use the traditional non-precision approach procedures.

5.6 Procedure design and implementation

Costs associated with the design and implementation of the new instrument approach procedures to Katowice were provided by PANSA for the TEN-T Mielec project [1]. These indicative costs for the implementation of an ILS compared to an LPV procedure are summarised in the following table.

Cost item	RNAV (GNSS) NPA Approach	APV SBAS Approach	RNAV (GNSS) NPA + APV SBAS approach
Procedure design	14400	19200	33600
Testing (Flight trials)	19180	19180	19180
Chart preparation (AIP format)	13200	13200	13200
AIP changes (publication)	1200	1200	1200
TOTAL COST (PLN)	**47 980**	**52 780**	**67 180**
TOTAL COST (EUR) (1€ = 4 PLN)	**11 995**	**13 195**	**16 795**

In addition to these costs, there are a number of other factors that may need to be included. These are repeated from the TEN-T Mielec project.

Cost item	
STAR design and publication (if needed)	9600
Airspace design	24000
Use of airspace rules establishment (optional)	7200
Air traffic collision analysis with neighbouring aerodromes	4800
Establishment of collision avoidance rules	19200
Implementation of airspace changes	9600
Co-ordination with other airspace users	4800
Preparation of necessary documentation for CAA ratification of airspace changes	2400
TOTAL COST (PLN)	**81 600**
TOTAL COST (EUR) (1€ = 4 PLN)	**20 400**

5.7 Navigation infrastructure costs

The provision of an LPV approach to either RWY 27 or RWY 09 does not require any additional investment on navigation infrastructure.

6 CONCLUSIONS

This paper has presented an initial impact assessment of the introduction of LPV procedures to Katowice. It has shown that, in addition to the safety benefits that have been recognised by the ICAO 36th General Assembly, the introduction of LPV procedures to Katowice can have a benefit in saving the number of disruptions at the airport.

Examination of the planned flight schedule for operations to Katowice for 2009 has shown that annually approximately 96 disruptions could be avoided through the introduction of APV SBAS (LPV) approach procedures of which more than 50% occurred during the winter months. This was examined through two scenarios to compare the benefits of a new procedure on a runway that has ILS and a runway that does not (Scenarios 1 and 2 respectively) against the currently available facilities.

This assessment has shown that avoiding these disruptions delivers a financial benefit to the operators when the cost of a disruption is taken into account. The analysis has shown that for Scenario 2 there is an annual saving of approximately € 446,000 from avoided disruptions and, taking into account traffic growth, the short term cumulative estimated disruption saving is approximately € 2.5M and in the 25 year period € 22M undiscounted. This contrasts markedly with Scenario 1 where the annual benefit is approximately € 8,000, in the short term € 57,000 and in the long term € 522,000 undiscounted. The difference between the two scenarios quite clearly illustrates the significant incremental benefits between providing APV SBAS (LPV) minima as a backup to an ILS approach (as in Scenario 1) or as an alternative to an NDB approach (as in Scenario 2) – which has larger benefits due to a lower than NDB operational minima.

This financial benefit assessment provides aircraft operators with the basis from which to develop a complete business case that takes into account their aircraft equipage capabilities and the potential network benefits of utilising APV SBAS (LPV) procedures at other aerodromes.

Likewise, the airport operator should use the findings of this report to undertake a more detailed analysis on the cost benefit case for the implementation of one or more procedures in line with the recommendations from ICAO for the replacement of NPA approaches. Indicative costs associated with the implementation of the procedures proposed in the scenarios within this report are provided.