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Application of Geoinformatics for the Improvement of Airport Processes

by

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Nyilatkozat

Alulírott Bite Katalin Emese kijelentem, hogy ezt a doktori értekezést magam készítettem, csak a megadott forrásokat használtam fel. Minden olyan részt, amelyet szó szerint, vagy azonos tartalomban, de átfogalmazva más forrásból átvettem, egyértelműen, a forrás megadásával megjelöltem.

Budapest, 2010. április.

Declaration

I, Katalin Emese Bite, hereby declare that this thesis was written by me, I only used the sources that I stated. I marked all sections that I took over word for word, or with the same content but different wording, with clearly indicating the source.

Budapest, April 2010

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Introduction

Today, more and more business and leisure travellers are flying to their destinations, the airports are overcrowded and operate at peak capacity to be able to satisfy the ever-increasing demand. Most of these people are flying through a third airport (a hub airport which is used as a transfer place) before reaching their final destination, as most of the airlines and airports operate in a hub-and-spoke manner. Sometimes, transfer times are very short, it is just a question of luck if someone, along with his/her luggage, arrives at the final destination on time. Transfer time 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. Another place to loose a baggage is the baggage claim of the final airport. After collecting their baggage, passengers leave the airport without checking if they are taking their own luggage and not someone else's.

Queues are long, passengers don't have time to spend on the airport queuing, but security restrictions must be kept. Everyone would like to lower the high costs wherever it is possible. Such an area is the amount of costs generated by baggage loss during the air travel.

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 above 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.

The goal of the dissertation is to elaborate an automated, secure system for the identification and tracking, especially focusing on passengers and baggage, improving on their handling by locating them, giving operational up-date information and follow their position. The point is to track airport elements on a new way by using geographical information system which can be implemented into the nowadays used technologies and the international trends. Where the technology and operational processes allow the extension or it is easy to apply for other airport elements (e.g. staff, cargo and mail handling, ground support equipment) I use the opportunity to enlarge the area of the efficiency.

My initial research goal is to study existing technologies and technologies under improvement, an analytic evaluation of such technologies and to explore any uncovered but still unused development possibilities.
The goal of my research is to work out a GIS system, capable of the followings:

- A better utilization of airport capacity and security
- Tracking and mapping moving elements,
- Improving on the efficiency of aircraft handling,
- Automation of passenger and baggage handling and increasing their efficiency,
- Minimizing human errors,
- Minimizing payback period.

I will design the above system with attention to the followings:

- Possibilities to use currently known technologies at an airport (GIS, identification and tracking, security),

- Passenger security and comfort,
- Transparency of current technologies,
- International development trends.

Costs generated by baggage loss and flight delays are very high for both airlines and airports. The application of Radio Frequency Identification (RFID) technology would reduce these costs extremely. The average industry cost per mishandled baggage is US$100-150. Approximately 1% of the 1.7 billion bags that pass through the system every per year is mishandled, and RFID is an ideal candidate to reduce these losses. With a full implementation, RFID would save the industry US$760 million annually. 1 minute delay costs 50 Euros for an airline as an average (IATA Data).

Airports and airlines are testing RFID only using RFID tags as baggage tags to minimize the costs for lost baggage. More can be achieved with this new technology, when it is applied to the baggage as well as for passengers, staff, ground support equipment, cargo and vehicles too.

Presently, there are many different tracking and IT recording solutions in use at the airports. 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.

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 with the possibility to integrate it into the local airport information 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 image processing. The monitoring of moving elements can be in real-time and non-real-time and can be continuously and at points.

The dynamic increase in air transportation (e.g. the numbers of flights, passengers and airports) causes more and more delays and baggage losses, which results in significant economic effects. In addition, airlines and airports require faster and more accurate ground services, while tending to decrease costs. There is a fierce struggle for passengers on the air transport market. Winning this struggle essentially requires the level of services to be high (e.g. accuracy of departures and arrivals, accurate baggage management, etc.).

The dissertation first gives an overview of the available technologies: GIS, identification and tracking technologies, then presents the airport and its operation, combines and integrates the chapters before for elaborating a new system.

1. Geographic Information System (GIS)

There are several definitions for GIS. The complexity of such systems makes it difficult to find one that encompasses all aspects:
Some examples:
Parker (1988): *"an information technology which stores, analyses and displays both spatial and non-spatial data."* (Maguire et al, 1991)
Aronoff's definition is (1989): *"any manual or computer based set of procedures used to store and manipulate geographically referenced data."* (Maguire et al, 1991)
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 et al, 1991). A similar and very appropriate definition, verified for all kind of applications, is: "A GIS is a computer system capable to assembling, storing, and manipulating, analyzing and displaying geographically referenced information, i.e. data identified according to their locations." (Maguire et al, 1991)
Dickinson and Calkins argued that GIS embraces three important components (Maguire et al, 1991):
1. GIS technology: hardware and software;
2. GIS database: geographical and related data;
3. GIS infrastructure: staff, facilities and supporting elements.

Practitioners also regard the total GIS as including personnel and the data that go into the system. The simplest way to define it is: a Geographic Information System is a computer software that allows spatial/geographical information to be created, queried and which assists, links, stores and analyses geographic information, with additional descriptive information. The map's information (geometrical information) is linked with a database tailored to the user's specific application. Only systems that contain data (objects, phenomena) with link to the reference site (georefence) are regarded as GIS systems.

GIS is handling together graphic (maps, aerial photos) and descriptive (containing thematic data) data and is able to make different type of analyzes according to the user's demand. The geographical element is more important than the attribute elements, and this fact differentiates it from other information systems (Maguire et al, 1991). The information can be updated and shared manually or automatically and refreshed readily. The GIS's most important co-specialty is informatics and cartography. Their development led to GIS. The results can be displayed graphically (e.g. map, digital elevation model) and as descriptions (e.g. tables).

The field of GIS is still a rapidly developing one. Among the main reasons for the massive interest in GIS is its great commercial significance and possibilities for use. It can handle in real time very large amounts of location and descriptive data, providing analysis and integrated reviews basically after a few clicks. Informatics is only a tool of geoinformation technology. The penetration of GIS and digital maps could only succeed with the development of the hardware and software techniques and the spreading of computers, PCs, portable devices (e.g. PDAs).

The following needs led to the origin and development of information technology, database management and naturally to GIS (Elek, 2006):

- Importance of spatial relation
- Need for interdisciplinary applications
- Penetration of integrated, complicated application
- Costumer's fast changing claims
- Importance of information flow within a company
- Conscious reliance on information
- Companies working in a fast changing market environment
- Business advantage in case of quick and good decisions

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 is now a special branch of information technology. The development of GIS is closely linked to the development of computing.

GIS developed differently throughout the world. With the development of computers GIS could progress faster. In the USA the government and the industry developed and managed the innovation. The leading companies are still in the USA. In Europe the research and development was more the goal of GIS. In some western European countries (Austria, Sweden, Switzerland) the Land Registry worked in early times with linked computer databases. In Europe national mapping agencies worked with GIS to maintain cadastral records of property. Bigger institutes had computer departments and research labs for pushing forward the new technology.
In Australia GIS initiated with cadastral mapping and applied scientific research began in the 70s (Maguire et al, 1991). It started with the production of maps of local government data, by 1982 a wide range of natural and socio-economic data were available.

Japan, the Soviet Union and developing countries showed interest for GIS only in the 80s. But in the People's Republic of China work on digital mapping had begun in 1972 and tapes of satellite imagery had been acquired by 1975.
In education there is also a difference between the two continents: in the USA geoinformatics is linked to the geography departments, while in Europe it is linked to geodesy and cartography (Reyes, 2007).

1.1. Milestones of GIS

Some experts are calling the thematic maps and atlases published before the computer era as analogue geoinformatics. Their claims have been supported by the fact that joint analysis of the maps can lead to scientifically valid conclusions. From maps information related to distances, directions, areas can be obtained and spatial relations can be understood. It can be seen as traditional information systems. The GIS is in a digital form (Reyes, 2007).

Although its antecedents, the manual predecessors go back hundreds of years in the fields of cartography and mapping, GIS as such began in the 1950s and 1960s, currently GIS is dominated by software and data models whose intellectual and conceptual lineage can be traced directly back to innovations in the 1960s. Computer-based GIS have been used since the late 1960's; it is in the last twenty-five years when it has been recognized as such. In the 1970s and 1980s, a GIS industry underwent vigorous development, with clear US leadership. GIS also has had a major influence on the discipline of Geography in the 1980s and 1990s, and is seen as a critical factor in reviving academic geography.

In the 1990s, a literature critical of GIS technology has emerged, raising questions of ethics, equity, technological biases, access, and privacy.

The relationship between GIS and computer-aided design (CAD), computer cartography, database management and remote sensing systems is important in its history (Elek, 2006). CAD was used for maps, too. It was clear from the early stages that the thematic contexts, attributes related to graphical objects must be handled simultaneously with maps. The early GIS software was derived from this recognition (Elek, 2006). Nowadays, GIS software handles database management, imaging, vector data map managing and analysis. Some software is better at working with vector data models and other with raster data model. In the 90's and after the millennium the software functions were expanded to manage and analyze 3D models.

Some important dates (Maguire et al, 1991)*:*
1959 Waldo Tobler outlines a simple model called MIMO (map in-map out) for applying the computer to cartography. Its principles were the origins for geocoding, data capture, data analysis and display. The MIMO system contained all of the standard elements found in any GIS software.
1963 Development of Canada Geographic Information (CGIS) was needed to analyze Canada's national land inventory and pioneered many aspects of GIS.
1963 The Urban and Regional Information Systems Association (URISA) was premier organization for the use and integration of spatial information technology to improve the quality of life in urban and regional environments. Formed, using information technology to solve problems in planning, public works, the environment, emergency services, utilities and throughout state and local governments.
1964 The Harvard Lab for Computer Graphics Research Centre started creating pioneering software for spatial data handling.
1965 SYMAP (Synagraphic Mapping Sytem) a pioneering automated computer mapping application and black and white automatic thematic map creation from database.
1967 US Bureau of Census DIME (Dual Independent Map Encoding) data format was developed by George Farnsworth.
Automatic Mapping System (AUTOMAP) was developed by the US Central Intelligence Agency (CIA). It could produce coastlines and any form of line or point data for representing any of the world's countries. It was a map compilation program at world level.
1968 The Transportation Information System (USA) was developed based on grid manipulation. It incorporated geocoded land use and travel characteristics. The output of this system was line printer dot maps.
1970 The Urban Atlas of Jerusalem was generated from a developed data bank of block inventory combined with a grid manipulation system.

1970 GBF/DIME (Geographic Base File, Dual Independent Map Encoding) Project. It was started in 1967 to automate the results of the census in the USA in 1970. It is important also because it attracted the attention of demographics specialists on the potentialities in GIS (Detrekői & Szabó, 2003).

1971 The Highway Inventory Information System (USA) was developed based on a database that contained items such as physical road characteristics, a road inventory, bridge records, traffic volumes.

1972 The first Landsat satellite launched (originally known as ERTS-1)

1972 IBM started the development of its Geographic Information System (GFIS), the same year the General Information System for Planning (GISP) developed by the UK Department of the Environment.

