IMPROVING ON AIRPORT'S GROUND HANDLING

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ABSTRACT

An integrated RFID and GIS system serves as the foundation of the unified identification and tracking for passenger, staff, luggage and freight, ground handling equipment. It includes the identification and tracking of all moving objects on the airport, thus enabling the operative management of business processes, the detection of errors and potential security breaches (e.g. unauthorized access). The costs associated with the loss of luggage, delays caused by late passenger can be reduced or avoided. The service level of the airport increases, while the associated costs are reduced and the ground handling of airports can be improved.

Keywords: RFID, Ground Handling, GIS, Benefit

1. INTRODUCTION

Today's airports are overcrowded and operate at peak capacity to be able to satisfy the ever-increasing demand. Most of the airlines and airports operate in a hub-and-spoke manner. Sometimes, transfer times are very short and it is just a question of luck if someone, along with his/her luggage, arrives at the final destination on time. Transfer times should optimally be at least one hour or more to make sure that the next flight can be reached in time and the baggage arrives as well. The allocation of the ground handling equipment must be very accurate to handle all the requirements for the on-time departure.

Queues are long, passengers don't have the time to spend on the airport queuing, nevertheless security restrictions must be kept. Everyone would like to lower the high costs wherever it is possible. Quick and accurate service, reliability, efficient use of available resources, the highest possible reduction in environmental burden and automation play an important role in air transportation. However, the all the above strive for efficiency must not impair security. Due to acts of terrorism, personal safety is of highest priority, but an accurate tracking and a more efficient organization in the control of other air services must not be omitted by the airport and its organizations either.

Another factor is the delay of flights, which may also be generated by passengers late at the boarding or even not appearing at all, or by a poor organization and management of ground support equipment and staff. Aircraft can only take off if all the checked-in baggage has its owner on board. If not, the baggage has to be offloaded.

Presently, there are many different tracking and IT recording solutions in use at the airports. Choosing RFID as the tracking technology I integrated these into a unified system, because Geographic Information System (GIS) is undergoing such a continuous development that it is now able to support indoor tracking in a cost-efficient way. Security rules have been continuously becoming stricter and stricter in the mass air transportation, which implies significant extra costs on airports, operators and airlines. Therefore, it is necessary to find solutions that meet security rules, while being able to render aircraft supply services in a sufficient quality and on time.

2. APPLICATION OF GIS IN AVIATION

There are several definitions for GIS, one of the most adequate is probably the definition by DoE (1987): "*a system for capturing, storing, checking, manipulating, analyzing and displaying data which are spatially referenced to Earth*" (MAGUIRE, 1991):. GIS is characterized by a great diversity of applications, it can be applied almost everywhere. They can include physical, biological, cultural, demographic, or economic information; they are valuable tools in the natural, social, medical, and engineering sciences, as well as in business and planning. It is integrating systems which bring together ideas developed in many areas including the fields of agriculture, botany, computing, economics, mathematics, photogrammetry, cartography, surveying, zoology, geography, informatics, aeronautics, defence, military etc. GIS is also a decision support system and management information system.

GIS was first applied in aviation around 1980's to handle more easily the aeronautical information and the map from a central database. It was applied for the production of Navigation Charts, Route Manuals, Aeronautical Information Publications (AIP) (Grootenboer, 1991). Around the 1990 a Holland company developed a demonstration system to see how GIS (ArcInfo) can be used in a command & control room as an aid to a security and control organization. It could only be applied as part of a multimedia system with additional data like pictures, video and sound to add information to the decision maker (Eijk & Holmuller, 1992).

Nowadays the airport infrastructure management uses geographical information system (GIS) extensively for tracking stationary objects (e.g. property). The air traffic control is using GIS with additional information (primary and secondary radar, GPS), for tracking airplanes, airport vehicles within the airport (airside and apron) if the required technology is available.

Nowadays mainly each airport has a Geographic Information System, applying for the land- and/or airside:

- Airspace Management
- Airfield Monitoring
- Flight Tracking (real-time)
- Aeronautical Information Management
- Facilities and Lease Management
- Airport Layout Planning
- Pavement and Asset Management
- Parking and Sign Management
- Utility and Facility Management
- Noise Monitoring and Modelling
- Environmental Assessment

Currently the management does not include tracking, passenger, luggage, crew and ground handling units, due to the lack of information and proper technical elaboration in the GIS.

3. GIS FOR TRACKING MOVING ELEMENTS

Stable and moving elements are identified by geographical coordinates in the GIS. Stable elements are very easy to identify: their geographical coordinates (latitude and longitude) are given in the system in relation to the Aerodrome Reference Point. The elevations of the airport and the highest point of the landing area are given, and the Aerodrome Reference Point, the designated geographical location of an aerodrome, is determined. As the airport is a small and delimitated area, moving elements are shown by their identification numbers (ID), and their geographical coordinates are only displayed on specific maps, as it is obvious that they are moving between the airport's geographical coordinates.

