GIS Technology Applied on Obstacles Data Flight Operation: A Review of Initial Project of Kuksi Airport Opening

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Abstract: ***Collection and maintenance of airport safety critical data is mandatory for certified airports. This paper is a review of the obstacle management process including obstacles data collection, 3D airport coverage areas, obstacle limitation surfaces, obstacles analysis and display of work load carried on prior setting up the new airport in Kukës, Albania. Terrain condition and obstacles are first essential priorities to take in consider when designing flight operation procedures. On the otherhand, the implementation of the eTOD requirements as stated by ICAO Annex 15 [ICAO International Civil Aviation Organization, Annex 15 – Aeronautical Information Service https://www.icao.int] lead to significant challenge and requires the collection and survey of a relatively large amount of terrain and obstacle data. This Review paper describes main elements of initiating the new airport in Kukës. It recommends that obstacles should be periodically monitored for any feature change since they are essential and critical to flight operations. Every change should be reflected in Database and Aeronautical Information Publication (AIP). The paper concludes that the software ArcGIS Aviation is a very good tool to analyse, create, visualize and provide ETOD for the operational purposes.***

Keywords: Airport, GIS, Obstacle data flight, Surfaces(OLS)

1. Introduction

Obstacles in terms of aviation are features with a vertical significance, compared to the surrounding terrain or surrounding features that constitute a potential hazard to aircraft operations. According of ICAO Annex 15, the definition of an obstacle is: "*All fixed (whether temporary or permanent) and mobile objects, or parts thereof, that: (a) are located on an area intended for the surface movement of aircraft; or (b) extend above a defined surface intended to protect aircraft in flight; or (c) stand outside those defined surfaces and that have been assessed as being a hazard to airnavigation*."[1]

Obstacle data is intended to be used in the following air navigation applications: (a) ground proximity warning system with forward looking terrain avoidance function and minimum safe altitude warning (MSAW) system; (b) determination of contingency procedures for use in the event of an emergency during a missed approach or take-off; (c) aircraft operating limitations analysis; (d) instrument procedure design (including circling procedure); (e) determination of en-route "drift-down" procedure and en-route emergency landing location; (f) advanced surface movement guidance and control system (A-SMGCS); and (g) aeronautical chart production and on-boarddatabases.

The object of the Aeronautical Information Service (AIS) is to ensure the flow of aeronautical data, and aeronautical information, necessary for global air traffic management (ATM) system safety, regularity, economy and efficiency in an environmentally sustainable manner. The role and importance of aeronautical data and aeronautical information changed significantly with the implementation of area navigation (RNAV), performance-based navigation (PBN), airborne computer-based navigation systems, performance-based communication (PBC), performance based surveillance (PBS), data link systems and satellite voice communications (SATVOICE). Corrupt, erroneous, late, or missing aeronautical data and aeronautical information can potentially affect the safety of airnavigation[2].

2. Methodology

Collection and provision of obstacle data as specified in ICAO Annex 14[3] and 15 are mandatory processes for an airport as an operational requirement, since they are potential hazards to flight operations. The implementations of these requirements were prior to opening the new airport in Kukës, Albania and passed through these main phases: (1) Obstacles data collection from field surveying; (2) Creation of 3D Obstacles limitation surfaces (OLS), analyzing obstacles and dominant obstacles for their effect to aircraft operations; (3) Creation of 3D electronic Terrain and Obstacles Dataset (eTOD) coverage areas and obstacle analysis for provision of obstacles data; (4) Initiating an aeronautical information (AIS) exchange language model database AIXM for obstacles provision; (5) Publishing obstacles in Aeronautical Information Publication (AIP)