1977 USGS developed the Digital Line Graph (DLG) spatial data format.

1978 The Global Positioning System (GPS) project got into Phase II with the launch of the first four NAVSTAR satellites.

1979 The ODYSSEY GIS was developed at Harvard Lab. The first vector GIS appeared.

1982 The SPOT Image company founded, the first commercial company established to distribute geographic information derived from Earth Observation Satellites on a worldwide basis.

1985 Geographic Resources Analysis Support System (GRASS) development begins in the US Army Construction Engineering Research Laboratories

1987 Idrisi Project started (USA). This is the first software which is able to deal with raster files and spatial statistical analyses.

1988 The first public release of the **US Bureau of Census TIGER** (Topologically Integrated Geographic Encoding and Referencing) digital data product.

1988 The National Centre for Geographic Information and Analysis (NCGIA) established in the USA. NCGIA research advanced the theory, methods, and techniques of Geographic Information Analysis (GIA) based on Geographic Information Systems (GIS). Three impediments hampered more effective GIS-based analysis: deficient capabilities for data-handling, insufficient analysis and modelling capabilities, and meagre understanding of applicability and user acceptance. Research addressing such impediments focuses at the outset on the accuracy of spatial data bases, languages of spatial relations, scale dependence in representations of cartographic features, and the value of geographic information in decision making. The NCGIA narrowed gaps among theory, technology, and applications in GIA/GIS in the engineering, natural, and social sciences.

1988 The GIS-L Internet list-server started by Ezra Zubrow, State University of New York at Buffalo.

1988 Indian Remote Sensing Satellite (IRS) is commissioned with the launch of IRS-1A

1992 The National Space Development Agency (NASDA), Japan, launches JERS-1 satellite.

1995 RADARSAT-SAR satellite is launched.

1997 NASA launches Landsat 7 carrying Enhanced Thematic Mapper Plus (ETM+)

1999 The first commercial satellite, Ikonos was launched. The satellite orbiting at 680km altitude provides 1 meter imagine resolution.

2003 The three differential GPS systems (WAAS, EGNOS, MSAS) launched. The positioning becomes faster and more precise.

1.2. Companies and Software of GIS

There are many companies developing GIS software, the most important producers and their software are (Elek, 2007):

ESRI: Environmental Systems Research Institute was founded 1969 in the USA. In the 1980's the company devoted its resources to developing and implementing a core set of application tools that could be used in a computer environment to create a geographic information system, this is known today as GIS. Innovations in computer technology allow sophisticated GIS operations to be performed in the field on a PDA, or a desktop PC. The first software was ARC/INFO, launched in 1981.
Goal/Focus: organizing and analyzing geographic information.
Software package: is ArcGIS, it is based on expandability, it contains:
ArcView: viewing maps and tables of ArcGIS, analyzing and querying spatial information, generating new maps, editing shape format data.
ArcEditor: dealing with special spatial data format, the geodatabase.
ArcInfo: real-time data and its application
ArcMap: interactive tools, for editing and drawing maps, analyzing and querying can be visualized, the form of visualization can be defined.
ArcCatalog: organizing data
ArcToolbox: tools and application possibilities of the ArcGIS software

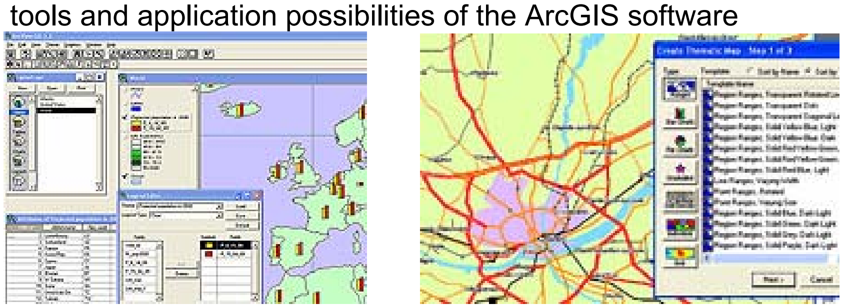

Figure 1: ArcView and MapInfo
(Source: www.esri.com, www.mapinfo.com)

Integraph Corporation: founded in the USA in 1969. It produces engineering and geospatial software that enable customers to visualize complex data. Intergraph operates through two divisions:

- Process, Power & Marine (PP&M): provides enterprise engineering software for the design, construction, and operation of plants, ships, and offshore facilities.
- Security, Government & Infrastructure (SG&I): provides geospatially powered solutions to the defence and intelligence, public safety and security, government, transportation, photogrammetry, utilities, and communications industries.

Software package: GeoMediaProfessional, for Windows
Goal: data capturing, analyzing, storing and displaying in georeferenced environment. Can gather and display information from different sources, different data configuration and projection systems. It has an automated trouble-shooter to find and correct the errors created by data capturing process.

MapInfo: was founded 1986. The first MapInfo software was launched 1991.
Focus: low-cost GIS software market and Desktop Mapping software.
Software package: MapInfo Professional launched for Windows 95 in 1995.

Goal: it is able to handle, analyze and visualize alphanumerical (relational) and graphical (digital maps) data simultaneously.

1.3. GIS Elements

Maintaining GIS software is a complex task. The harmonized cooperation of the components results the intended use.
These components are (Detrekői & Szabó, 2003):

- Hardware: should be high performance, high performance graphics, very fast central processing unit, high storage capacity,
- Software: role is :data importation, handling, analysis and display,
  should handle: alphanumerical and graphical data simultaneously
- Database: the data and database are the most important part of GIS, the database has to be up-to-date, maintained continuously,
- Skills: knowledge and experience of the user and of the designer and communication between them are very important. The user must specify precise requirements.

These four elements need to work together perfectly to use GIS for its planned application and make it profitable. .

1.3.1. Data Capturing

Data capturing is the most time-consuming part, the new information must be integrated in an extant system, and relation to the already coded elements must be accurately defined. Data structures captured can be raster files (data model) and vector files (data model or digital data).
To ensure high quality, it is better to make it manually than automatically. In case of automatic data capturing it has to be verified (Zentai, 2003).

The input of the raster data model can be the following:

- Scanned maps
- Existing maps
- Maps imported from other software

The input of the vector data model can be the following:

- Typing in data
- Existing database
- Scanned maps
- Aerial and spatial picture
- Documents, pictures
- Alphanumerical data
- GPS
- Mobile phones
- Coordinate-geometry
- Field survey
- Photogammetry
- Digitizer board
- Maintenance of data of maps and texts

Data capturing of the attributes can be done importing tables separately, scanning or they can be imported from other systems. The data updates and distribution are automatically applied in real-time and non real-time.

1.3.2. Raster and Vector Data Models

Nowadays the most common data capture is scanning printed maps; the obtained raster file is the base. The scanned map used should be up-to-date, to have the latest changes on screen. On the monitor the raster file can be turned on or off and it can be integrated into the frame of reference of a vector map file. This was not possible in the 70's and 80's as the GIS software by that time was not supporting raster files.

The raster data model contains an area covered by a virtual grid and to its each point, called pixel, an attribute is ordered. A raster file consists of: the raster grid's geometry (rows, columns, pixel size, possibly the transformation parameters of the frame of reference). A terrain feature may contain more pixels; these pixels are differenced by colour codes from the surrounding pixels. The number of the attributes is the number of pixels the map has. The rows of uniform cells coded according to data values (land cover classes). The size of a raster data model is very large as each raster point attribute is stored. The elements of the map are not accessible; it is not possible to work with them. The raster format is more suited for storing pictures. It is faster but generates larger amounts of data, too.
The size of the file depends on the resolution and the number of attributes linked to a pixel.

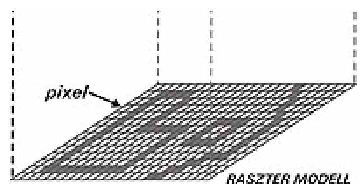

Figure 2: Raster Model
(Source: www.fhwa.dot.gov/planning/toolbox/images/)

The point of the vector data is that the graphical objects are stored by the coordinates of their parameters, e.g. the points (or line nodes) or single points (nodes) (e.g. a spring) are given by their coordinates. The direction and order of the linked points have to be given. Vector digital data have been captured as points (nodes), lines or polygons (as a series of point coordinates), or areas (shapes bounded by lines). It is more accurate. The GIS can determine adjacency (what is next by), containment (what is enclosed by what), proximity (how close is something to something else). The input of the data can be: manual, digital table, on screen digitalizing (Detrekői & Szabó, 2003).

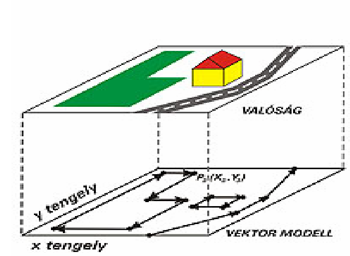

Figure 3: Vector Data Model
(Source: www-eio.upc.es/)

The topology results from the superimposition of the points (nodes), lines and areas. There is no commonly used standard for it; each software producer is having his own topology solution. The vector data model has two problems: first, the complex topology causes problems in the data exchanges between different software and also between different map manipulations within the same software. Second is the scale true graphical visualization of the stored objects.

The GIS software is able to mix and handle both data capturing models. The conversion between the vector and raster data model is very important. Conversion of raster data models into vector data models is the most important for GIS. Only very high quality and therefore expensive software is able to convert it automatically. To convert vector data model into raster data model is simple, but it is important to fix the user's requirements for choosing the right parameters.

The data must be converted into code that is understandable for the computer. The location of objects is given by coordinates that are relevant to the chosen frame of reference and the rates must be correctly stored for the used data model.

1.3.3. Database Management

GIS is based on database management. A database is a sound data collection. The data are in tables. The parameters of vector models, the pixels of a raster data models are stored in the rows of the database. These are called records. The columns are containing fields where the characteristics of the records are stored. Records can be settled according to one or more field, e.g. alphabetical, growing or descending order. The databases can be linked with chosen common fields, key fields. To the objects in the database (records) coordinates must be associated. Without coordinates the objects cannot be spatially displayed. This is the process of geocoding. Geocoding is not only accessible via coordinates. at large scale it can be managed using numbers, postal addresses too, it can be executed with just one click.

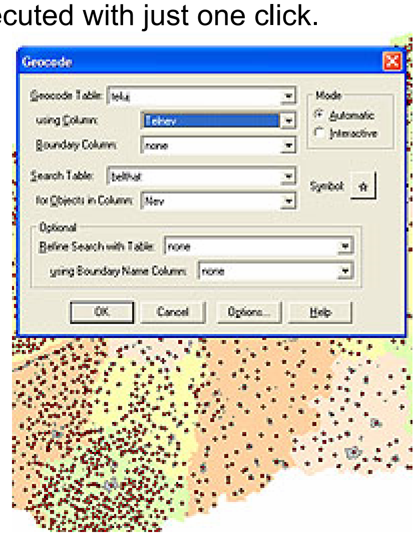

Figure 4: Geocoding
(Source: www.csis.u-tokyo.ac.jp)

The descriptive databases are not only containing text and numerical data. Nowadays it is common to have black and white or colour photos, sound recordings and videos. These are known as multimedia databases as they are describing with a variety of multimedia tools the objects stored in them. Traditional cartography already applied multimedia solutions: atlases displayed thematic information not just with maps but diagrams and pictures. The rapid development from the 80's allowed in relatively short period of time to apply multimedia in GIS.