3.1. Stable Elements in the GIS

The airport's stable elements (except for buildings) are only mapped by their 2D coordinates, as their altitude is not always important. To see their geographical coordinates and location at the airport, the 2D coordinates are enough. Buildings or objects with more than one floor are mapped by each floor separately. The height of buildings is important in order to separate their floors to trace the movements of people and items. The actual movements on the different floors are shown on different maps, one map for each floor. It is possible to change between the actual maps displayed, and zoom in and out. It is also possible to see only one thematic (e.g. runways, lavatories, shops, etc.) on the map by turning on and off layers. However, zooming into the map, the actual real video footage is displayed in the background too, so it is possible to see things in real-time the chosen area. To define the geographical coordinates in the GIS, a reference system is necessary (Detrekői & Szabó 2003). An airport has its own reference system and reference point, for each airport individually.

3.2. Moving Elements in the GIS

Moving people and items within the airport are located by an identification and tracking technology, the RFID, and aircraft by SMR (Surface Movement *Radar).* On the map, always up-dated by the RFID signals and GIS, actual locations of moving elements are shown by their identification numbers (ID), and, in the background database, their geographical coordinates can be displayed too. There is no need to show geographical coordinates as first information, as the area of movements is an enclosed area. The information, i.e. the coded identification numbers (globally unique serial numbers generated by the tag producer) generated by the RFID tags used, appears on the screen as 2D points. By selecting the video view, the information appears in 3D. The coded identification numbers can be represented by just one character, depending on software pre-sets. It is easier to recognize to whom an RFID tag belongs. Obviously, if too many objects were put on the map, it would become chaotic and unreadable. In order to avoid this high object or information density, the system can set the process of generalization (Elek, 2007), and show only the requested type of moving elements. The system does not provide more information than the serial number, so the privacy rights can be kept. Further information is only given after the authorization steps.
The RFID signals are channelled into GIS through an interface system, which should be installed based on the requirements for handling processes business processes and security requirements. The interface is converting the RFID signals to able to be captured in the GIS *(see Fig. 1)*.

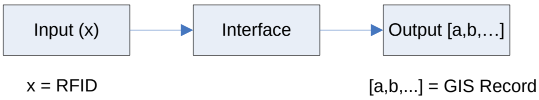

Figure 1-Interface transmitting RFID into GIS

(Source: Own Research)

The RFID signal (x) at the reading point after the channelling is opening the corresponding data (records) in the GIS ([a, b, …] are the data listed *below*. The gained information can be visualized in different ways in the GIS (e.g. maps, lists, diagrams, reports, tables, etc.) and in video format. Identification numbers are automatically shown on each map: the large airport map, e.g. just the map of the building, and the specific floor map. The user can choose which map he needs to pinpoint a location. On the map, the movements of each element are updated automatically. Depending on the tracing technology, in case of a point –to – point tracing, the position just jumps from one point to the other (passive RFID tag). In case of a

continuous tracing, the movement flow will be drawn on the map (active RFID tag). Beside the identification number in the background table or by clicking with the mouse, specific information on people and items is shown on the map step by step. On the screen behind the map, the location's actual video is shown; the video cameras' recordings are integrated into the GIS. The two steps of opening the information and authorization requirements are necessary due to privacy issues.
Based on the analysis of information required for the traffic and operational management and monitoring of airports (Bite, 2008) the proposed data structure and content for an RFID enabled architecture with the required security allowance to the data is shown in for passengers below and for the other moving elements (baggage, cargo, ground support equipment, staff, vehicle) it can be elaborated in an analogue way.

Departure and Transfer Passengers:

RFID ID Number

ID tag reading

Flight Number
Boarding Time + Gate
Security and Border Control Information
Passenger's Location inside the airport

Special Authorization
(e. g. Flight Agent)

Pass. Name
Pass. Mobile Number
Pass.-Bagg. Reconciliation
Final Destination (if Transfer)

Arrival Passengers:

RFID ID Number

ID tag reading

Flight Number
Bagg. Belt Number
Security and Border Control Information
Passenger's Location in relation to its Bagg.

Special Authorization
(e. g. Flight Agent)

Pass. Name
Pass. Mobile Number
Pass.-Bagg. Reconciliation

In case of the following elements, the information on the screen for the authorized person is:

- ***Passengers (P)***: Passengers' RFID numbers or just P's for Passenger are shown on the map. By clicking on the ID or the letter code with the mouse the first information that comes up is:
    - Flight number
    - Boarding Time (on time or not) and Gate
    - Security and Immigration Information
    - Passenger's location in relation to his/her flight

  If the system or the employee spots any problem with the location of a passenger (e.g. he/she is late to his/her flight, etc.), the system (automatically) or employee (manually) sends a signal (e.g. sound, vibration) to that passenger's RFID tag to warn him/her not to be late at the gate. If the passenger is not reacting properly, the employee can ask for authorization from the flight agent or send a signal to the flight agent to inform the passenger by name. If the authorization is granted, the following information will appear in the table of the passenger:

- Passenger's Name
- Passenger's Mobile
- Passenger's Checked-in Baggage data and Actual Baggage Location
- Final Destination (in case of a Transfer Passenger)

- ***Baggage (B):*** By clicking on the ID number or just a B for Baggage it is shown automatically its:
  - Flight Number
  - Flight Time
  - Final Destination
  - If it has been already checked by the security
  - If it has been already sorted
  - Its actual location:
    - On the way to the aircraft
    - In the container or tug
    - Waiting position

  If it is not in the right position in relation to its flight number and data, the system (automatically) or the employee sends a signal to the handling agent with the above listed information. If there is a problem, only the handling agent is authorized to receive the following information from the system:
  - Baggage Owner's Actual Location
  - Baggage Owner's Information (Transfer Passenger)

Analogously, it is possible to identify, monitor and manage the staff, cargo, mail and the ground handling equipment, alerting in case of process errors or abnormal activities (e.g. entering restricted areas without authorization).