[1] ICAO Annex 15 – Aeronautical Information Service

[2] ICAO Annex 15 – Aeronautical Information Service

[3] ICAO Annex 14 – Airports design and operations

2.1 Obstacles Data collection from field surveying

Prior to setting up the new airport in Kukës and flight operation procedures, the obstacles field survey data collection was held. The aim of airport obstacles survey was to determine the position in WGS-84 Grid Coordinate System of all relevant obstacles captured by coverage areas defined in ICAO Annex 15, OLS surfaces ICAO Annex 14 and Take of Flight Path Area (TOFPA) slope 1.2% defined in ICAO Annex 4[4], with a better survey accuracy than the minimum requirements. The ISO 19131 Terrain and Obstacles data model allows the definition of several data quality requirements. Each requirement can be associated with a scope, ensuring a precise description of the quality requirements for each feature type, in each terrain and obstacle data area. The minimum quality requirements for the obstacles are designed according to PANS- AIM Doc10066[5]

Data evaluation Procedure**:** Accuracy has been determined by independent control surveys using conventional terrestrial survey methodology to assure three times better accuracy than minimum requirements. All surveying techniques were carried out in accordance with standard surveying practices and in strict accordance with SARPS and ICAO Doc 9674 “WGS-84 Manual”. All survey observations were made to within the stated manufacturer’s equipment accuracyspecification.

Airport obstruction survey**:** The methodology used for the Airport Obstruction Surveys for Runway 01/19 at Kukës Airport is as following. The relevant obstaclescaptured by coverage Area defined in ICAO Annex 15, were surveyed by combination of theodolite intersections and bearing and distance measurements from baselines positioned using differential GNSS. These baselines were referenced to the airport control network, thus resulting in the production of WGS-84 and UTM/EMG96 coordinates for each obstacle. A typical baseline would be 400m - 600m long, up to 2500m from obstacle to be surveyed by intersection. Two deferential GPS points formed the ends of baselines. Two theodolites readings were then taken to the top of the obstacle from each end of the baseline where obstacles were surveyed by intersection. A theodolite reading and binocular range were taken from one or both ends of the baseline where taken from one or both ends of the baselines where obstacles were surveyed by bearing and distance measurement. Dominant obstacles were measured twice from independent baselines whenever practical and many obstacles were surveyed by both intersection and bearing and distance measurement. All observations were made using Leica dual frequency GNSS Receiver, Leica electronic theodolites and Leica Vector Laser binocular. Field survey is carried up in cooperation with Enav[6]company surveyors.

Data processing: All GNSS observations were processed using LeicaInfinity software. All measurements are analyzed, verified and validated for their spatial location and attributes using ArcGIS and authorized state Orthophoto 20 cm from ASIG.

2.2 Creation of 3D Obstacles Limitation Surfaces(OLS)

Different geographic areas and 3D-surfaces constitute the spatial scope of the ICAO obstacles collection and provisions. The majority of these areas and surfaces are related to airport geometry. They are defined in the following ICAO Annexes and PANS: Annex 15 and PANS-AIM (coverage areas); Annex 14 [3] (obstacle limitation surfaces); Annex 4 [1] (take-off flight patharea).

The obstacle limitation surfaces are depending on the airport reference code defined for the airport, which for Kukës Airport is three (3). The surfaces are listed as following: *Take off Climb Surface* (TOCS); *Approach Surface* (AS); *Transitional Surface* (TS); *Inner Horizontal Surface* (HIS); *Conical Surface* (CS). It should be noted that the obstacle limitation surfaces extend up to 15 km, which is different to Area 2b, whose extension is only 10 km. OLS described above and specified in ICAO Annex 14 and Annex 15 are created in 3D using Arc GIS for Aviation and displayed as shown in the *Fig.1*. Surfaces are created depend on Kukës Airport spatiallocation, runway 3D dimensions and future procedures for flight operations.

Inner Horizontal Surface **(IHS);** is 396.18m (351.18m + 45m) high. Inner Horizontal Surface is shown in orange in *Fig.2*. In red is represented portion where terrain penetrates the surface; in yellow penetratingobstacles

Conical Surface **(CS);** is a surface sloping upwards (5% - 1:20) and outwards. The internal edges are coincident with the periphery of the inner horizontal surface and have a width of 2000m. Significant terrain and obstacles for this surface is shown in green in Fig.3. *In* red is represented portion where terrain penetrates the surface; in yellow penetrating obstacles.

