Developing a Comprehensive Digital Library Using Airport Geographic Information Systems (AGIS)

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Abstract. GIS can provide airport management staff with visual pavement information and powerful analysis tools. The spatial information managed by GIS can ensure the accumulation of valid data concerning the attributes of airport pavement. Based on the principles and general implementation process of GIS, and the characteristics of airport pavement management, this paper describes the implementation process of GIS for planning and design of Erbil airport.

To organize the spatial entities effectively, several layers were set according to the characteristics of spatial entities. The spatial database was established, and then the function design of GIS software is presented including map exploration, map location, spatial query, rendering style and output of map.

Airports are finding that integrated geographic information systems (AGIS) can help them to better manage both air- and ground-side operations. In this paper we present a representative case study of the AGIS for Erbil International Airport buildings and pavements. The study generated results in the form of a multi-layer map, whereby each layer has information that contains a comprehensive database.

There are two primary types of pavement utilized in the construction of runways, taxiways and aprons for modern airports. These are classified generally as rigid pavement and flexible pavement, each involving a different approach of analysis, design and construction. The choice of which to use depends upon local conditions, construction difficulties and economics. Consequently, a comparative study of each type of pavement was made to find the most suitable pavement structure for Erbil International Airport (AIAP). The digital library for Erbil International Airport includes general information about aircraft noise pollution and its effect on the surrounding area of the flight track, generating a noise pollution map.

Keywords: Airports, Digital Libraries Digital Maps, GIS, Mapping, Photogrammetry, and Transportation
1. Introduction

Airports are now rapidly evolving and growing in number due to increased demand. Consumers and travelers are causing existing airports to think of new ways to meet their needs, while new airports generate the daunting prospect of building new facilities that are wholly integrated on both ground and air sides, and connected through integrated services that allow for higher levels of data management and provision of digital services to travelers.

Large airports might contain constant services for base operator, air traffic control, seaplane docks and ramps, emergency services, and passenger facilities such as lounges and restaurants. Also, an air station or airbase may be used as a military airport. Figure 1 illustrates.

![Figure 1: Example of an airport enterprise [1].](image)

In this research we tried to make use of the new GIS applications for airports. The integration of digital photogrammetry implementations into geographic information system (GIS) database presents many new possibilities. This integration allows photogrammetric data collection in a raster/vector-based GIS environment. In this section we describe the production of a mosaic for our study area, stereo pair and how the the ArcGIS software generated to prepare a digital map with multiple layers and themes, rather than making a noise pollution digital map.

GIS software provides civil engineers with a framework for the deployment and maintenance of critical data and applications across every aspect of the infrastructure project’s life cycle. This includes planning and design, data collection and management, spatial analysis, construction, and operations management and maintenance. The GIS provides the tools to assemble intelligent GIS applications and improve the project process by giving engineers, surveyors, construction contractors, and analysts a single data source from which to work. The central hosting of applications and data makes it easy to manage, organize, and integrate geographic data, including
CAD data, from existing databases to visualize, analyze, and make decisions [2]. Figure 2 illustrates this.

![GIS applications](image)

**Figure 2:** GIS applications [2].

1.1 Case Study

Erbil International Airport, (IATA: EBL, ICAO: ORER), is the master airport of the city of Erbil, which is located in the north of Iraq. Erbil International Airport (EIA) was built on land that was previously used as a military base and airfield until 1991. After the 2003 Iraq War, Erbil became popular with foreign investors. In light of the increasing need for safe access to the country, the Iraqi government invested US$550 million into the construction of a modern airport, which can be seen in Figure 3 [3].

![Erbil International Airport](image)

**Figure 3:** Erbil International Airport.
1.2 The old airport

The old airport of Erbil had a gross area of 7,000 m² (75,000 sq. ft), and was separated into arrival and departure halls. The old airport had three gates and one runway, which was originally intended for military purposes. The runway was 2,800 m (9,200 ft) long and was provided with an ILS system. The old airport’s services included a tourism information office, a branch of the Kurdistan International Bank, the airline company's offices, a cafeteria, duty-free shops, and a Korek Telecom office [3].