- ***Cargo (C):*** By clicking on the ID number or just a C for cargo shipment or mail it is shown automatically its:
  - Flight Number
  - Flight Time
  - Final Destination
  - If it has been already checked by the security
  - If it has been already sorted
  - Its actual location:
    - On the way to the aircraft
    - In the container or tug
    - Waiting position

  If it is not in the right position in relation to its flight number and data, the system (automatically) or the employee sends a signal to the handling agent with the above listed information. If there is a problem, only the handling agent is authorized to receive the following information from the system:
    - Shipping Documents Reconciliation
    - Sender and Consignee Personal Information
- ***Item (I)***: A good organization of the Ground Support Equipment is very important. The RFID ID or an I for Item appear. The employee can see the following information:
  - Current daily or periodic timetable of the item
  - Its Current Task and the Performance of it
  - Current Location
- ***Staff (S):*** The locations of employees are very important to know. The security officer or the task organizer can see the following information by clicking on the ID or an S for Staff of an employee :

- Employee's Current Task
- Employee's Location
- Employee's Allowance to its actual Location

If the system realizes that an employee's current location is within an area not authorized for that employee, the system sends an alarm and shows more information on it:

- Employee's Name
- Employee's Company Name
- Employee's Field of Work

- ***Vehicles (V)***: The RFID ID's or V's are shown. All cars, buses, etc. entering or being active within the airport must be tracked with the following data:
    - Official Visitor's Car or Employee Car
    - Current Location and Task
- ***Aircraft (A):*** All aircraft on the ground are indicated. Aircraft ID numbers are provided by the SMR. The following information is listed:
    - Departure Time
    - Parking Position
    - Handling Situation: Done and still to do items
    - Handling and Departure Time Relation

To obtain this information the RFID tag has to fulfil a set of minimal technical requirements. The minimal memory to store and manage the above information has to be able to handle a maximum of 10-15-20 data, each data has max. 20 records (characters), according to this the minimum memory needs to be 400 byte concerning that 1 character is 1byte. The nowadays memory of an RFID tag is varying between 8byte and 32kbyte (RFID Journal. 2010), so there is possibility to use any special character with higher memory needs but then the tag is price is as well rising. The reading time to read the RFID tag is1-2 seconds, to transfer the information from the RFID reader into the GIS through an interface the minimal data transfer time of 1-3 seconds. The reading distance is depending on whether using a passive tag or an active tag. In case of a passive tag where special reading gates (points) are necessary the distance is depending on the height of the gate and in case of active tag the airport size of the active area has to be defined. The reading distance depending on the used RFID tag can vary from 10 cm up to more 100meters.
The passenger and handling process does not change, but the way the passengers and their baggage are identified and tracked changes with the RFID/GIS integration compared to the nowadays applied technologies. With this system the alerting and problem solving is fast and automated. On the figure below are shown *(see Fig. 2)* all the RFID activation-de-activation points, reading points and their information. Before the RFID de-activates itself at the boarding, passenger and baggage will be reconsiliated. It tracks and shows if the boarding passenger's luggage is already in the airplane's compartment or not or where it's actual location is. It is important that a plane can only take off when all loaded baggage has their respective owners on board. In case of lost baggage delivery this is not possible, but this information is stored on the RFID tag of the baggage, so no false alarms can be sent out. The RFID tags will only be de-activated if both are on the plane or on the last check point. If the luggage is on the airplane but its passenger not, the alarm will be sent out to the flight coordinator at the boarding gate. In the RFID/GIS system the information is shown immediately and in case of any problem the database opens itself after the security allowance steps taken *(see above)*, no extra communication is necessary to be taken.