Approach Surface **(RWY 19**); Runway direction 19 has been considered as a non- instrumental approach runway. The surface has been designed using the ICAO standard parameters below reported: Only one section 3000m slope 2.50%. Penetrating terrain obstacles and terrain is represented below and assessment has pointed out that the first 950m of the approach surface is significantly interfered both by natural and artificialobstacles.

Approach surface RWY 19 is shown in light blue in *Fig.4*. In red is represented portion where terrain penetrates the surface; in yellow: penetratingobstacles.

[4] ICAO Annex 4 – Aeronautical Charts
[5] PANS- AIM Doc 10066– Aeronautical Information Management
[6] Enav https://www.enav.it

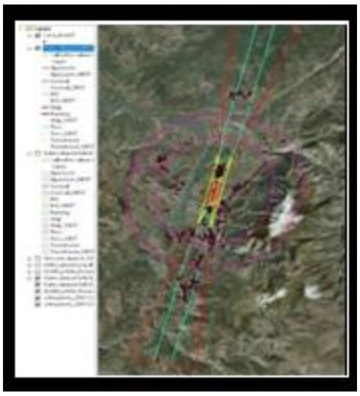


Figure 1: ObstacleLimitationSurfaces
[***Source***: Kukës Airport project]

Figure 2: Inner Horizontal Surface
[***Source****:* Kukës Airport project]

Figure 3: Conical Surface
[***Source****:* Kukës Airport project]

Approach Surface (RWY 01); Runway direction 01 has been considered as a non- instrumental approach runway. The surface has been designed using the ICAO standard parameters below reported: Only one section 3000m slope 2.50%. As represented in the next figure terrain in the south direction is highly impacting on the whole surface. Approach surface RWY 01 is shown light blue in *Fig.4*. In red is represented portion where terrain penetrates the surface; in yellow: penetrating obstacles

Transitional surface; has a lower edge beginning at the intersection of the side of the approach surface with the inner horizontal surface and an upper edge located in the plane of the inner horizontal surface. It is extending upward and outward with a slope of 14.33% (1:7). Its height is +45 m above the lowest THR. The figure 5, shown 13 trees and 19 artificial obstacles that penetrate surfaces. The transitional surface is shown in violet in *Fig.5*. In red is represented portion where terrain penetrates the surface and in yellow: penetrating obstacles

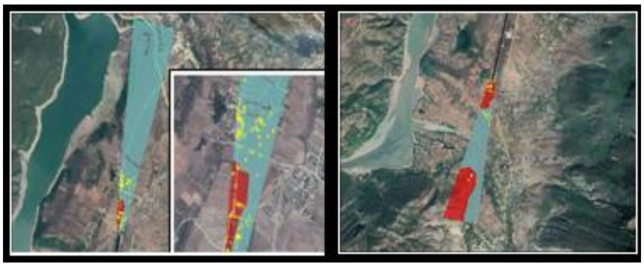


Figure 4: Approach surface RWY 19) (Left side); Approach surface RWY 01 (Right side)
[**Source**: Kukës Airport project]

Figure 5: Transitional surfaces
[**Source**: Kukës Airport Project]

The take-off flight path area: is defined in ICAO Annex 4 [1]. The take-off flight path area consists of a quadrilateral area on the surface of the earth lying directly below and symmetrically disposed about, the take-off flightpath,

Take-off climb surface TOCS **(RWY 19, RWY 01):** is an inclined plane, or other specified surface beyond the end of a runway or clearway. The elevation of the inner edge shall be equal to the highest point on the extended runway centre line between the end of the runway and the inner edge, except that when a clear way is provided the elevation shall be equal to the highest point on the ground on the centre line of the clearway. The Fig.6 *illustrates* the TOCS RWY 19 in pink; Portion where terrain penetrates the surface in red; and penetrating obstacles in yellow. The *Fig.7* illustrates the RWY 01 in Pink is shown TOCS RWY 01; in red is represented portion where terrain penetrates the surface; and in yellow is presented penetrating obstacles. The hill near Gostil highly impacts the surface at the first 800-900 m. TOCS RWY 01 is shown in pink.