1.3.4. GIS-GPS

Nowadays one of the main features of GIS is tracing and tracking nodes (vehicles) on roads and other outdoor or limited places (e.g. airport's restricted area). All nodes (vehicles) should be equipped with GPS receivers to get its own instant geographical coordination, maps, GIS and required communication equipment inside.
To acquire position information with meter accuracy via GPS, an unobstructed line of sight to at least three or much better four satellites is required for non-degraded performance. If one of the satellites is shaded the position information can not be precise. With GPS dynamic data is captured and visualized on maps.
The movements of vehicles can be demonstrated on a map with just points of the movement, after sending the position information or it can be visualized as a movement flow. This depends on the software settings.

1.3.5. Output and Visualization

The result of GIS can be visualized as:

- Soft copy (e.g. PC, PDA, etc.)
- Printed version (e.g. paper)
- Web

The quality of the output depends on the hardware configuration. Output and displaying of the GIS can be:

- Maps:
  - Traditional
  - Thematic
  - With Real-time movements
  - With Non-real-time movements
- Graphics
- Diagrams
- Lists
- Statistical data, lists
- Tables
- Digital elevation model
- Screen dump of the display
- Reports

Maps Support for Decision Making

In GIS the digital map is a product. One of the main purposes of the maps is to support decision making, it helps precise analysis and interpretation. If all the correct data is entered, the GIS software can be used to predict all options in future possibilities, changes, development and can visualize them helping the companies taking decisions.

On maps the information (geographic data) can be visualized in layers. Each layer represents a particular topic of the map (Elek b., 2007). It enables to play with the data. It is possible to display only one type of data at once, or two types or more types. The topic can be everything, e.g. hydrography, topography, settlements, roads, farmland, industrial plants, buildings, parks etc. The layers constitute the digital basic maps. Depending on the goal of the work the layers can turned on and off. The layers can be laid on top of one another (like transparencies), creating a stack of information about the same geographic area. Depending on the user's goal and demand showing just the most necessary information can help to make decisions but further help is that all information can be visualized at once, to see everything globally and take decisions.

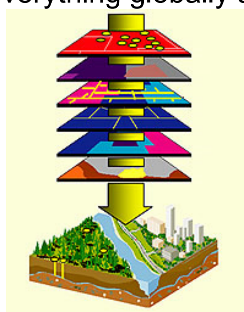

Figure 5: Map Layers
(Source: www.lazarus.elte.hu)

Maps can be printed from the software. The difference between a printed map and a digital map is, that a printed map shows only the depicted information, while a digital map shows all the information, is storing the information in a database e.g. where a point is located, how long the road is, etc. It is stored in digital format and can be viewed in different ways. On a printed map different colours and cartographic signs are showing the meanings of the elements. A digital map can be used in different ways: the output is a printed map then it is just a tool, or the goal of the process was to create a digital map (computer database) for further digital uses. In GIS not the graphical design of the map is important but the object's geometrical accuracy, the coordinates, the clear database-relation and correct topology (Zentai, 2003). The data form must be compatible with the other specialties. Most GIS softwares are not containing sophisticated cartographic functions yet, it is getting more and more important to retrieve thematic maps from data.

Maps made with GIS software and maps made for cartographic use are not and do not have to be the same quality. The quality of a GIS map depends on the application and on the software attributes. Even between different software there are differences, the goal is to provide appropriate digital maps for decision making, some cartographical approach is necessary. Often maps made with GIS software will not be processed for cartographical usage as they are not applying cartographic rules. In GIS the maps are processed automatically, therefore, sometimes they are difficult to understand. The map is having an important rule as an information infrastructure in a decision making process, so the quality of the information is crucial. The content is important, appropriate tools are necessary for production and display.

1.4. GIS Applications

Maps were used for centuries already. Over the past few decades with the deployment of computer science and information technology GIS could develop fast and be applied in a wider area. It can be applied almost everywhere. It became a part of mainstream business and management operations around the world in organizations as diverse as municipalities, state government, utilities, telecommunications, railroads, civil engineering, petroleum exploration, retail, commerce, etc. both in the private and the public sector. This array of institutions is integrating GIS into daily operations, and the applications associated with these systems are equally broad, ranging from infrastructure management, to vehicle routing, site selection, research and/or analysis.

The basic information for almost each application area is the same: geographical data of a certain area of the world with information depending on user's demand to that area. The principal data for each application in the geographical area is: relief, hydrography, and already built infrastructure (e.g. roads, railway, settlements, etc.).

The thematic information which is the goal of using GIS is put above these information to gain data related to our thematic. The difference can be the resolution needed or information needed of the map source for a special application.

In its early times GIS software was used by the military force, for exploration, mission planning, accident investigation, wargaming, simulation. First point of using GIS was to deal with land, real estate management, urban planning, and infrastructure.

The advantage of GIS is the data storage, cost savings, transparency, possibility of simulation and taking quick and precise decisions. But in the era of information society, information theft and on the cracking of web sites can be dangerous for GIS information put on the Internet.
In the following section some GIS applications are detailed.

1.4.1. GIS in Land Information Systems

Land Information System is covering a wide range of possibilities. Information can be gained about:

- Real Estate register (e.g. built-in areas, free areas)
- National Parks and Protected Areas (e.g. flora and fauna)
- Agriculture parcelling (e.g. raisings)
- Archaeology, Geography
- Mineral Resources (e.g. still untouched resource pools, oil, etc)
- Health Care (e.g. hospital density, lack of medical equipments, etc.)
- Utility register

For example planning land use in a hilly area:
Town planners and engineers require basic information such as the geology, topography, landform and zones which are potentially unstable. To prepare the various derivative maps, a GIS System is used to analyze data for these four attributes. The thematic maps produced serve as a guide for integrated land use assessment of proposed development project by Local Authorities, and in land use zonation by town planners, and engineers refer to these maps for preparing the layout of building plans and in deciding on the most appropriate earthwork plan and method of construction. The geospatial maps have potential to be used as a monitoring tool for any changes of landform or natural morphology and initial stage of geohazard assessment in an area proposed for development in a hilly region. Results can be displayed in 2D and in 3D.

1.4.2. GIS for Urban Planning

The basic information is a very good and detailed map of a town with all local infrastructures (houses, important building, parks, public transportation with stops and numbers, etc.) or that area where new infrastructure (industrial zone, new houses, new public transport, new road, etc.) is being planned to be built. The extra information on the map which is different for each application can be for examples:

- Real Estate register
- Local Monument register
- Transportation possibilities
- People movements by using public transport
- Environmental effects (noise, air, etc.)
- Protection against flooding
- Citizen complaints (web-based notification, complaints of citizens about the local infrastructure: e.g. busses are not running frequently enough, too few shops or petrol station in an area, wrong traffic light settings, etc.)
- etc.

The basic information and the plans are added together and displayed have a potential to prove simulation to see the affect of the planned development. The plans can be changed and the simulation is updating itself. It can be displayed in 2D and in 3D.

Urban planning is good for monitoring:

- Where developments are needed e.g. more public transport, road or shops is needed, etc.
- How and where some traffic legislation or traffic system should be changed (e.g. one-way, no traffic, walking street, etc.)
- How the local government's plans would affect the local people's life
- To improve the environmental conditions (e.g. minimizing speed, ban trucks, etc.)
- Optimize the planning of waste transport and street cleanings
- To see the endangered areas of the environment (e.g. rain-flooding, noise, wind, volcanism, earthquake, etc.)
- Planning of emergency situation
- etc.

Showing more detailed examples of the above mentioned:
Goal of Noise Mapping can be to:

- improve the environment for people living in that area with noise protection possibilities
- Where and how a new building or traffic route would influence the life of the local people related to noise
- Where changes are necessary and their influence

The thematic information in this application is the noise data of the affected area. Depending on the area it can be affected by the noise of: road, rail, air or water traffic. It has daytime and night-time and average data. The colours used for displaying are established in intervals according to noise values of the local standards. The focus is to match the actual situation against a standard. The modification of the current situation in any kind of changes (e.g. new building, new road, new transport, velocity regulation, traffic diversion, etc) can be displayed, too. The information can be handled, visualized together (shown all at once) or separately. Depending on the software's facilities the information captured can be displayed in 3D, too (Bite & Bite, 2005).

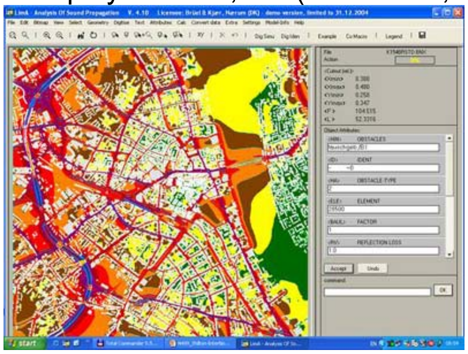

Figure 6: GIS for Noise Mapping
(Source: www.vibrocomp.hu)

1.4.3. Military and Defence Applications of GIS

It plays a pivotal role in military and defence operations as they are essentially spatial in nature. The concepts of Command, Control, Communication and Coordination in military and defence operations are largely dependent on the availability of accurate information in order to arrive at quick decisions for operational orders.
Important role for:

- Battlefield management
- Terrain analysis
- Remote sensing
- Military installation management
- Monitoring of possible terrorist activity
- Mission planning
- Military commanders in the operations, seeing route or target changes
- Sharing information about any kind of changes

1.4.4. GIS in Business Processes

The need for coordinated and collaborative business processes is changing the face of how these processes are modelled, executed and managed. Most business problems include significant spatial components and GIS enables decision makers to leverage their spatial data resources more effectively.
Used in:

- Customer Relationship Management
- Enterprise Resources Planning
- Supply Chain Management
- Any kind of Solutions designed to extract and analyze information from data warehouses and allow decision-makers to perform at a higher level of efficiency.
- etc.

Good for:

- Common language that is understood within and across organizational boundaries within an enterprise
- Weaving together and integrate traditionally disparate business functions
- Gain quickly and transparent information
- Take decision fast

1.4.5. GIS Based on Vehicle Tracking (Navigation)

GIS system applied for navigation is in continuous development since the time GPS started. To gain, handle, store and display dynamically changing information in real-time a special device is necessary to maintain the changes based. Of course, depending on the software, it can be visualized in real-time and non real-time. Queries can be generated and the answers can be displayed for special moments in time or for a continuous period of time on the map. To maintain such a system a special device (e.g. GPS, radar, etc.) must be installed into the tracked vehicle to get its own instant geographical coordinates. A central station/software is necessary where all the location data from each vehicle is stored and shown on a map. It is based on road maps, traffic regulations, speed and location of vehicles.
Applied for:

- Police
- Rescue service
- Transportation companies
- Citizens for navigation (e.g. route planning)

Good for:

- Location Service and Routing Protocol
- Allocating vehicle resources
- Fleet management, inter-vehicle communication
- Mobile resource management
- Identifying problematic areas in transportation (e.g. where a truck is spending too much time, route changes)
- Route planning
- Planning for emergency situations
- Vehicle Tracking
- Security and Safety
- etc.