On July 1st, 2003 the construction of the airport began and on December 15th, 2003 the first aircraft landed at the original Erbil airport. Flights between Erbil in the north of Iraq and the surrounding regions and neighboring countries began shortly afterwards. In 2005, Iraqi Airlines began to run direct flights from Erbil to Europe [3].

The warehouse had cargo space amounting to 4,320 m² (46,500 sq. ft) and comprised export and import sections [3].

Figure 4 shows the location of the airport, relative to the city of Erbil.

![Figure 4: The site of Erbil International Airport relative to the city of Erbil](image)

1.3 The new airport

Having cost US$550 million, the new airport and its terminal building opened in 2010. The new airport covered an area of 27,000 m² gross with 17 gates included, and was completed by the Turkish company Makyul Cengiz, to designs by a company the Scott Wilson Group, a British company [4].

The new airport has the longest runway of the Middle East airports and the fifth-longest airport runway in the world after those found at airports in China, Russia, South Africa and America. Erbil’s runway is 4,800 × 90 meters (15,748 × 295 feet) and equipped for ILS CAT II operations. Six air bridges have been installed for easy access to and from the aircraft, and in total
the airport can accommodate 12 aircraft at any one time. The new terminal features modern amenities such as currency exchange offices and duty-free shops. The terminal features CIP zones for visiting business jets and a VIP terminal for visiting dignitaries and diplomats [3]. Figure 5 shows the terminal building.

Figure 5: Erbil International Airport terminal building

1.4 Data collection and conversion

Both digital and analogue data were gathered for the study area, including a digital base map for the Erbil airport site; eight digital aerial photos supported by surveying department as given in Figure 6; historical data, photographs, survey and reproduction details, along with additional descriptive data, was also collected.

A mosaic is the assembly of series of overlapping aerial photographs to form one continuous picture of the terrain. It might consist of a single strip of photographs, termed a strip mosaic, or it may be several overlapping strips. The images used in this study were captured from space by the military, whereby focal length is 152.16 mm, flying height 456.48 m and the scale of the image 1 / 25000. Figure 6 illustrates. The completion of this work required sufficient aerial photos of the area. The mosaic was constructed from aerial photographs taken in flight. The entire mosaic has four images, so that there are common areas that show each image of the photo that followed in the line of flight, one is called the forward overlap or overlap the front and reaches 60%. There is also an overlap (i.e. side lap or (end lap) of under 30%. We converted this image to a digital format using a scanner.

Matching the mosaic images usually implies that the radiometric intensity data from one image indicating a specific feature should be matched to the intensity data from the second image, representing the same feature. This means more than just matching image intensity data correlation, because the same feature may look completely different from various points of view, or at different times.
2. First Step: Building the Themes of the Digital Map

After producing the photo for our study, a stereo pair of the final form ArcGIS software was utilized to prepare a digital map of multiple layers and themes. Configured themes were: buildings theme, runway theme, taxiway theme, runway and taxiway shoulder theme, blast pads theme, public and service access road theme, car parks, helipad, fences theme, aprons theme.

Subsequent completion of the drawing layers produced a digital map in its final form with scale of 1:25,000. The scale is convenient to the scale of digital aerial photographs, and used for producing the digital map with 14 points, which are listed in Table 1 and shown clearly in Figure 8. These were selected as check points and they were measured by using total station instrument for computing the outcome accuracy root mean square error (RMSE) through trying the below equations:

\[ R_i = \sqrt{Rx_i^2 + Ry_i^2} \] (1.1)

Where:

Figure 6: Digital aerial photos of the Erbil airport site, captured in 2010.
The Root Mean Square Error for check point \((i)\).

\(R_x\): The \(X\) residual for check point \((i)\), (the distance between the source and the transformed coordinates in \(x\) direction).

\(R_y\): The \(Y\) residual for check point \((i)\), (the distance between the source and the transformed coordinates in \(y\) direction).