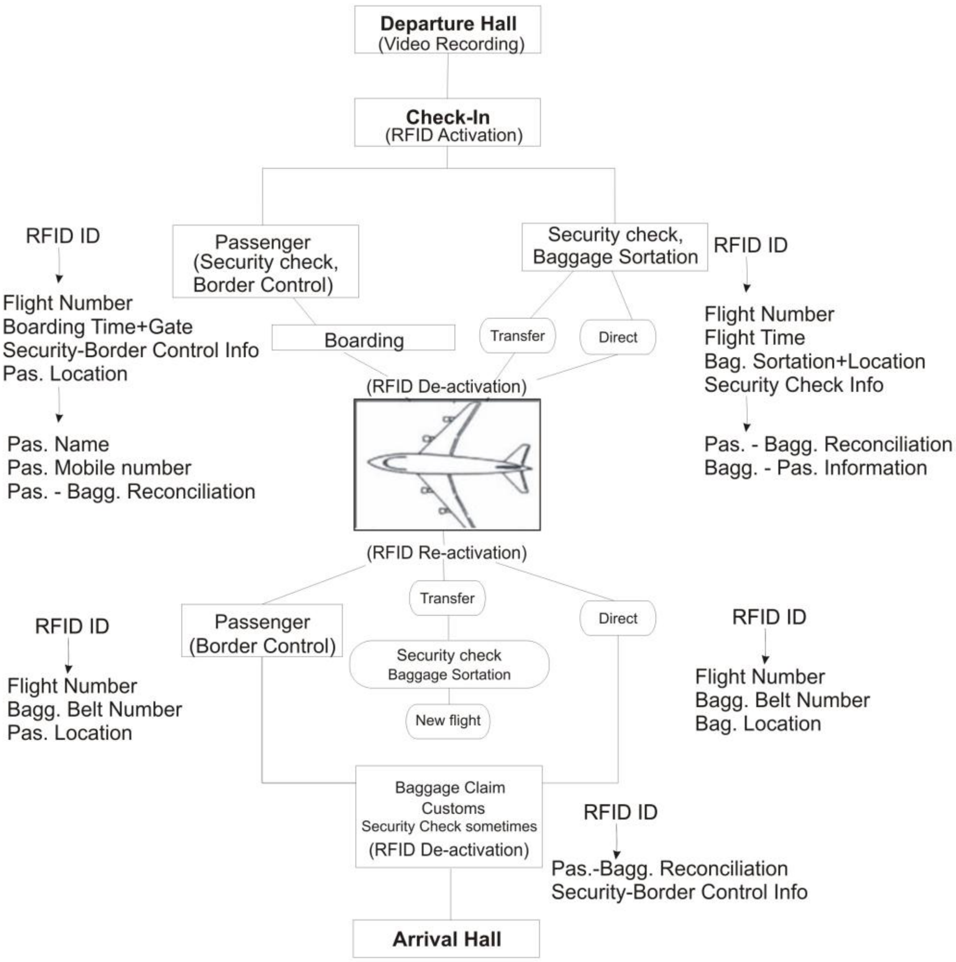

Figure 2-Passenger and Baggage GIS Data Checkpoints

(Source: Own Research)

The figure below *(Fig. 3.)* shows the RFID activation – de-activation points and the necessary combined security information required at any type of access point for people working at the airport. The authorization and the type of task information *(see above)* will be monitored at those points as well. The non-public entering points are covering all those areas that need special permit for accessing and are not open for passengers and visitors, etc., for the people working at the airport are many special restrictions for accessing the airport areas, these will checked here too. The computer-based workstation covers the computer, PC, PDA, etc. and all software that need special allowance to be accessed.

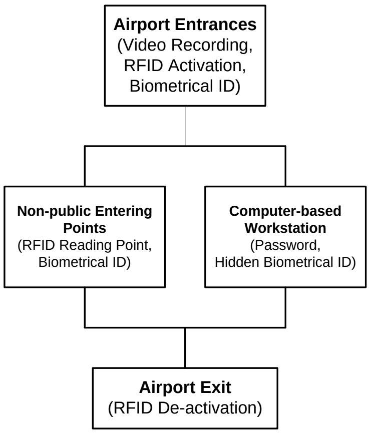

Figure 3-RFID/GIS Data Checks at Access Points for Staff

(Source: Own Research)

Analogously, it is possible to identify, monitor and manage the staff, cargo, mail and the ground handling equipment, alerting in case of process errors or abnormal activities (e.g. entering restricted areas without authorization). It allows to send new information for the staff and ground handling equipment, to overwrite their actual processes and tasks. The better staff and GSE allocation is possible in a real-time format and up-dating their business is any time possible. The only difference is that in case of passengers and their luggage other additional information is necessary to be on the RFID then for staff and GSE equipment. The cargo and mail handling requires to store similar information to the passenger's and to that of baggage handling. The difference is their location within the airport and the document it requires, etc. The necessary information on the RFID tag is listed above for each person and item separately. The cargo and mail handling is analogue with the passenger-baggage handling, the staff's operative management and controlling is analogue with the GSE. Only the required and stored information for the effective handling, alerting and operative management is different.

3.3. Integration into the Local Information System

The above listed information is necessary for security, for traffic and operational management and business processes. All this information is shown on the GIS. On the main screen, ID numbers are displayed and after taking the steps, the information will be shown in the database. Each specific area of the airport can see restricted information from the database. Only information that needs to be known by a particular area is allowed to be shown in that area. Each specific area has its own GIS (as listed) within the large Airport GIS and all of them can be integrated together into the airport information system used nowadays (e.g. AODB, FIDS).

Security-GIS

The security personnel always receive information about the location of the elements shown above. The GIS provides a map and information on the current locations of the RFID ID numbers or the letter codes or currently chosen subject layer. On the screen, it is shown with the CCTV's actual footage.
In any case, if there is any kind of problem, the GIS have to recognize it automatically and inform the responsible personnel.

Comment [LT1]: értelmetlen

In case of late passenger, the system first automatically alarms the passenger's RFID tag and if there is no reaction of the passenger, the system alarms the security personnel and authorized personnel (e.g. the flight agent to that specific flight).
In any case, the movement history of a tracked person or item is stored and it is available for the authorized personnel to monitor. The history can be displayed in a graphical form by tracking the movements or the data can be shown in table form. The history is stored for 30 days.
From the system, employees can request to see the data for a given flight, or just see a single passenger's location, or to see all moving elements on the screen. But each handling agent's specific monitor (for each flight, one handling agent is responsible) can only see information necessary for that particular flight. Making special requests is possible.