1.4.6. GIS for Buildings

This type of GIS is not the traditional GIS based on geographical information, it is based on the parameters of buildings, coordinates and spatial information of buildings. It is a new application area and still in its infancy.
It is applied in:

- Warehouse management
- Architecture

It is important for:

- Information about where the items are located
- Tracking the items movement within a building

1.4.7. GIS for Aviation

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 & Holsmuller, 1992).

The airport infrastructure management uses GIS extensively for registering 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

2. Identification and Tracing Technologies

Identification and tracing can be understood and categorized in many ways. In this work identification, localizing, tracking and security issues are in focus. Maybe the simplest definition of identification is something that identifies a person or an item.
Tracing is, as the widely known international definition says: the ability to track and trace with standard identification technologies, knowing the relations between the identifications of an item's (e.g. product, information) way and life, place and application, places and people in its process (Kecskés & Krázli, 2007).

In the aviation sector both in the air and on the ground identification and tracking, monitoring is very important. Listing all identification and tracing methods are is not within the scope of this work, but those, which are currently applied at airport's landside or which may be applied or could improve the efficiency of the suggested system will be described in detail.

People and Items can be Identified by:

- ***Manpower:***
  - Senses:
    - Manual looking
    - Touching
    - Feeling (by animals too)
    - Smelling (by animals too)
  - IDs:
    - Personal ID (for people)
    - Passport (for people)
    - Delivery documents (for items)
  - Signature
- ***Technical Equipment:***
  - Coding:
    - Password
    - PIN-Code
    - Electronic Signature
    - Magnetic Stripe
    - Smart Card
    - Barcode, 2D Barcode (human operator necessary too)
    - RFID, RFID Passport
  - Biometrical:
    - Blood
    - DNA
    - Fingerprint
    - Iris – Retina Scanning
    - Facial Recognition
    - Voice Analysis
    - Gait Analysis
    - Vein Recognition
    - Odour Recognition
    - Ear Shape Recognition
    - Nail Bed Identification

Tracking and Tracing can be:

- ***On Spot:*** each of the above mentioned
- ***Continuous:***
  - RFID in case of Active Tag
  - Video Camera
  - GPS
  - Radar

2.1. Identification and Tracing Technologies on Spot

2.1.1. Senses

Sight, touch, and smell are the basic methods to recognizing and identifying people or items. Security officers are trained to watch passenger's behaviour and recognize suspicious behaviour. Sniffer dogs are drilled to find drugs, explosives, etc.
Application: anywhere
Application at airports: check-in, security check, border crossing, boarding gate, etc.

2.1.2. IDs

An identity document (ID) is an official paper or card which is used to verify aspects of a person's Personal identity. In some countries the possession of a government-produced identity card is compulsory while in others it may be voluntary. For a person leaving his/her country, the passport is the most important document. Citizens, of countries with special border agreements (e.g. Schengen countries), travelling between those countries need only Personal ID card and not the passport. For items the correspondent document is the ownership paper or delivery paper.
It is checked by human operators.
Application: any entrance, border crossing, shipping, etc.
Application at airports: check-in, border crossing, security check, boarding gate, cargo handling etc.

2.1.3. Coding

Password: it is a secret word (e.g. name of a pet) or phrase that is used for admittance or access to computer-based information by proving identity or membership. It is (should be) only known by the issuing authority and by the group of people entitled to use it. It can be generated automatically, randomly, or by a person. It can contain be numbers, upper and lowercase characters or their variation.
Application: access to licensed software, PC, etc.
Application at airports: staff authorization for any software (e.g. FIDS, DCS), etc.

PIN-Code: is the Personal Identification Number. A combination of numbers, it is known only to its user (e.g. 12345).
Application: access to restricted areas, mobile phones, bank cards, etc.
Application at airports: staff access to restricted areas (some airports), etc.

Magnetic Stripe: it is a type of card capable of storing data by modifying the magnetism of tiny iron-based magnetic particles on a band of magnetic material on the card. It is read by physical contact and swiping past a reading head. They may also contain an RFID tag, a transponder device and/or a microchip mostly used for business premises access control or electronic payment.

Figure 7: Magnetic Strip
(Source: Own Edition)

Application: identity cards bank cards, transportation tickets etc.
Application at airports: Boarding Pass (used until the end of 2010 for IATA members)

Smart Card: any pocket-sized card with embedded integrated circuits which can process data. The card may have metal contacts connecting the card physically to the reader, while contactless cards use a magnetic field or radio frequency (RFID) for proximity reading. Hybrid smart cards include a magnetic stripe in addition to the chip. New trend is to store user's biometrics on it and have a double check at the reader to avoid unauthorized card change.

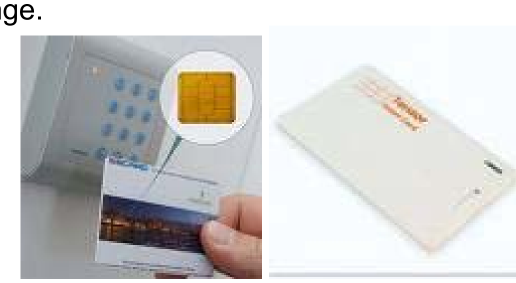

Figure 8: Smart Card
(Source: www.sis.com.mt, tensor.co.uk)

Application: security authentication, access control, payment card, etc.
Application at airports: staff access control

Barcode: is an optical machine-readable representation of data. Originally, barcodes represented data in the widths (lines) and the spacing of parallel lines, and may be referred to as linear or 1D (1 dimensional) barcodes or symbologies. They also come in patterns of squares, dots, hexagons and other geometric patterns within images termed 2D (2 dimensional) matrix codes or symbologies. Although 2D systems use symbols other than bars, they are generally referred to as barcodes as well. 2D barcode has more data representation capability and the accuracy reading rate of 2D barcode is higher than at 1D barcode in case of vulnerability. To read the barcode a scanner is necessary (Kecskés & Krázli, 2007).

0 36000 29145 2

Figure 9: Barcode and Scanner
(Source: www.blendedtechnologies.com)

Figure 10: 2D Barcode
(Source: www.laserfiche.com)

Application: logistics, document Management, supermarkets, entrance tickets etc.
Application at airports: boarding pass, baggage tag

Radio Frequency Identification (RFID): It is a data collection technology that uses electronic tags for storing data. It is a technology incorporated into a silicon chip that emits a radio signal which matches a user-defined serial number with an item. The tag is made up of an RFID chip attached to an antenna. The tags vary from being battery-powered (active tag) or derived their power from the RF waves coming from the reader (passive tag). It is possible to link databases and make security more efficient (Kecskés & Krázli, 2007).
RFID passport: Standards for RFID passports are determined by the International Civil Aviation Organization (ICAO), refers to the ISO 14443. The chip stores the same information that is printed within the passport and includes a digital picture of the owner. The passports will incorporate a thin metal lining to make it more difficult for unauthorized readers to "skim" information when the passport is closed.

Figure 11: RFID
(Source: www.erpsoftwarebusiness.com)

Application: library, product tracking, transportation payment, etc.
Application at airports: baggage tag with barcode, ground support equipment, aircraft parts etc.

Attributes	**Barcode**	**Smart Card**	**RFID**
Optic reader	Necessary	Necessary	Antenna is reading from the distance (10 cm – more 100ms)
Reading possibility	Scanner points	Reading points	Active tag: always, Passive tag: access points
Real time matching	No	ID check	With the people
Reading amount simultaneously	1	1	several
Read rate, accuracy	80-90 %	95-99%	95-99%
Read – Write	Read only	Read only	Read-Write,
Reading	Manually	Automated	Automated
Updating	No	No	Always
Data	Definite	Definite	Indefinite
Location	Top of bags	Staff's badge	Anywhere
Removable, Vulnerability	Easily	Easy to exchange	Impossible
Reading after Vuln.	Mishandling		It can be identified correctly
Configuration	Paper	Card	Can be embedded in everything
Technical equipment	Paper, Printer Scanner	Card, Reader	Tag Read-Writer Antenna
Environments	Disposable	Re-usable	Re-usable
Speed	Slow	Fast	Fast
Price	6-8 cent		20-42 cent
Cost	Low	low	Tag dependent, + implementation costs,
Maintenance	Has to be cleaned daily	Little	Little, Less time, costs
Application at airports	BagTag 2D: Boarding Pass	Access Control	BagTag

Table 1: Comparing Barcode, SmartCard and RFID Technologies (Source: Own Research)

2.1.4. Biometrical Identification

Biometrics is an automated method of recognizing a person based on physical or behavioural attributes. It has long been used by the government's –secret agencies for access-control applications. Biometrical Identification can be: hand (fingerprint) geometry, Iris-Retina scanning, facial recognition, voice recognition, gait analysis, vein recognition, odour recognition, ear shape recognition, nail bed identification. These technologies can be applied simultaneously. These technologies are not 100% reliable individually, they can be effective in counter-terror methods only combined (Griffiths, 2009). In the aviation industry the followings are used today (Griffiths, 2009):

Fingerprint, Hand Geometry: it is the oldest method. Everyone has unique, immutable fingerprints. It relies on pattern matching, followed by the detection of certain ridge characteristics, points of identity, or minutiae, and the comparison of the relative positions of these minutiae points with a reference print, usually an inked impression of a suspect's print. There are three basic ridge characteristics:
the ridge ending, the bifurcation and the dot (or island).

Figure 12: Fingerprint Analyzer
(Source: www.dailymail.co.uk)

Application: police, defence, computer login, etc.
Application at airports: staff access control, check-in, border control (some airports, mainly in the USA)

Iris Recognition: It is an optical fingerprint, having a highly detailed pattern that is unique for each individual and stable throughout life. It combines computer vision, pattern recognition, statistical inference, and optics. Its purpose is real-time, high confidence recognition of a person's identity by mathematical analysis of the random patterns that are visible within the iris of an eye from some distance. The iris is a protected internal organ whose random texture is complex, unique, and it can serve as a kind of living passport or password. It is used mainly for screening purposes and not for monitoring intent, it should be combined with other biometrical applications.