Depending upon the residuals, the root mean square error in \(X\) coordinate, the root mean square error in \(Y\) coordinate, and the total root mean square error can be computed from the following equations:

\[
R_x = \sqrt{\frac{1}{n} \sum_{i=1}^{n} R_{x,i}^2}
\]  

(2)

\[
R_y = \sqrt{\frac{1}{n} \sum_{i=1}^{n} R_{y,i}^2}
\]  

(3)

\[
R_T = \sqrt{R_x^2 + R_y^2}
\]  

(4)

Where:

\(R_T\): total RMSE.

\(n\): number of check points.

The precise RMSE calculated through application of a specific equation (1.4) as represented above was 50 cm, which is the maximum resolution that can be used for research and scientific purposes; other resolutions are used for military purposes and other confidential studies. Figure 7 shows Erbil International Airport ArcGIS themes.


Table 1: Check points measured in EIA

| Remark | X (Northing) | Y (Easting) |
|--------|--------------|-------------|
| 1      | 404688.232000 | 4013278.768000 |
| 2      | 409169.326000 | 4013278.768000 |
| 3      | 404688.232000 | 4008490.757000 |
| 4      | 409169.326000 | 4008490.757000 |
| 5      | 406928.779000 | 4010884.762000 |
| 6      | 405808.506000 | 4012081.765000 |
| 7      | 408049.053000 | 4012081.765000 |
| 8      | 405808.506000 | 4009687.759000 |
| 9      | 408049.053000 | 4009687.759000 |
| 10     | 406928.779000 | 4013278.768000 |
| 11     | 406928.780000 | 4008490.757000 |
| 12     | 404688.232000 | 4010884.762000 |
| 13     | 409169.326000 | 4010884.762000 |
| 14     | 405808.506000 | 4010884.762000 |

Figure 8: EIA geometric correction points

2.1 Buildings

Erbil International Airport consists of many buildings; we represented these buildings as layers on the map and defined their information on the attribute table, then we divided them into four groups to facilitate the study of the project. Each group included subgroups, and they were given a specific color for each layer within the group as well as the data they contain. The groups were:

- Passenger Services
2.2 Runway theme

In Erbil airport there are two runways, the first one has a length of 4800 m and a width of 90 m (75 m without shoulders), the second has a length of 2800 m and a width of 36 m (30 m without shoulders). Figure 10 shows the layers of the runways [3].

Figure 9: EIA buildings theme

Figure 10: Runway theme
2.3 Taxiways theme

Figure 11 illustrate the types of taxiway, which are parallel and connecting taxiway, a path for airplanes to the runway.

![Figure 11: EIA taxiways theme](image)

2.4 Runways and taxiways shoulders theme

Figure 12 shows both runways’ shoulders; the long runway has a shoulder width of 7.5 m and the other has a width of 3 m, also this figure shows taxiways shoulders theme which focus on paints and lights.

![Figure 12: EIA runways and taxiways shoulders theme](image)
2.5 Blast pads theme

Figure (13) shows the areas where blast pads were situated, at the start and end of the runway.

![Erbil International Airport Blast Pads](image1)

Figure 13: EIA runways and runway blast pads theme

2.6 Public and service access roads theme

A network of roads, as shown in Figure 14, is used by passengers to access the terminal buildings inside the airport and also for other services.

![Erbil International Airport Roads](image2)

Figure 14: EIA public and service access roads theme
### 2.7 Car parks, helipads and fences theme

Figure 15 shows where the passengers and staff park their cars, areas for helicopter landing and airport fences.

![Figure 15: EIA car parks, helipads and fences theme](image)

### 2.8 Aprons theme

Figure 16: shows the placement of aprons in relation to the runways and taxiways with their shoulders and blast pads.

![Figure 16: EIA aprons theme](image)
3. Second Step: Building the Themes of Pavements of the Digital Map

Before generating a pavement digital map, we concluded that the Erbil International Airports road pavements may be divided into three groups, each group containing a different pavement layer which represents different airport road parts, as mentioned in Tables 2, 3, and 4, and shown in Figure 17.