Ground Handling – GIS

For the GH companies, it is necessary to know the latest information on the locations of their elements and the status of their current activities. This GIS for the GH, as shown below, always shows current task information and location. It shows the time left until finishing an activity. The GH items' locations are displayed on the map, so it is easy to find.
Locations of passengers and baggage are as important to avoid delays as they are for the security to detect any suspicious activities. Flight delays cost the airlines a lot of money and problems, depending on the kicked timetable in case of missing a slot. Knowing the information shown below, each employee of the GH company has access to the displayed information on his/her PDA used in his/her work. He/she is not allowed to see any personal information. The personal data are only available for the flight agent by a special allowance and only if there is no other possibility.
General Aviation is also served by a GH company if requested. As its passengers and baggage are handled differently from their own, further information is useless for the software. Border Control information and security screening information is available.
After analyzing the airport operational and business processes I extended the use of RFID technology that was originally proposed for passenger and luggage tracking to include other processes with similar characteristics such as the cargo and mail handling and the tracking of GSE. There is no principal difference from the tracking point of view, the only difference is the information stored on the tag.

Comment [LT2]: ez értelmetlen

Airport – GIS

The GIS above described and displayed is one piece of software. Its different users (e.g. GH, Security) are authorized to see different information, as for their work, different information is necessary.
The GH – GIS does not exchange information with the Security – GIS. The two units are integrated into the large Airport – GIS. For the airport, it is necessary to know where their employees and vehicles are and what their current tasks and shifts are, so they appear as different units. Also, the Border Control is exchanging information with the large Airport-GIS.
The GH-GIS sends the quantitative data information to the Airport – GIS (this is already the case now) for facility allocation. The new information sent to the Airport – GIS would be the current location, the current task report and a map, which is necessary for planning (especially in case of delays).
The Security – GIS exchanges information related to the security screening and the behaviour of any moving element.

Airport-GIS Integrated into the AODB currently used

AODB is the database used presently to see the future and the past. It is an Airport Operational Database, collecting all necessary information of all airport facility users and

minimizing the redundancy of information sent. It does not just deal with the information for preparing a flight's arrival (e.g. usable Check-In counters, Gate, aircraft parking position) it also makes the billing for an aircraft, and the shifts of the airport's employees. The Airport GIS can be implemented into the AODB and send the same information supplemented with current location information if queried. Previously, quantitative data were sent only to know facility attributes and allocation. With the Airport GIS, the allocation already knows how much time the previous task will take or after it is finished, sends an automatic current task report and shows everything on maps; image processing is available as well. The integration into the local airport information system enables to monitor, track, allocate and have all airport moving elements in one integrated system. The used GIS system needs to be able to handle many data and to have all-time a back-up system.
For airports not using AODB it can be integrated into any airport operational information system (e.g. FIDS, etc.).
The Airport GIS can be also send flight arrival/departure information to the requested places (e.g. internet, Taxi stand, Public Transport connecting the airport with the city centre or other cities, etc.)

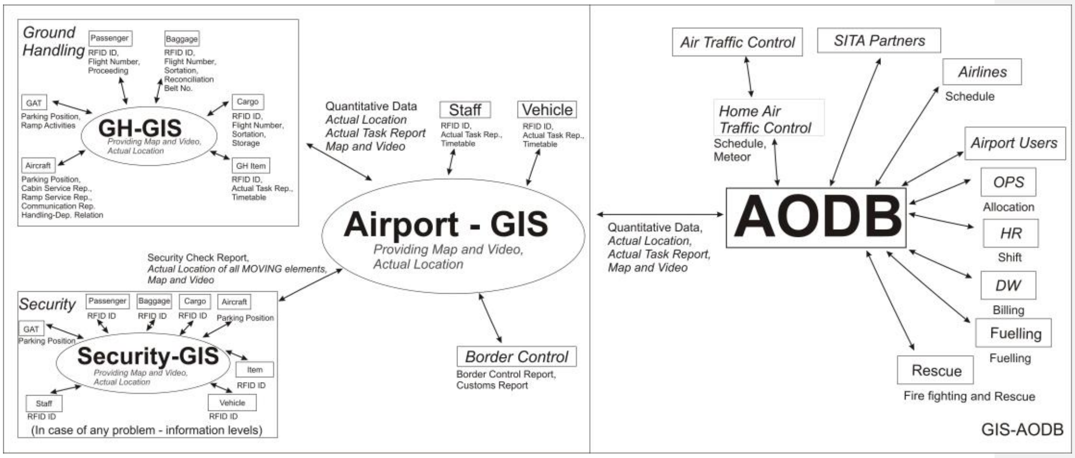

Figure 4- Airport- GIS-AODB

(Source: Own Research)

4. BENEFITS OF THE RFID/GIS

The RFID integrated into GIS can help reduce the costs of airlines and improve the airport's efficiency and capacity while improving the security.
The investment in such a system is worthwhile for many reasons:

- Less delays caused by ground handling activities
- Reduction of Passenger Handling and Baggage Handling time and achieving a higher efficiency (while reducing turn-around times)
- Decreasing baggage loss expenses
- Faster location of employees, passengers, ground support equipment, etc.
- Reducing time of some operational procedures (time requirements in minutes can be reduced to seconds)
- Less prone to human errors
- Faster and more accurate information flow
- Automated maps, image processing, reports and querying any statistical data
- Protection against terrorism

- Re-allocation of functionalities/resources and human resources
- Less problems with documents (e.g. reduced paperwork, reduced possibility of document loss)
- Environmental friendly (e.g. paperless)
- Improving Customer Service
- Improving reputation
- Real-time and non-real-time tracking of all airport moving elements
- The integration of all data required for an efficient airport operation management in one system

All the above-mentioned advantages result in a reduction of costs and time requirements and enable the re-allocation of current resources and expenses for better efficiency. It is very difficult to quantify all advantages, as a part of information in that regard are kept very strictly due to the fierce competition between companies, and some points are simply not possible to quantify at all. For this reason, the investigation of the efficiencies of the suggested system is based on the saving losses caused by baggage losses and flight delays caused by the ground handling, where the quantitative information on the real problem was available and published. The calculation is made with data where the source was not allowed to be published. The estimation in this chapter is based on the same data source of the same regional airport for the same year.

4.1. Qualitative Measures for the Analysis of Baggage Tracking System

The baggage loss is one of the biggest problems for airlines. Causes for losing a luggage can be diverse:

- Airline baggage system integration,
- The baggage process of an airport is overly complicated,
- New and stricter security regulations at the airport
- More congestions at the airport,
- Tagging errors or mistakes in the identification, sorting, loading or unloading of the baggage (it could simply fall off the trolley) at the departure or/and arrival /transfer airport,
- The transfer baggage could be directed to a false destination due to wrong identification or due to too short transfer times,
- Due to human errors at check-in (e.g. wrong typing, late check-in of passengers),
- Weather or space-weight restriction,
- Communication errors between the agents (e.g. in case of rerouting) or
- The BagTag may fall off the baggage.

In the last case the baggage is lost forever, the finding system lost luggage can not find it as it is not possible to identify it. According to IATA data this is the case with 800,000 bags in the world every year. The baggage can also get lost at the baggage claim without the error of the airline, airport or the operator:

- It can be taken by another passenger accidentally (due to similar appearances)

or

- It can be intentionally stolen.

The weak points of the baggage tracking system *(see Fig.5.)* points of the today's infrastructure are shown below, those problems can be minimised with the RFID/GIS integration.

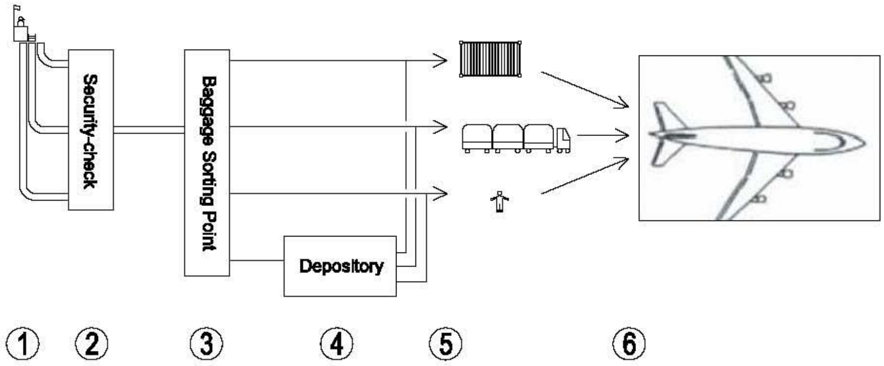

Figure 5: Weak Points of the Baggage Handling
(Source: Own Research)

In the model the group of problems of the weak point are united in one C factor as it is very difficult to express each of them and it is depending on the airport infrastructure and the actual type of applied equipment. The numbers are showing the main points where the application of the RFID/GIS can optimize the system and minimise the caused errors and generated losses and costs.

- **1. Check-in:**
    - Generating and printing barcode is more slowly then RFID tag issuing,
    - Data transfer time within the GIS is quicker then between the Departure Control System (DCS) and Baggage Reconsiliation System (BRS),
- **2. Security check:**
    - Congestion risks,
    - Number of available baggage belt is depending on the airport,
    - RFID reader can be implemented into the security check facility, then the reading and the sorting can be automated
- **3. Baggage Sorting point:**
    - Data transfer problems (e.g. has not arrived yet), with GIS it stays in the system,
    - Data reading speed is much quicker (about 1-3 sec),
    - Technology's reliability factor
    - No human worker is necessary,
    - Human errors can be minimised,
    - Congestion caused by slowly reading of the barcode is minimised as reader can be built into the security point or into a separate gate but the flow of the belt will not be stopped.
    - The sorting takes too much time, the system is reducing the time.
- **4. Drop-to-Drop service depository room**, which means that the passenger is checking-in remote in a hotel and will receive it back in the destination hotel. The luggage will be stored in a so called depository room.
    - The only error here by using the barcode application if the stevedore forgets the luggage in the storage room. The RFID/GIS system is remembering the stevedore of the drop-to-drop baggage, sending pre-signs to the competent workstation and showing the location and luggage details, in case of no reaction, the system sends automatically more warnings with higher pressure.
- **5. 2nd reading point before loading**:
    - The equipment allocation can be managed better,
    - Less human error,

- *See number 3*

- **6. Final check:**
  - With the GIS it is automated,
  - No extra reading if there is,
  - Automated match with the passenger boarding, with the barcode system it is not automatically checked and is more time consuming.