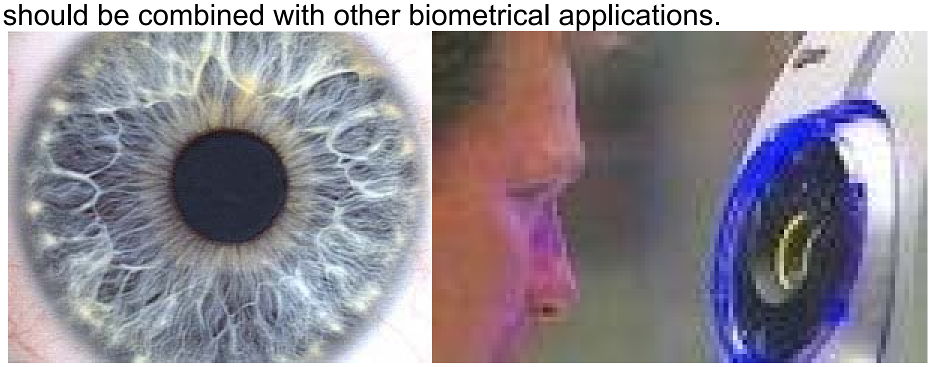

Figure 13: Iris and Iris Scanning
(Source: www.airport-technology.com)

Application: passports (automated international border crossing), database access, computer login, access control, hospital settings including mother-infant pairing in maternity wards, "watch list" screening at border crossings;
Application at some airports: border control, check-in, aviation security, access to restricted areas

Facial Recognition: It is a computer application, automatically identifying or verifying a person from a digital image or a video frame from a video source. One way to do this is by comparing selected facial features from an image and a facial database. It is typically used in security systems and can be compared to other biometrics such as fingerprint or eye iris recognition systems. It can make a 3D picture by using 3-D sensors to capture information about the shape of a face. This information is then used to identify distinctive features on the surface of a face, such as the contour of the eye sockets, nose, and chin. One advantage of 3-D facial recognition is that it is not affected by changes in lighting like the traditional technique of facial recognition. It can also identify a face from a range of viewing angles, including a profile view. It can be implemented within crowd situation. It is not reliable, the biggest issue has been the excessive quantity of false positives.

Figure 14: Facial Recognition
(Source: www.i-to-i.com)

Application: casinos, security, prevention of voter fraud, fully automated border control etc.
Application at some airports: border control, check-in, aviation security, access to restricted areas

Ear Shape Recognition: It is based on the distinctive shape of each person's ear and the spectrum of the projecting portion of the outer ear. The test showed 99% accuracy. This technology is still in his infancy.

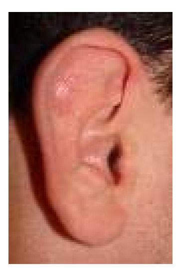

Figure 15: Ear Shape Recognition
(Source: www.blogs.abc.net.au)

Application possibilities in future: identify people from CCTV footage, smart camera systems system, incorporated into telephones for identifying the caller, etc.
Application at airports: still not applied
It could be very effective and reliable in conjunction with any of the above mentioned biometrical identification mode.

Attributes	**Finger Geometry**	**Iris Scanning**	**Facial Recognition**	**Ear Shape Recognition**
Optic reader (Physical contact)	Necessary	No	No	No
Feasible without realizing	No	Yes	Yes	Yes
Reading possibility	Scanner points	Scanner points	Anywhere	Anywhere
Reading amount simultaneously	1	1	Any	Any
Read rate, accuracy, software dependent	50%	50%	Resolution, distance, etc.	99%
Reading	Automated	Manually	Automated	Automated
Removable, Vulnerability	Easy to trick	Surgery	Easy to trick	Surgery
Technical equipment	Scanner, Software	Scanner, Software	Video, Software	Video, Software
Speed	Slow	Fast	Fast	Fast
Maintenance	Has to be cleaned after each person	Little	Little	Little
Connected to a worldwide database	Yes	Yes	Yes	Yes
Application at airports (if applied)	Check-in, Border Control, Access Control	Check-in, Border Control, Access Control	Check-in, Border Control, Access Control	No

Table 2: Comparing Biometrical Identification Methods
(Source: Own Research)

2.2. Tracing Technologies with Continuous Information Display

RFID Active Tag: see 2.1.4.

Video Camera: It is used for electronic motion picture acquisition. The video cameras are used in two modes:

- The camera feeds real time images directly to a screen for immediate observation. Such usage is characteristic of security, military/tactical, and industrial operations where surreptitious or remote viewing is required.
- Having the images recorded to a storage device for archiving or further processing. Recorded video is used, but also surveillance and monitoring tasks where unattended recording of a situation is required for later analysis.

It is only serving to show that are people moving around and their actual activity, but it is not showing their personal identity. The cameras can be connected to observe in a bigger area all the movement of the people. There are cameras turning around all the time at 360°. A new type of cameras enables real-time views of the scene in multiple formats, and a 360° video analysis. This software is configurable to perform motion detection, motion tracking and even tracking of multiple targets simultaneously. Facial and ear recognition can be built into the video camera software, too.

Figure 16: 360° Video Analyze
(Source: www.grandeye.com/images/airport1.jpg)

Application: television and film production, live broadcast, security, military, industrial operations, monitoring, leisure
Application at airports: aviation security

Global Positioning System (GPS): It is a Global Navigation Satellite System (GNSS). GPS uses a constellation of between 24 and 32 medium Earth orbit satellites that transmit precise radio wave signals, which allow GPS receivers to determine their current location, time, and their velocity. An unobstructed line of sight to four satellites is required for non-degraded performance. GPS horizontal position fixes are typically accurate to about 15 meters (50 ft). Reading accuracy is between less than 1 m – 100m, mostly the accuracy is 10-30m, depending on the quality (Borza et al, 2005). It can only be used outdoors.

Figure 17: A Type of GPS
(Source: Edition)

Application: aid to navigation, police, defence, leisure
Application at airports: vehicle tracking (some airports)
aircraft tracking (could be possible)

3. Airport and Airport Operations

3.1. Airport

The airport forms a pivotal point of air transportation. It is the physical site where a modal transfer takes place, the connection between air mode and any kind of land modes (Ashford, Stanton & Moore, 1998).
An Aerodrome defined by ICAO is a defined area on land or water (including any buildings, installations and equipment) intended to be used either wholly or in part for the arrival, departure and surface movement of aircraft.

To ensure safe and secure flying is a very precise and complicated work of four main members:
- Airport Operator
- Airline
- Air Traffic Control
- Ground Handling Service

Around these there are many other companies and authorities.

There are main international organizations standardizing the aviation industry, recommending practices and rules:
- International Air Transport Association (IATA)
- International Civil Aviation Organization (ICAO)
- Société Internationale de Télécommunications Aéronautiques (SITA)
- European Aviation Safety Agency (EASA)
- EuroControl

The goal or function of an airport is:
- Arrival and departure of different type and functional aircraft and helicopters
- It can host only passenger and only cargo traffic, but mainly are both
- Hub and spoke function

The effect of an airport on the environment (Legeza, 2001):
- Positive effect: Regional development
- Negative effect: Pollution, Noise, etc.

The airport capacity: the volume of passengers and cargo that can be accommodated within a given time period, usually measured in hours (Kővári, 2004).

Airport Categories: airports can be categorized in many ways:
- Function type:
  - Civil
  - Military
- Range:
  - Domestic
  - International

- Traffic type:
    - Passenger
    - Cargo
    - Passenger & Cargo
- Traffic Density:
    - Light
    - Medium
    - Heavy
- Runway length
- Aircraft characteristic
- Traffic characteristic:
    - Point- to- Point
    - Hub & Spoke

3.2. Airport Elements

An airport is divided into airside and landside. Each is performing different but very important operations for safe and secure air transportation. On both sides are many stable and moving objects and people to identify and monitor.
The definitions according to ICAO Annex 14 of the below *(see 3.2.1.)* listed airport elements can be found in the Appendix *(see App. 1.)*

3.2.1. Stable Elements of an Airport

The stable elements (objects, items) of an airport are:
On the Airside:

- ***Runway:***
    - Guard lights:
        - Landing Direction Indicator
        - Aeronautical Beacon
        - Capacitor Discharge Light
        - Barrette
    - Holding Position
    - Turn Pad
    - Strip
    - Runway End Safety Area
    - Threshold
    - Touchdown Zone
    - Stopway
    - Shoulder
    - Markings
- ***Apron:***
    - Aircraft Stand:
        - Outer Parking Position
        - At the Terminal Building
    - Service Roads
    - Service Road Holding Position
    - Holding Bay
    - Markings

- ***Taxiway:***
  - Strip
  - Intermediate Holding Position
  - Intersection
  - Markings
- ***Air Traffic Control:***
  - Control Tower
  - Technical Equipment for Approach and Departure (e.g. Radar, ILS, MLS, DME, etc.)
  - Lights:
    - Hazard Beacon
    - Aerodrome Beacon
  - Airway Marker
  - Navigation Tools
- ***Rescue and Fire Fighting***
- ***De-icing/ Anti-icing Facility***
- ***Markings***
- ***Obstacle: if there are***

On the Landside:

- ***Passenger Terminal Building:***
  - Departure and Arrival Hall
  - Viewpoints
  - Border Control Point
  - Security Check Point
  - Transit Area
  - Baggage Claim
  - For Passenger Restricted Area:
    - Security Check for Checked-In Baggage
    - Baggage Sorting
    - Internal Offices:
      - Ground Handling Companies
      - Police and Customs Offices
      - Cleaning Rooms
  - First Aid Rooms
  - Bars, Restaurants, Shops
  - Offices
- ***Parking Area for:***
  - Visitors:
    - Short-term
    - Long-term
  - Employees
- ***ATC Headquarter (e.g. in Budapest)***
- ***Offices of:***
  - Authorities:
    - Police (Customs and Finance Guard)
    - Civil Aviation Authority
  - Meteorology Centre (it can be anywhere)
  - Etc.

- ***Cargo Terminal:***
    - Reception
    - Warehouse(s)
- ***Hangars***
- ***General Aviation Terminal (GAT)***

3.2.2. Moving Elements of an Airport

The moving elements (people, items) of an airport are:

- ***People:***
    - Passengers
    - Permanent Employees working at the airport (e.g. Ground Handling Staff, Airline Crew, Airport Staff, etc.)
    - Temporary Employees entering at the airport (e.g. Catering Truck Drivers, Cargo Delivery, etc.)
    - Passenger's Relatives, Private Visitors
    - Official Visitors entering the airport (e.g. Companies, Authorities, Auditors, etc.)
- ***Items:***
    - Aircraft
    - Ground Support Equipment *(see below)*
    - Staff-, Visitors vehicles (etc. Crew Cars, Airport Cars and Buses, Trucks, etc.)
    - People Mover between Terminal Buildings:
        - Buses
        - Train (e.g. SkyTrain)
    - Obstacle if there are (Actual and Permanent)

Ground Support Equipment (GSE):

- Non-Powered Equipment:
    - Baggage Carts
    - Dollies for Container and Pallets
- Powered Equipment:
    - Refuels
    - Tugs
    - Tractors
    - Ground Power Unit
    - Buses
    - Container Loaders
    - Transporter
    - Air starter
    - Portable Water Truck
    - Lavatory Service Vehicle
    - Catering Vehicle
    - Belt Loader
    - Passenger Boarding Stairs
    - Pushback Tugs and Tractors
    - De/Anti-Icing Vehicle

Passenger's relatives and visitors are only entering the open areas such as Departure and Arrival Hall and the Viewpoint. They are not entering the airport's secure area, so there are not important in this work. In many countries (e.g. India, Kenya, etc.) they are not even allowed to enter the Departure and Arrival Halls. A separate waiting hall is established for them.