**Table 2: Composite Pavements (Rigid and Flexible) used in Airport Runway**

| Layer                        | Thickness                                                                 |
|------------------------------|---------------------------------------------------------------------------|
| **Surface course layer** -  | 23 to 40 cm Portland cement concrete material + 5 to 10 cm asphalt surfaces |
| Bound surfaces of Portland cement concrete material covered with a layer of 5 cm to 10 cm asphalt surfaces that supply durability and stability for year-round traffic operations. | |
| **Base course layer** -      | 15 to 30 cm crushed stone or gravel material                             |
| a high quality gravel material or crushed stone which is imported to satisfy stability under high aircraft tire pressures. | |
| **Subbase course layer** -   | 30 cm lower quality granular aggregates                                  |
| built simply with non-frost-susceptible lower quality granular aggregates. Sub-bases are important for reducing the effects of frost action on the subgrade and increasing the pavement strength. | |
| **Subgrade** -               | Natural soil layer                                                       |
| is the ordinary on-site soil substances that have been split into an order, or in a fill portion. This layer must give a uniform and stable assistance for the overlying pavement structure. | |

**Table (3): Flexible Pavement used in Airport Taxiways**

| Layer                        | Thickness                                                                 |
|------------------------------|---------------------------------------------------------------------------|
| **Surface course layer** -   | 5 to 10 cm Asphalt surfaces                                               |
| Bound surfaces of 5 cm to 10 cm Asphalt surfaces that supply durability and stability for year-round traffic operations. | |
| **Base course layer** -      | 15 to 30 cm crushed stone or gravel material                             |
| a high quality gravel material or crushed stone which is imported to satisfy stability under high aircraft tire pressures. | |
| **Subbase course layer** -   | 30 cm lower quality granular aggregates                                  |
| built simply with non-frost-susceptible lower quality granular aggregates. Sub-bases are important for reducing the effects of frost | |

...
action on the subgrade and increasing the pavement strength.

**Subgrade** - is the ordinary on-site soil substances that have been split into an order, or in a fill portion. This layer must give a uniform and stable assistance for the overlying pavement structure.

| Layer                        | Thickness                      |
|------------------------------|-------------------------------|
| **Surface course** - Bound surfaces of Portland cement concrete material that supply durability and stability for year-round traffic operations. | 23 to 40 cm Portland cement concrete material |
| **Base course layer** - a high quality gravel material or crushed stone which is imported to satisfy stability under high aircraft tire pressures. | 15 to 30 cm crushed stone or gravel material |
| **Subbase course layer** - built simply with non-frost-susceptible lower quality granular aggregates. Subbases are important for reducing the effects of frost action on the subgrade and increasing the pavement strength. | 30 cm lower quality granular aggregates |
| **Subgrade** - is the ordinary on-site soil substances that have been split into an order, or in a fill portion. This layer must give a uniform and stable assistance for the overlying pavement structure. | Natural soil layer |

Table (4): Rigid Pavement used in Airport Aprons, Blast Pads & Helipads
**Figure 17:** Flexible Pavements used in Airport Public & Service Access Roads, and in Shoulders

**Note** that we used the maximum depth for each layer of pavements in our works, because Iraqi Specifications for Roads and Transportation used the maximum.

**Figure 18:** Erbil International Airport road pavements

4. Third Step: Building the Map Database

At the beginning we must have a personal geodatabase, containing the works which involve declared distances, statistics analysis, and the road pavement layers of Erbil International Airport. Figure 19) shows this.
Then inside the geodatabase we must create a new feature dataset as shown in Figure 20, in order to collect the data of feature classes.

The feature dataset must have a spatial reference as shown in Figure 21, this spatial reference is obtained from the satellite photo (import the reference) to ensure that layers of feature dataset (feature classes) are matched with the satellite photo.
Another feature class inside the feature dataset are developed as illustrated in Figure 22. (It takes the same reference of feature dataset, which will help us in defining the spatial reference only once in the feature dataset).

Each feature class represent a layer and we must define their shape as a polygon, line, point etc. In these layers, more fields can be added for each data type, as can be seen in Figure 23.
All other building geodatabases steps are illustrated in Appendix A, as images captured from the ARC GIS software, showing the consequent steps of building the database with the information and properties of the layers.