Figure 6: TOCS RWY 19
[**Source**: Kukës Airport project]

Figure 7: TOCS RWY 01
[**Source**: Kukës Airport project]

2.3 Creation of 3D electronic Terrain and Obstacles Dataset (eTOD)

According to ICAO Annex 15, there are defined four coverage areas (Area 1, Area 2, Area 3, Area 4) which have different numerical requirements apply for sets of electronic obstacle data (*Fig.8*).

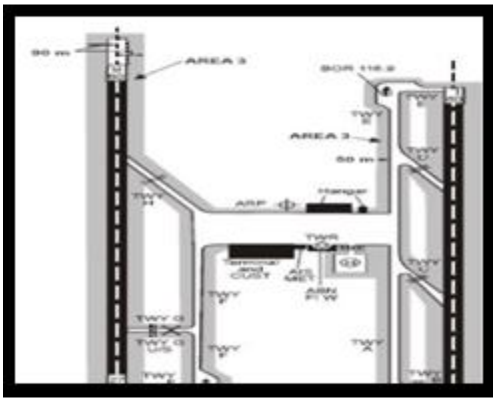


Figure 8: Area 3, according Annex 15
[**Source**: Annex 15]

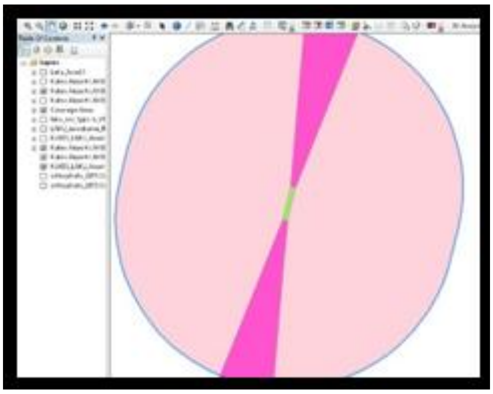


Figure 9: eTOD Coverage Areas
[**Source**: Kukës Airport project]

Using GIS in eTOD coverage implementation: Implementation of eTOD coverage areas specification for Kukës airport and creation of 3D areas starting from runway edges, are made using ArcGIS for Aviation. With known and surveyed points, runway 3D centerline and runway strips are created. Areas 2a, 2b, 2c and 3 are created from runway edges as described in Annex 15 and are demonstrated in this paper in *Fig.9*.

During the topographic survey detailed positional data for more than 2000 artificial obstacles were acquired and also about more than 300 natural elements (trees and vegetation). All data features surveyed and collected from field survey in the field phase of the project are displayed geospatially in ArcGIS for Aviation. In the same project we created coverage areas and verified in order to analyze their spatial location in coverage areas in 3D. Data features areanalysed to fulfill spatial requirement to be classified as "*obstacle*" in a particular coverage area. Those requirements are given in ICAO Annex 15[7] and ICAO Doc 10066 PANS-AIM[8]. The requirements described above are illustrated in *Fig.10*

Data features collected from field survey are spatially analyzed using ArcGIS for aviation for fulfilling the requirement above and those data that do not fulfil the requirement are excluded from being an obstacle. From all over 2000 data features collected from field survey campaign, 643 data features fulfilled the requirements, and are classified as obstacles, accordingly to their coverage areas. The results are displayed as above in *Fig.11*

In an obstacle data set, all defined obstacle feature types shall be provided, and each of them shall be described according to the list of mandatory attributes provided in ICAO Pans - AIM Doc 10066, Appendix 6, and table A6-2[9]. By definition, obstacles can be fixed (permanent or temporary) or mobile. Specific attributes associated with mobile (feature operations) and temporary types of obstacles are annotated as optional attributes. If these types of obstacles are to be provided in the data set, appropriate attributes describing such obstacles are also required.