The simplified model for the estimation is:
The exact calculation for lost baggage according to the above is very difficult as it is mainly depending on the given special airport and it is different for each airport. To valuate or measure the above problems a long period observation is necessary. The observation period must include for example:

- Peak-hour
- Non-peak-hour
- Variation of human worker
- Variation of the facility
- Etc.

The simplified model can be used very well for each airport as information in relation to the real problem of the weak points of the infrastructure. But it has to be specified for each airport.

Estimated number of lost baggage: E_{LB}

$\boldsymbol{E_{LB} = B * R_L * C}$, [Pieces]

where B= total number of baggage,

R_L= Rate of lost baggage, formally:

$\boldsymbol{R_L} = 1 - \boldsymbol{f_R}$,

f_R= Factor of reliability, which is the reliability of the reading accuracy of the used technology *(barcode 85%, RFID 97%)*

C= Average constant factor (for a year), depending on the following attributes such as:

- Technological attributes(C_1):
  - Data issuing time (data generating and printing)
  - Data transmission speed from DCS to BRS
  - Data reading speed
  - Data damage possibility
  - Facility requirements (e.g. maintenance)
- Airport infrastructural attributes(C_2):
  - Number of available baggage belts
  - Congestion of the baggage due to human reading speed
  - Other errors due to human factors
  - Available staff working at the check-in
  - Available staff working at the baggage sorting
  - Congestion of the baggage on the belt
  - Airport size (e.g. handled traffic)
  - Airport configuration (distances)

This list is extending by analysing and specifying a special airport. C_1 and C_2 are independent from each other.

$$C = \prod_{i=1}^{n_1} C_{1_i} + \prod_{j=1}^{n_2} C_{2_j} = \sum_{k=1}^{2} \prod_{i=1}^{n_k} C_{k_i}$$

Estimated value of costs: E_C

$$E_C = E_{LB} * C_{LB}, \text{[EURO]}$$

where: C_{LB}= the cost per lost baggage of the company.

Based on statistical data of a regional airport (the source cannot be published due to company restrictions) the model can be estimated and the result of the estimation is shown below *(see Table 1.):*

Table 1-Costs Caused by Baggage Loss for a Regional Airport in 1 Year

Regional Airport With Barcode	*Passenger Checked-in baggage [Pieces]*	*Mishandled Baggage [Pieces]*	***Costs= Euro 93/Luggage***	***Savings*** [EURO]
2009	3,342,022	19,346	1,791,428	
2008	3,006,199	26,382	2,443,480	
Regional Airport With RFID	*Passenger Checked-in baggage*	*Mishandled Baggage*	***Costs= Euro 93/Luggage***	
2009	3,342,022	3,870.06	***358,445***	***1,432,983***
2008	3,006,199	5,278.89	***488,930***	***1,954,550***

According to the calculation of *Table 1.* the RFID/GIS technology reduces the baggage losses to 20%, that means that the reduction of baggage losses is 80% due to better reading reliability factor. Concerning the estimation a reduction of 21,104 baggage loss can be expected which means a cost saving of 1,954,550 Euros a year, the return on investment can be expected in 1-2 years just from the reduction of the baggage losses.

The above elaborated model can be analogously applied for passengers, for cargo and mail handling, where the principle and operational management is the analogue only the location or check-points, or the tools are different.

4.2. Quantification of Flight Delays due to Late Passengers

The elaborated model for the baggage handling can be applied in an analogue way for the passenger handling. The differences of the weak points are shown in the figure below *(see Fig. 6)*. Those points can be speed up and their problems minimised by using the RFID/GIS technology.

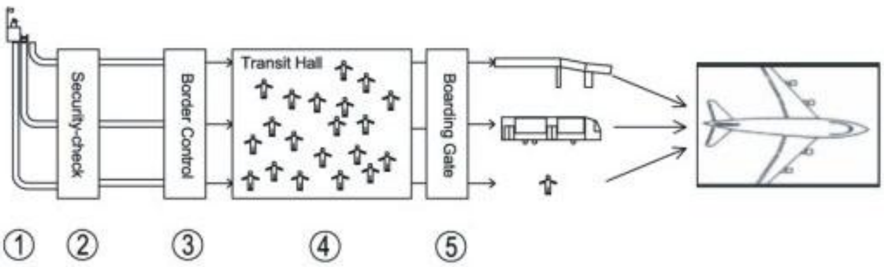

Figure 6: Weak Points of the Passenger Handling before Departure
(Source: Own Research)