5. Developing the Final Map

Two final maps were developed as shown in Figure 24 and Figure 25 which include the EIA total map. This indicates nine themes, a scale bar and compass direction.
These two maps were produced according to the rules of drawing and production of maps from the Engineering Unit of Erbil International Airport.

6. Airport Development Suggestions

The year of 2013 underscored the position of Erbil International Airport as a departure point and entry point for Iraq. Of all passengers, 90.3% arrived from, or were departing to, international
destinations. Just 9.7% of passengers were travelling on domestic routes. For this reason, and others mentioned above concerning the growth of the city of Erbil, this indicates the growth of its airport, and plans should be made for the future development of Erbil International Airport. We propose three suggestions, starting from the main part of the airport, and using analysis of the runway from the airport master plan using Arc GIS software:

- To increase the capacity of the airport we propose to build a new runway parallel to the current one. The spacings between parallel runways vary vastly; the width of that spacing can be divided into far, intermediate, and close, depending upon the separation centerline distance among a pair of parallel runways. Close parallel runways are spaced from a minimum of 213.36 m (700 feet) for air carrier airports to a distance of less than 762 m (2500 feet). For our proposal we used a close parallel runway spacing of 250 m, and this is shown in Figure 26.

- Numerous airports possess a pair or multiple runways in various orientations, passing each other. These are referred to as intersecting runways. Intersecting runways are important when there is relatively strong wind from many directions, resulting in extreme crosswinds when only one runway is used. When the wind is strong, only one runway of a couple of intersecting runways can be provided, lowering the capacity of the airfield substantially. If the wind is relatively light, the two runways can be used simultaneously. The capacity of both intersecting runways relies on the location of the intersection (i.e., midway or near the ends), the manner in which the runways are operated for landings and for takeoffs, referred to as the runway use strategy, and the aircraft mix. Since the annual wind rate of the city of Erbil is northeasterly winds and the current runway is to the north, we propose the establishment of a second runway facing eastward, which intersects with the existing runway to increase the capacity of the airfield. Figure 27 illustrates.
Our third proposal involves increasing the width of the existing runway by 10 m (75+15 m old to 85+15 m new), taking into consideration modification of the existing buildings, roads and fences. The current length of the runway is adequate, and could be retained. Figure 28 illustrates.

**Figure 27:** Runway proposal development 2 (intersecting runway)

**Figure 28:** Runway proposal development 3 (widening existing runway).
CONCLUSIONS

Given that Erbil International Airport is rapidly becoming one of the main entry and departure points for Iraq, and in view of the clear growth of the city of Erbil which indicates the growth of its airport, plans should be made for the future development of Erbil International Airport with a view to increasing its capacity. From the results obtained in this study, the following main conclusions can be drawn and recommendations made;

1. Most airports still rely on the use of AutoCAD in mapping, meanwhile much useful data and information is lost with the passage of time.
2. To organize the spatial entities effectively, several layers were set according to the characteristics of spatial entities. These layers were developed depending on the using of the orthophoto of Erbil airport, which was corrected analytically and then considered an input for the AGIS.
3. The spatial database was established, and then the function design of the GIS software was presented including map exploration, map location, spatial query, rendering of map style and map output.
4. The AGIS digital map is essential for different applications including airport monitoring and management, pavement analysis, site development, noise pollution determination, and several navigational operations.
5. It is recommended to intersect the runways, since relatively strong multi-direction winds occur, which results in more crosswinds as just one runway is used. Both runways can be used simultaneously, when the winds are light.
6. It is recommended to increase the width of the existing runway by 10 m (75+15 m old to 85+15 m new), taking into consideration modification of the existing buildings, roads and fences. The current length of the runway is adequate.
7. It is recommended to increase the blast pads or safety area width of the runway, which is 90 m, while the minimum standards must be 500 ft (152.4 m). These modifications should also be applied to the runway proposals described above.
8. It is recommended that the construction of new residences around the Erbil International Airport site should be restricted, to reduce the noise pollution generated by aircraft activity.

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