Those attribute are listed as: Area of coverage Mandatory;

[7] ICAO Doc 10066 PANS-AIM
[8] ICAO Annex 15 – Aeronautical Information Service
[9] ICAO Pans – AIM Doc 10066, Appendix 6, Table A6-2

Data originator identifier Mandatory; Data source identifier Mandatory; Obstacle identifier Mandatory; Horizontal accuracy Mandatory; Horizontal confidence level Mandatory; Horizontal position Manda- tory; Horizontal resolution Mandatory; Horizontal extent Mandatory; Horizontal reference system Mandatory; Elevation Mandatory; Height Optional; Vertical accuracy Mandatory; Vertical confidence level Mandatory; Vertical resolution Mandatory; Vertical reference system Mandatory; Obstacle type Mandatory; Geometry type Mandatory; Integrity Manda- tory; Date and time stamp Mandatory; Unit of measurement used Mandatory; Operations Optional; Effectivity Optional; Lighting Mandatory; Marking Mandatory.

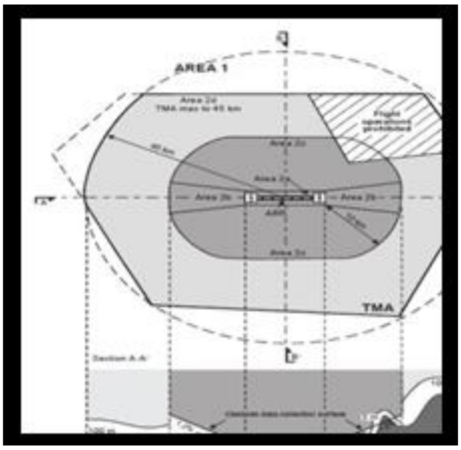


Figure 10: Area 2 - Numerical requirements for collection of obstacles
[***Source****:* Annex 15]

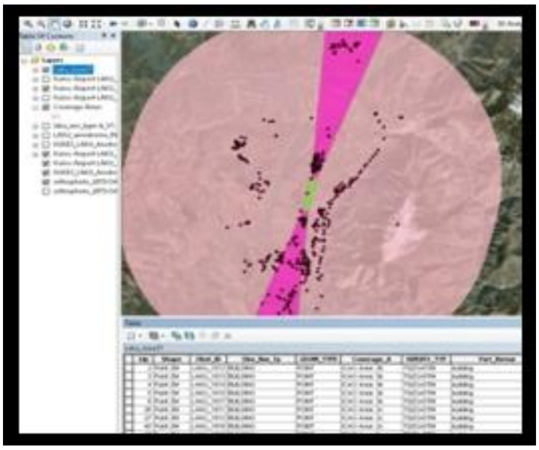
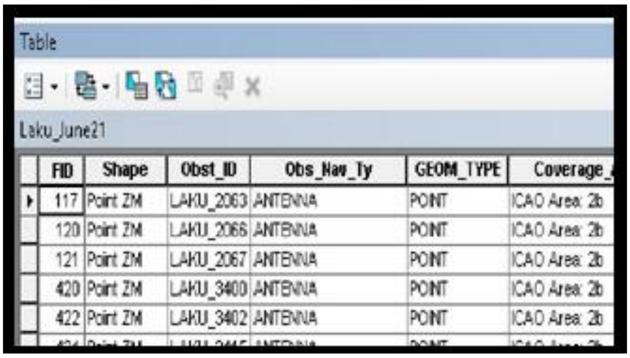


Figure 11: *ArcGIS Data classified as obstacles*
[***Source:*** Kukës Airport project]

Those required attributes are created for every obstacle and listed in the table of attributes in ArcGIS for every obstacle (*Fig.12*). Also, random checks are made for verification and validation of obstacle data. Those analysis are made to verify obstacle data for attributes and Standardization and to validate obstacle data for its 3D spatial location and its relations with 3D coverage area (*Fig.13)*. Obstacles data are analyzed, checked, verified and validated and prepared with all relevant attributes and information and ready for provision for intended users in required format and ready to be published in Aeronautical Information Publication.