3.3. Airport Functions

Airport functions are in close cooperation with airlines and their tasks. These are:

- **ATC functions on the ground:**
  - Technical Equipment for approach and take-off operations (e.g. runways, taxiways, holding positions, safety strips, airside markings etc.)
  - Ground Navigation instruments and lights at the airport and in its surrounding
  - Controlling the movements within the airside of the airport coordinated by ATC
- **Preparation of:**
  - _Flight and Aircraft_:
    - *Flight Planning and Dispatch/Watch:* Information supplied by
      - ATC
      - Air Weather Service (Meteorology)
      - Flight Plan
      - Giving advices for the flight
      - Final Flight Plan coordination with the captain
    - *Operations Control:* Required documents for operation
      - Fuel needs
      - Passenger List
      - Cargo List
      - Requiring Ground Handling Services
      - Load Sheet
      - Captain's Signature
    - *Aircraft Ground Handling (see 3.4.1)*
    - *Air Traffic Control (not relevant for this work)*
  - _Terminal Ground Handling:_
    - Passenger Handling *(see 3.4.2)*
    - Baggage Handling *(see 3.4.2)*
    - Cargo and Air Mail Handling *(see 3.4.2)*
- **Additional Functions:**
  - _General Functions_: Ensuring facilities for the above mentioned functions:
    - Airport Infrastructure Facilities for any operation at the airport
    - Warehouse, Maintenance and Parking Infrastructure
    - Refuelling Infrastructure
    - Infrastructure for Authorities (Police, Border Control, Customs, Safety and Security)
    - Rescue
  - _Special Functions:_ Ensuring Facilities for the Passenger Service, for Visitors and Staff:
    - Waiting Area and Viewpoints (e.g. VIP Lounge, Airline Lounge, etc.)
    - Hotel, Bar and Restaurant

- Rooms and equipment for companies hosted at the airport (e.g. Meeting Rooms, Travel Agency, etc.)
- Commercial Units (e.g. Duty Free Shops, Food stores, Newspaper stands, etc.)
- Other Services (e.g. Porter, Parking service, Banks, Church, etc.)

3.4. Ground Handling Operations

The aim of this work is to monitor the efficiency of airport operations required for the preparation of airplane take-off. The responsibility for all required activities is shared among airport operator, authorities, airlines, ground handling companies and ATC. The aim of this work is also to focus on the information providing and localizing of questioned people and items necessary for take-off. The point is to have all the information of fixed and moving elements required for the preparation of an aircraft in one common system with map, data and video visualization.

The Ground Handling (Aircraft and Terminal) activities mentioned below are necessary for making ready to take off.

Ground Handling Services: It is the servicing of an aircraft while it is on the ground between the time it arrives at its parking position and the time it departs on its next flight at an airport. The two major types of procedures are aircraft and terminal operations.

3.4.1. Aircraft Ground Handling

The preparations of an aircraft for take-off are the following:

- ***Cabin Service***:
  - Cleaning
  - Replenishment of on-board consumables or washable items (e.g. soap, pillows, tissues, blankets, etc)
  - Catering
  - In-flight entertainment
  - Minor servicing of cabin fittings
  - Alteration of seat configuration
- ***Field Operation Service:***
  - Dispatches the aircraft
  - Maintains communication with all of the operations at the airport and with Air Traffic Control
- ***Ramp Service:***
  - Guiding the aircraft into and out of the parking position (Marshalling)
  - Towing, moving with pushback tractors
  - Safety Measures
  - Lavatory drainage
  - Water cartage
  - Air conditioning, cooling and heating
  - Air start units
  - Passenger boarding and de-boarding (Border Control officer necessary)
  - Checked-in Baggage loading and unloading
  - Gate checked luggage: handled on the tarmac as passengers deplane
  - Air cargo, Air Mail and Equipment loading and unloading

- Catering trucks supply
- Refuelling: maybe done with a refuelling tanker truck or refuelling pumper
- Ground power supply
- Passenger stairs supply
- Wheelchair lifts, if required
- Hydraulic mules
- De-icing
- Door Closing
- Routine maintenance
- Non-routine maintenance
- Repair of faults
- Wheel and tire check
- Crew transporting to/from the aircraft
- Documents signed by the captain
- Rescue (Airport responsibility)
- Fire fighting (Airport responsibility)

3.4.2. Terminal Ground Handling

Passenger, baggage and cargo/mail handling operations are the following:

- ***Passenger Handling:***
  - *Departure services*:
    - Check-in:
      - Ticket Validation
      - Check-in Baggage Labelling (as Baggage Identification)
      - Boarding Card issuing (as Passenger Identification)
      - Checking the necessary documents for international passengers (e.g. Visa validity, etc.)
      - Giving points for Special Airline Programs
    - Immigration (Border Control, Customs): (responsibility of Authorities)
      - Passport check
    - Security check (responsibility of Authorities)
    - Boarding passengers at the Gate
    - Closing the flight
  - *Arrival:*
    - Passenger de-boarding
  - *Staffing:*
    - Transfer Desks
    - Customer Service Desks
    - Airline Lounges, VIP Lounges
    - Lost and Found Desks
    - Information Desks
  - Passenger Information (responsibility of the airport)
- ***Baggage Handling:***
  - Baggage Check-in:
    - Labelling (as Baggage Identification)
  - Security Check (responsibility of Authorities)
  - Baggage Sorting, Resorting
  - Baggage Reconciliation

- Baggage Loading and Unloading
- Baggage Forwarding to the Baggage Claim

- ***Cargo and Air Mail Handling:***
  - Cargo and Mail reception
  - Publishing Transport Documents
  - Security Check (responsibility of Authorities)
  - Sorting
  - Toll Handling (Customs) (responsibility of Authorities)
  - Loading and unloading
  - Recipient Information at Arrival

Hence only passenger and baggage reconciliation and security issues are detailed due to the focus and the limited length of this work.
The cargo handling is already coordinated at some airports by the RFID technology. The ground support equipment is coordinated by radio. Further details are in the chapter of *Suggested System (see 4.).*

3.4.3. Passenger and Baggage Reconciliation

After arriving at the airport, the traveller enters the terminal building at the departure hall. There the passenger checks in and his baggage, and will be part of the Departure Control System (DCS). The DCS, after entering all the necessary data, will print a Boarding Pass as Passenger Identification information and the long Baggage Tag (BagTag) with a barcode as Baggage Identification. The Boarding Pass is printed to inform the passenger of the flight number, boarding time, boarding gate number and seat number, and it is used to identify the passenger at the security and immigration checkpoint and boarding gate. The barcode of the checked-in baggage serves the identification until the final destination. The longer part of this BagTag is put on the checked-in baggage. The passenger receives the smaller slip that contains the same barcode as the checked-in baggage. In case of baggage loss, the airline is able to identify and find out where the baggage has been lost. Without the passenger having this receipt the airline is not obligated to find the lost luggage and compensate the passenger.
In recent years industrial deployments have changed the previous infrastructure of the departure hall. The operation of the check-in system has not changed much, but for cost reduction, the used tools (check-in desks, boarding card) have been replaced. The operation's rate of automation increased and the passengers are more independent.

Currently on many airports there are different check-in facilities available:

1. **Traditional check-in desks with an agent:** serving mostly the business, frequent flyer and the through check-in passengers.
2. **Self check-in kiosks:** where the passenger has to check-in himself, following the indications of the touch-screen kiosks. The passenger has to provide the requested data and can print his own boarding pass and baggage tag and then continue to the Baggage Drop to weight and drop off the checked-in baggage. When self check-in kiosks are introduced, an agent can help the passengers.

Figure 18: Self Check - in Kiosk
(Source: Own Edition)

3. **Portable Agent Workstations, Mobile Check-in device:** agents circulate around the check-in area looking for customers for checking them in with a hand-held personal computer. These agents can also print the boarding pass and baggage tag, and then the passenger can continue to drop off its luggage. This method is rarely used (e.g. Kingfisher is using it at Madras Airport). (Pilling, 2001)
4. **A mixture of the above mentioned possibilities.**
5. **New trend is for passengers without checked-in baggage:**
    - Web check-in: the boarding pass is issued through the web and the passenger has to print it at home
    - Mobile check-in: the passenger can check in via his mobile and the boarding pass will be sent by SMS/MMS to the passenger's mobile phone

   Solutions are being prepared for this kind of check-in for passengers with checked-in luggage too.
6. **Remote Check-in:** in some cities (e.g. Las Vegas) it is possible to check-in at the hotel or in other cities (e.g. Hong Kong) at major interchanges and the airline will deliver the checked-in baggage to the airport.

The above mentioned check-in possibilities can use several tools too:

1. **Boarding Passes as Passenger Identification:**
    - Traditional Magnetic Strip
    - BarCoded Boarding Pass: using 2D barcode printed on a paper from the airport's check-in facility or outside the airport from the web or sent to mobile phones or PDAs in SMS/MMS format. It should be used by all IATA member airlines by the end of 2010, and it should completely replace the magnetic strip
2. **Baggage Tag as Baggage Identification:**
    - Barcode: this is the commonly used solution
    - RFID tags embedded in the back of barcode paper: some airports and airlines have adopted it after some trials (e.g. Las Vegas, Hong Kong)

After the check-in, the road taken by the passenger and the baggage will separate, and meet again at the Baggage Claim of the final destination. The following graph (*Fig. 19)* shows the stations a passenger and a luggage go through while travelling by airplane:

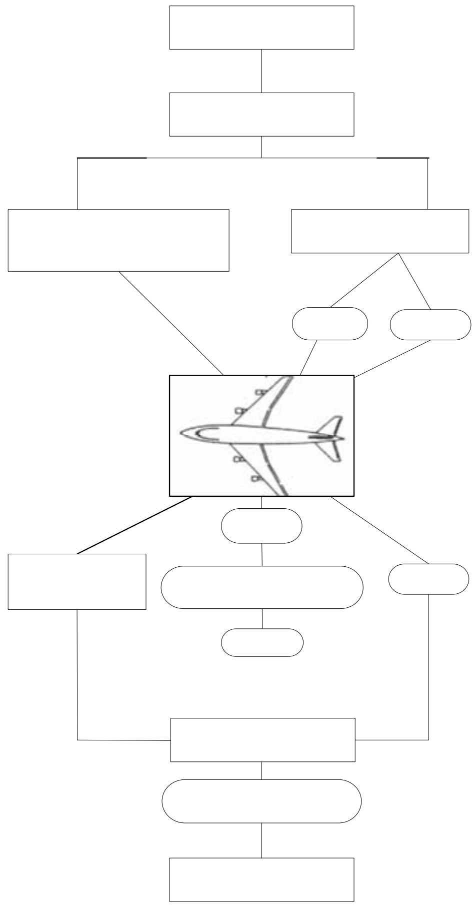

Figure 19: Passenger and Baggage Flow During the Flight Procedure
(Source: Own Research)

The passenger is attending the security and border control checks, the order depends on the airport and then at the time of boarding it will proceed to the plane. In the meantime, after the baggage check-in, the baggage passes through security checks and baggage sorting. In the sorting room, with today's reconciliation technology, the stevedore scans the BagTag's barcode with a scanner that translates the encoded barcode and shows the stevedore to which baggage cart or container and airplane the luggage should be directed to. Before take off the flight agent has to make a passenger manifest report. No check-in baggage is allowed to take off without its owner on board. After arrival of the flight, in case of a direct passenger, the passenger continues to the immigration check and then to the baggage claim to collect his baggage and leaves the airport through the arrival hall. At the exit of the baggage claim nobody checks if the baggage was taken by its owner or another person. In case of a transfer passenger and baggage, the passenger stays in the transit of the terminal building after leaving the aircraft, and he passes through immigration check (depending on the destination) and a security check before re-boarding. The baggage passes through security check, re-sorting and then goes to the new aircraft. If the transfer time is one hour or less, the baggage is tagged with the ShoCon sign. However, when the airplane is delayed, and the baggage would be needed to be transferred quickly to the next airplane, there is no special sign tagged on the luggage (originally it was supposed to arrive on time and supposed to have enough transfer time), the possibility of the non-arrival of the baggage is very high.