- **1. Check-in:**
    - Generating and printing 2D barcode takes more time then RFID tag issuing,
    - Data transfer time within the GIS is quicker then between the DCS and BRS,
    - The nowadays used self-check in or web-check-in makes it unnecessary, but using the RFID or RFID Passport as Boarding Pass is even more facilitating the process
- **2. Security check:**
    - The risk of congestions are very high,
    - The queues are long,
    - Not sufficient security gates are open,
    - The security check proceeding is too slow
- **3. Border control:** If there a border control *see number 2*,
- **4. Error due to passengers mistake**: The plane can only take off if the owners of the checked-in baggage are on board. Passengers might be late at boarding gates due to a wide array of reasons:
    - Late arrival at the airport
    - Being held up in the long queue of border control or security check
    - Getting lost within the terminal building,
    - Not being able to find the way to the correct gate,
    - Signs at the airport are not clear enough,
    - Being lost at the shops or any of the airport facilities,
    - Having forgotten the time and the flight,
    - Not being able to understand or hear the loudspeaker in case of a gate change,
    - Medical problems or emergency might have occurred
    - Losing Boarding Pass within the terminal
    - Late arrival of the previous plane (the airline decides on the spot whether to wait or not)
- **5. Boarding:**
    - Queuing
    - By manually check of boarding cards, the proceeding is slowly

To simplify and speed up even more the procedure of handling and search connecting the border control, security and check – in, this way the queuing ups and the waiting time could be reduced. In case of indirectly connecting the 3 points, at least a message could be sent to the boarding gate of the passed RFID ID to know if the passenger has already passed those checks or not. Due to privacy rights, only the RFID ID could be sent, not any private information. The order of proceeding concerning security check and border control depends on the airport. Uniting the check-in, security and border control check would reduce the queues and waiting time and increase the service level for passengers.

RFID used as **baggage** tags would speed up **searching time to 3-5 minutes** as with the **GIS system**, the stevedore immediately knows where bags are and can unload them directly as the search is not based only on his memory. The waiting time for a passenger is now **between 5-20 minutes**. To find a passenger with RFID and GIS monitoring, this time could be **reduced to 1-5 minutes**. This amount of delay can be made up leeway, the delay cost is 0.

Using the GIS/RFID speeds up passenger, baggage and cargo handling and the total handling the aircraft by knowing at any time what where is and to what extent the current task is completed. This information is in available real-time to the flight related employees. Later, if there was any mistake, problem or delay, the information can be traced back to who was not on time or who is responsible for damage. No paper is used, everything is automated and environmental trends are kept.

Estimated number of late passengers: E_{LP}

$E_{LP} = P * R_L * C$, [Pieces]

where P= total number of passengers,

R_L= Rate of late passenger, formally:

$R_L = 1 - f_R$,

f_R= Factor of reliability, which is the reliability of the reading accuracy of the used technology *(barcode 85%, RFID 97%)*

C= Average constant factor (for a year), depending on the following attributes such as:

- Technological attributes(C_1):
  - Data issuing time (data generating and printing)
  - Data reading speed
  - Data damage possibility
  - Facility requirements (e.g. maintenance)
- Airport infrastructural attributes(C_2):
  - Number of available security gates, border control gates
  - Congestion at the security gate, border control gate due to human reading speed
  - Other errors due to human factors
  - Available staff working at the:
    - Check-in
    - Security gate
    - Border control gate,
    - Boarding gate
  - Congestion of the checks (e.g. many passengers)
  - Airport size (e.g. handled traffic)
  - Airport configuration (distances)

This list is extending by analysing and specifying a special airport. C_1 and C_2 are independent from each other.

$$C = \prod_{i=1}^{n_1} C_{1_i} + \prod_{j=1}^{n_2} C_{2_j} = \sum_{k=1}^{2} \prod_{i=1}^{n_k} C_{k_i}$$

Estimated value of costs: E_C

$E_C = E_{LP} * C_{LP}$, [Euro]

where: C_{LP}= the cost per late passenger for the company.

Based on statistical data of a regional airport (the source cannot be published due to company restrictions) the model can be estimated and the result of the estimation is shown below *(see Table 2, see Fig. 6.):*

Table 2-Costs Caused by Late Passengers for a Regional Airport in 1 Year

Delay Caused by Passengers	**Actually**	**Reduced**
Present Delay times (mm:ss)	8:38	2:09
Amount of flight [Pieces]	39	10
Costs (50Euro/Min) [Euro]	450	100
Annually saved [Euro]		**350**

(Source: Own Estimation)

Delays caused by passengers, which are not able to be made up in the leeway even with the system are, according to the above *(see Table 2.)* estimated calculation with the minimum efficiency of 30% with the average cost rate of 50 Euro/Min. It is just 0,17% of the total delay times. According to the estimation a reduction of 29 flight delays due to late passengers can be expected which means a cost saving of 350 Euros a year.

I analyzed the extensibility of the model to include the delays caused by business process errors, I defined the critical factors for delays. I came to the conclusion that the model can in an analogue, parallel way only be partially extended to the delays that are due to handling activities.

5. CONCLUSION

The primer goal of GIS is to identify the geographic coordinates and attributes of stationary objects. RFID integrated into GIS and the technologies in common enables to identify moving elements within a closed area in- and outdoors, while serving the improvements of airport capacity and airport operations.

GIS is the best system to integrate all airport stable and moving elements into one system and to identify their actual location and tasks report, and gives a solution to all the above described problems in one common system. For identification and tracking of the moving elements and for the automation of terminal operations, the best current technology is RFID. GIS enables also to integrate video recordings. The monitoring of moving elements can be in real-time too that facilitates the re-allocation of equipment, tasks for staff and a better operative management and it is improving on the ground handling activities and services.

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