Table
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FID	Shape	Obst_ID	Obs_Nav_Ty	GEOM_TYPE	Coverage_
117	Point ZM	LAKU_2063	ANTENNA	POINT	ICAO Area 2b
120	Point ZM	LAKU_2066	ANTENNA	POINT	ICAO Area 2b
121	Point ZM	LAKU_2067	ANTENNA	POINT	ICAO Area 2b
420	Point ZM	LAKU_3400	ANTENNA	POINT	ICAO Area 2b
422	Point ZM	LAKU_3402	ANTENNA	POINT	ICAO Area 2b

Figure 12: Table of obstacle data attributes
[***Source****:* Kukës Airport project]

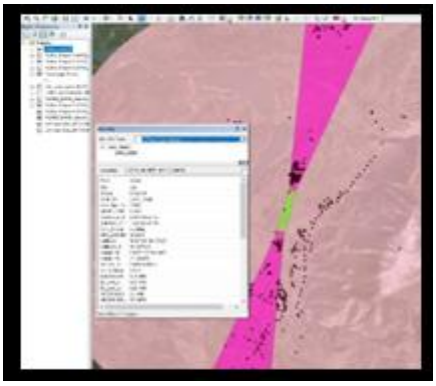

Figure 13: A random check for obstacle data to verify attributes and validate 3D spatial location
[***Source:*** Kukës Airport project]

2.4 Initiating an Aeronautical Information Service (AIS) exchange language model database AIXM for obstacles provision

Each data set shall be provided to the next intended user, together with at least the minimum set of metadata that ensures traceability. Globally interoperable aeronautical data and aeronautical information exchange models shall be used for the provision of data sets. To complete those requirements, an Aeronautical Information Service exchange model database is created. The objective of the Aeronautical Information Exchange Model (AIXM) is to enable the provision in digital format of the aeronautical information that is in the scope of Aeronautical Information Services (AIS). AIXM is based on Geography Markup Language (GML) and is one of the GML Application Schemas which is applicable for the Aeronautical domain. In order to meet the requirements of this increasingly automated environment, AIS is moving from the provision of paper products and messages to the collection and provision of digital data. AIXM supports this transition by enabling the collection, verification, dissemination and transformation of digital aeronautical data throughout the data chain, in particular in the segment that connects AIS with the next intendeduser.

The Aeronautical Information Conceptual Model (AICM) is a conceptual model of the aeronautical domain. It describes the features and their properties (attributes and associations) within the domain. The conceptual model is designed using the Unified Modelling Language (UML). The AIXM XML Schema is an exchange model for aeronautical data and a concrete implementation of AICM. It is an implementation of the Conceptual Model as an XML schema. Therefore, it can be used to send aeronautical information to others in the form of XML encoded data, enabling systems to exchange aeronautical information. The AIXM database is created using ArcGIS for Aviation and SQL express database technology [https://www.microsoft.com/en-us/sql-server].