Problems with Boarding Passes

The boarding pass in general has a very short life-time: from the check-in until the boarding gate. It is serving to show passengers the necessary information for their flight and the short part of it taken at the boarding gate it is showing the airline the real amount of passengers on flight and is forwarded to the airline's revenue division (Legeza, 2004).

The web-check-in based 2D BCBP is very good possibility to reduce the costs for the airlines but it is still not environmental friendly. The option of SMS/MMS to mobile phones or PDAs is environmental friendly but not all passengers have the suitable equipment for it and the battery of the equipment can run out easily.

Problems with in-use Barcode-Scanner System for the Checked-In Baggage

Most of the world's airports use a scanner and a paper printed barcode for baggage identification.

The key problems with the barcode and scanner are as follows:

- The barcode needs optical readers, which without a good line of sight, can not read correctly
- Concurrently the scanner is able to read only a single barcode, which is time consuming
- Barcode baggage tag read rates average 85%
- Barcode is printed on a paper that easily crumples, thus the scanner is not able to decode the information properly
- After printing the barcode it is not possible to overwrite the information (only by printing a new one)
- The paper of the barcode is long, full of information that comes off easily, thus making it impossible for the stevedore to identify where the luggage is supposed to be sent and the airline is unable to find it in the computer database. It will be regarded as the airline's mistake, and the airline has to compensate the passenger.
- *Fig.20.* shows that the barcode is printed on a long-hanging paper, which is only attached at the middle or at a suitable part to the luggage. The most important part of the paper is just hanging down – without being fixed to the luggage- so it can easily come off.

Figure 20: Today's Baggage Barcode Solution (Source: Own Edition)

3.5. Security

In most of the world's airports everybody can enter the departure and arrival hall of the terminal building while the transit hall is reserved for passengers only after passing the strict rules of the border control and security check, the order depends on the airport. Mainly in African (e.g. Kenya) or Asian (e.g. India) countries the visitors are not allowed to enter the terminal building, there are separate waiting halls next to the terminal. To enter the terminal building the passenger has to show the flight ticket and (together with his/her baggage) go through a first security check. For example in Madras (India) the visitor can pay an extra fee to enter until the check-in, but the waiting area is strictly separated from the check-in queue. The airport is fully equipped by visible and hidden cameras. People are informed of being monitored by a sign at the entrance door: 'The building is monitored by a security camera'. Both passengers and baggage are passing through a security screening after the check-in to ensure that they lack any suspicious articles on board. After entering the departure hall the movement of each person is recorded by a video until leaving the terminal. Some airports possess 360 degree camera, but it is new and still not common. Passengers, employees of restricted airport areas undergo metal detector test at security checks, in case of a problem the person will be checked separately, to speed up the manual check the staff can use the mobile metal detector. In some countries the passengers are checked twice.

The hand and checked in baggage, employee's belongings, cargo and postal matters pass through security checks of a 3D x-ray. The checked in baggage undergoes a security check right after check-in. Afterwards it can be directed instantly to the aircraft or it stays in a waiting position somewhere in the baggage sorting area. Transfer baggage passes through security control after offloading, before the new sorting. There is no extra security control right before the luggage is taken to the aircraft. In the meanwhile it is easy to struggle something into it or take out some items. Even though that area is equipped by cameras if the worker is with the back to the camera no one sees what is happening.

3.5.1. Tracking Staff

Before the employment on an airport, the past of the future worker will be scrutinized for the last five year.

Entering the Security Restricted Area (SRA) the employee need a special authorization. They pass at each entering through a very strict security control as passengers do. They have strict entrance authorization and are watched all the time by visible and hidden video cameras. The authorizations are given by the airport authority according to the field of work, for those places it is important to have access to fulfil job well. The personnel of sensitive areas such as the baggage sorting or the cargo area have to be checked as well very strictly to avoid any mishandling (e.g. steal something from the baggage or the shipment, put something into it) of the baggage or shipment waiting for a flight.

Today's mainly applied identification for access control is the smart card. Entering a restricted area the employee has to place his smart card to the reader at the door of that area. If the permission is given, the door opens, if not it stays closed. Anybody can use anyone's smart card as at the entrance there is just a card reader without any other kind of personal identification (e.g. password, PIN code, biometrics). In reality nobody really can be sure who enters that special area. The video camera inside that area is not identifying the employee's identity just showing a person. CCTV footage's supervisor doesn't know everyone's access authorizations. It is easy to trick it out.

At some airport after entering the SRA while passing the X-ray and metal detector a security guard is checking manually the badge of the entering person. The only problem with this is that many times the security guard doesn't check the badge properly, doesn't know all the letter code used at the airport. The given authorization is marked on the badge of the employee by letter codes to identify the areas the employee can enter. If two persons look very similar it is difficult to differentiate them without proper analyses of the picture on the badge.

Security Failing due to Human Factors of Staff

Not only passengers can be wrongdoers or terrorists, for staff members it much easier to take anything inside airport's restricted areas. Human factor can be the key to effective security but a weak link too. Not just the gullibility, good temper but money, attractive item, bribery etc. can lead to failure of the security restrictions and technologies. Lost uniforms and ID cards, repeated journalistic intrusions, incompetent screeners, and inoperative monitoring cameras are just sample examples how easy it is to trick out the security technology (Establier, 2009). Everyone has a weakness where he/she can be blackmailed.

Many aircraft hijackings during 1980's were easy to organise for terrorists due to the complicity of the airport staff (Establier, 2009).

In December 2001 at Paris CDG Airport Richard Reid boarded a flight into the USA with explosive device concealed in his shoes. He could board the aircraft due to two reasons: the limitations of the metal detector and the laxity of the authority (Establier, 2009).

In August 2004 two airplanes departing from Moscow's Domodedovo Airport were brought by two Chechen women. Not just because of the technology's failure, the police neglect and corruption allowed the activities of local mafia elements conducting regular criminal activity within the airport. The police officers were very cheap, they cost only USD170 (Establier, 2009).

Australian authorities identified airport employees being behind drug trafficking at Sydney Airport in June 2005 (Establier, 2009).
In September 2005 at Vienna International Airport armed people went through the security check. Similar things happened in London, Warsaw, Philadelphia, Ottawa etc. (Establier, 2009).
2007 Royal Canadian Mounted Police inquiry claimed that 8 major airports were integrated into organized crime. Hundreds of police files and hundreds of people were involved in criminal activities, including 300 current or former employees (Establier, 2009).

Screening baggage is implemented to detect terrorist and their attacks but it also helped the growth of the airport-based criminalities to identify the items worth stealing (Establier, 2009).

3.5.2. Tracking Ground Support Equipment

The Ground Support Equipment if they are tracked, it is done by radar or GPS. Some Ground Handling companies are starting applying RFID.

3.5.3. Tracking Aircraft

The aircraft are tracked by Surface Movement Radar (SMR) on the ground.

3.5.4. Tracking Vehicles

Vehicles entering the airport or circulating always within the airport are tracked, if they are tracked, by a transponder, SMR or GPS. Some companies are trialling RFID.

3.6. International Trend for Ground Handling

Current trends in the aviation industry, following the Simplifying the Business (StB) program of the International Air Transport Association (IATA), are: simple and seamless travel experience with minimised hassle and more control by the passenger (e. g. less queuing, less time needed at the airport, more independency), meet the consumer friendly expectations, establish financially sustainable business environment, lower the costs of the airlines, environment friendly (paperless e-ticketing), faster and more efficient baggage handling, to create industry-wide standards (IATA b.)
A goal was to introduce the BarCoded Boarding Passes (BCBP) using 2D barcode. They can be accessed from anywhere, from mobile phones, PDAs, web, they don't need to be printed on expensive paper stock, and they facilitate off-airport check-in, they are cost saving and environmental friendly.
Another program run by IATA related to passengers was Simplifying Passenger Travel (SPT). The goal was to facilitate the flight procedure for passengers, while emphasizing the simplified and secure passenger processing.

IATA's StB Program had a part concerning RFID, but the related project was closed. On the website (www.iata.org) of the organisation it is written: "Because the value of RFID is subject to the individual merits of each business case, there is no mandate for the universal adoption of RFID from IATA." The project standardized the used RFID tag and frequency for the aviation industry, implementing it into the paper BagTag on the back of the barcode.
Still the aviation industry is trialling and applying RFID. Airlines, airports, ground handling companies try to face and take advantage of the possibilities given by this technology. The most common is to apply it for baggage handling but tracking Ground Support Equipment (GSE), catering, cargo is becoming common too.
Another useful application of the RFID technology is the access control of vehicles to airport operational areas (Pilling, 2001). At London Heathrow airport American Airlines' access control system prevents unauthorized drivers from using American Airline equipment as the driver can only start the vehicle's engine by using Airport Security pass which is recognized by the use of RFID technology supplied by Vehicle Telematics Information System (VTIS) (Ornellas, 2007).

Airbus and Boeing cooperated in using RFID for the parts of aircraft. Airbus applied it to track tools and for inventory control on inbound shipping pallets (Mecham, 2005).

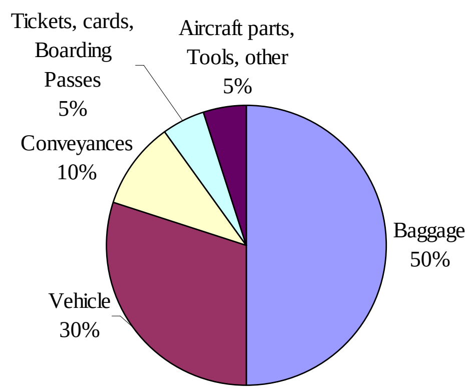

Figure 21: Spent on RFID Systems in the Civil Aviation Industry in 2006 (Source: Ornellas, 2006)

3.6.1. RFID for Baggage Handling

At the Passenger Services Conference in Geneva November 2005 the International Air Transport Association (IATA) has introduced a global standard for RFID baggage tags that paved the way for the use of RFID. In 2005, however, only two or three European countries have permitted site licenses for testing at the higher power level.