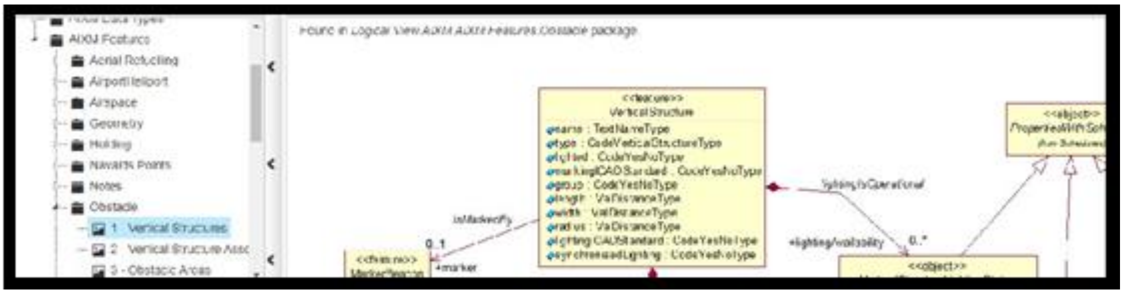

Figure 14: UML schema for AIXM database for Obstacle domain
[Source: AIXM Aero]

2.5 Publishing obstacles in Aeronautical Information Publication (AIP)

Aeronautical Information Publication (AIP) is a publication issued by, or with the authorityof a State and containing aeronautical information of a lasting character essential to air navigation. AIP contain several information related to general rules of flight operation, flight operation procedures, airports, radio communications, airports facilities, obstacles and aeronautical maps. Publication of obstacle data sets has to be announced in the National AIP in section GEN 3.1.6. Obstacle data for Kukës Airport are announcedine AIP Albania, in website https://albcontrol.al/al/aip/inGEN3.1.6.

Data sets shall be amended or reissued at such regular intervals as may be necessary to keep them up to date. This requirement means that every time there is a change in obstacles dataincluding new obstacle, deleted obstacle or change in any of attribute of obstacle, they have to be keeping updated in Aeronautical Information Publication (AIP). The availability of up-to-date obstacle data is especially relevant in the vicinity of airports, since operational take-off performance calculations fully depend on proper obstacle information reflecting the current reality. The eAIP Albania obstacle data can be founded and download in the linkhttps://albcontrol.al/al/aip/

3. Conclusions and Recommendations

Reviewing the Initiating Project of Kuksi Airport arrived in conclusions that:

Obstacles collected from field survey campaign and analysis carried out with ArcGIS for Aviation for the present preliminary assessments identified some significant areas where obstacles and terrain are highly impacting the obstacle limitationsurfaces.

According to obstacle limitation surfaces analysis it is clear that in the Southern area of the airport (in the approach to runway direction 01 and take-off from runway 19 direction) the scenario is more critical, and because of that depth analysis will be done with respect to instrumental flight procedure[10] development perspective related to approach RWY 19 and departure RWY01.

The software ArcGIS Aviation is a very good tool to analyze, create, visualize and provide ETOD for the operational purposes.

It is recommended to be developed a Feasibility study to displace threshold 19 to mitigate limitations provided by both artificial and natural obstacles located on the Northern area. To guarantee the accommodation of foreseen commercial traffic, it is highly recommended that landing and take-off available distances should be maintained and so an extension in the southern direction of the runway has to bedeveloped.

Depending on obstacle data analysis and aircraft flight operation[11], Runway 19 is recommended as most relevant scenario for designing the flight procedures[12] for arrivals and departures.

List of obstacles in corresponded areas will be used to design flight procedures for Kukës airport. Therefore, is highly recommended that obstacles data have to be monitored and up to date since are especially relevant in the vicinity of airports and operational take-off performance calculations fully depend on proper obstacle information reflecting the current reality.

Therefore, to achieve the objectives the collaboration between authorized sources to assure the interoperability and traceability of data processes from data collection to flight operation is recommended. This consists of several Stakeholder Lines of Action (SloA) for State regulators (REG), ANS Providers (ASP) and Airport Operators(APO).

4. Acknowledgments

This paper Review is realized with understanding of AIS Director at Alb control Mr.Ilir Zhamo. All data published

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[11] ICAO Annex 2 – Rules of Air
[12] ICAO "Aircraft Operations" Doc 8168

here have the prior approval of ALB CONTROL.

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