Various tests are conducted at major airports with RFID baggage tags. At Las Vegas McCarran International Airport, Hong Kong International Airport it is already operational. Paris, Amsterdam, Milan and San Francisco airport the trials are still going. Trials were completed in Vancouver, Philadelphia, New York, Honolulu, Nairobi, Frankfurt, London, Amsterdam, Rome, Kuala Lumpur, Beijing, Narita in Japan and some Korean airports (IATA a.).

Hong Kong Airport is using the technology for the checked-in baggage and is providing for the transfer baggage arriving to the airport without a RFID tag an extra tag. Currently, more than 70 airlines are involved in this project (Ornellas, 2009).

Heathrow started a six month trial of RFID technology for Emirates passengers (Ornellas, 2008).
For 2004 Delta Airlines has tagged its 40 thousandth passenger's baggage within a pilot program. While in 2004, the amount of RFID enabled baggage tags delivered was only a couple of thousands (and all in a trial setting), by 2005, however, this amount has increased to about 15 million, with an average price of 22 cents per tag.

Currently airports, airlines, operators testing RFID are embedding the RFID tag into the common barcoded BagTag paper and then attach it to the baggage. Even though the paper can come off, the identification is much easier. The other main problem is that if only some airports are applying RFID and the rest is using only barcode application it is not as efficient and still can get lost during the air travel and two technologies must be applied simultaneously. IATA calculated that airlines would save $768 million annually from reducing their mishandled baggage by only 1%. About three times as much can be saved by airports. The use of RFID in transfer processes was carefully analysed by IATA as part of the RFID transition plan. This analysis showed that only 80 airports needed to adopt RFID to deliver an annual benefit of over US $200 million to the industry (IATA, 2008).

3.6.2. RFID for Passengers and other Improvements on Passenger Handling

One of the latest possibilities is the boarding pass sent to mobile phones or PDA-s via SMS or MMS. The greatest advantage of this technology is that the passenger can be informed of the changes related to his trip, but this requires the user to have a modern mobile phone or PDA capable of receiving MMS, which is always on, and can communicate on all frequencies. These solutions are targeted for frequent flyers and business passengers, they cannot be used for all passengers, because it cannot be expected that everyone has a mobile phone or PDA with such technology. Another problem with this innovation is that a mobile phone or PDA can run out of battery without possibility to recharge it.

Figure 22: Boarding Pass with Barcode, 2D Barcode in a Mobile Phone, RFID in a Paper (Source: Own Edition)

Figure 23: Automated Boarding Gate
(Source: www.airport-int.com)

The automated boarding gate can read 2D barcode Boarding Passes from mobile phones, PDAs and paper. It is not only a boarding gate it has the facility of the basic process of automated passenger authentication. That means to have the biometric data of the passenger scanned while he is standing in the gate, to instantly compare this data to an existing biometric template of the same passenger and to check if both match. The second step is to check whether this passenger ID is included in the list of passengers who checked-in for the flight. The biometric data is sufficient to perform both steps and reading the boarding pass is not necessary (PTEC). In such an automated boarding gate an RFID reader can be integrated easily.

At Copenhagen Airport 4% of the flight delays for Scandinavian Airlines (SAS) are due to late passengers at the boarding gate (Ornellas, 2008). Therefore, SAS tested there a more efficient passenger process. Passengers having an extra RFID tag card were informed by SMS in case they were not appearing on time at the gate or changes (Ornellas, 2008). The only problem with this is that the passenger has to have a boarding card and a RFID tag card as well.

Swissair conducted a trial at Zurich airport for checking in passengers with RFID tags. Each TravelClub member an e-pass was issued, which is based on the membership number. Upon booking the flight this is entered into the reservation system of the airline. The trial involved only for members of the TravelClub without a checked-in baggage. They were automatically checked-in when they passed through the passport control and showed their passport (the reservation system passes their data to the DCS), after the border control they had to proceed to the information desks and pick up the boarding pass (Pilling, 2000). The problem with this is that they still needed to print a boarding passes for passengers and not the immigration gave them the boarding passes, they had to find the information desk and queue again, which was time-consuming.

3.6.3. Improvement on Security

Some airports, especially in the USA are introducing biometrical identification simultaneously with the smart cards for access control to restricted airport areas. The extra identification is placed next to the card reader before entering the restricted area. Most commonly used biometrical identification method for this is the IRIS recognition, facial recognition or fingerprint or their combination. The biometrical data are stored on the smart card and while supervising the access permission it is checked for matching and access permission. The problem with this is that if the scanner is not properly cleaned it can be easily source of infections and that the biometrical identifications if they are not combined applied are easy to trick out and are not 100% accurate.

Biometrical identification, especially facial and Iris and fingerprint scanning is getting popular for the border control, staff access control and some airlines apply it at the check-in too, also implemented into self-check-in kiosk.

Companies are trialling laser system built into doors where passengers are passing through. This laser system is only serving for counting the passed passengers but it whether saying who it was whether is tracking or monitoring the people. This system is not connected with any flight or DCS specifications e.g. for counting the passed through passengers to know how many are still missing at the gate.

Another improvement is to track people entering the airport terminal building by their mobile phone’s blue tooth. The main problem with this that passengers must have a mobile phone, the mobile phone has to be turned on, the mobile phone has to work on that frequency and needs to have blue tooth. These are too many criteria to rely on. This type of tracking can not be applied for all passengers maybe just for frequent flyers or VIP.

There is nowadays a technology applied that focus on passenger and its hand luggage and monitors distance between them. The only problem is if the passengers change their hand luggage or leaves them to someone, the system generates false alarm.

4. Operation of the Suggested System: RFID Integrated into GIS

GIS is the best system to integrate all stable and moving elements at an airport into one monitoring and surveillance system and to identify their actual locations (positions) and tasks. For identification and tracking of the moving elements and for the automation of terminal operations, the best current technology is RFID. GIS also enables integration of video recordings and monitoring capture. Monitoring of moving elements can take place both in real-time and non-real-time, at reading point and continuously RFID can be integrated into GIS (Bite a., 2010). The geographical information systems (GIS), information technology (IT) and radio frequency identification (RFID) together can identify and track moving objects in a restricted space as an airport.
Currently, GIS is used at the airport for infrastructure management and the ATC is using it with additional information for tracking airplanes and airport vehicles *(see 1.4.7)*.
The application does not include the tracking passenger, luggage, crew and ground handling units integrated into a common GIS system with RFID *(see 3.6.)*.

4.1. Improving the Efficiency of Ground Handling

4.1.1. Using RFID Tag Implemented into a Bracelet for Passengers and Baggage

Presently common boarding passes with magnetic strips or new 2D barcode boarding passes have a very short lifetime, and they are not used after the boarding, except for collecting frequent flyer points. The recently introduced 2D barcode Boarding Pass, which should be adopted by all IATA members until the end of 2010, avoids printing a new boarding pass for each connecting flight; it can store the boarding pass data of all the connecting flights. But still, after the last boarding, it will be thrown away and it is not possible to re-use it. Analyzing the identification technologies *(see 2.),* comparing their most important attributes *(see Table 1.)* RFID is the most applicable technology which fulfils all requirements for my system.
Giving passengers an RFID chip implemented into a watch/bracelet, passenger tracking during the flight procedure can be ensured and it also facilitates the orientation at the airport for passengers (Bite e., 2008). In case of a problem, it is much faster and easier to locate the passenger and its luggage. The passenger's way after the check-in could be tracked until the end of the flight procedure. This would make the following possible (Bite a., 2008):

- The RFID tag implemented into a watch/bracelet, etc. would be machine fixed to the baggage at the check in or at the baggage drop (BagDrop). (It would be almost impossible to remove it.) No more barcode would be attached to the baggage. (It would be almost impossible to remove the bracelet from the baggage.) The possibility for the Bag RFID Tag to come off or for someone to tear it off is zero. The machine that fixes the bracelet to the baggage could be built into the check-in counter or into the baggage drop. At all the baggage checking points, an RFID reader can be implemented instead of the presently used scanner system*:*

Figure 24: RFID Implemented into a Bracelet
(Source: Own Research)

- The passenger's bracelet could have a small display to show the information of today's boarding pass, the flight information, and, at the arrival to the final destination, the details about the baggage claim. In case of a transfer flight, the actual details would be shown. This would make the passenger's orientation much easier. In case of any changes (e.g. boarding time, gate, etc.) the tag could be updated.
- With a passenger bracelet equipped with a speaker and vibration alarm, it would be possible to warn passengers in advance so they would not be late at the gate. In case a passenger is late, it would be much easier to find him. The flight coordinator could contact the passenger or simply find him in a second within the terminal and the time and costs of unloading its luggage could be minimized or totally avoided.
- In the transit hall, right at the entry point or at several points, an information appliance could be installed to facilitate the passenger's orientation with a touch display. Passenger have to hold their RFID tags against the machine and the machine automatically shows how much time they need to get to the gate and how far they are by means of drawing the right way on a printable map. It is also possible to offer a list of shops and additional services on the way. In case of arriving passengers, it could show the number of their baggage belt and the way to it, and whether the baggage is already circulating on the belt or not. This could be a good service provided to passengers feeling lost at large, complicated airports.

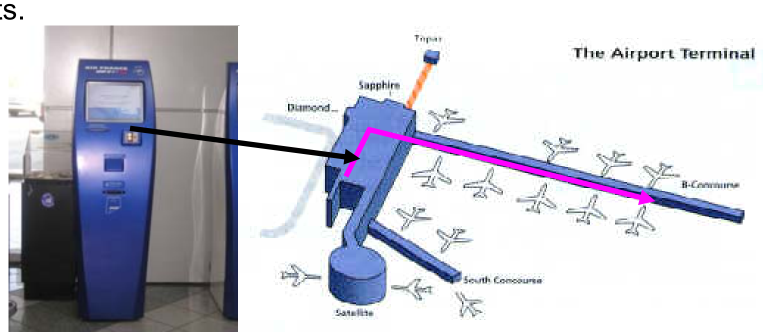

Figure 25: Passenger Information Kiosk
(Source: Own Research)

- At the boarding, where boarding passes are checked manually nowadays, the whole process could be automated with much less human intervention. Passengers would only have to hold their chips against the identifier, and if a passenger is at the wrong gate, it would automatically alert with a sound or just simply say: 'Sorry you are at the wrong gate'. In case of an automated boarding gate, the door would not open if a passenger is at the wrong gate and would automatically display the correct gate number and time along with a map where the passenger is supposed to board. While a passenger is crossing the boarding gate, the system automatically checks if his/her baggage has already been loaded or not. If not, it knows where it is. At the end of the boarding procedure, the system shows to the flight agent, whose baggage has already been loaded but the owner hasn't passed yet the boarding gate.

- If the passenger has an RFID tag with the same data as his/her baggage, the passenger-baggage check at the customs – before leaving the airport – could be effectively carried out. The possibility that a baggage is taken away by another passenger either by accident or intentionally stolen, would be almost zero. It could be checked automatically, so it would be quick and it would not affect or slow down the passenger flow. Costs generated here for the airline could be reduced enormously.

Of course passengers' privacy must be protected. The personal information of passengers and their locations should only be accessed by the flight coordinator if there is a problem. Until the system does not send any alarm to the flight coordinator, employee will only monitor RFID tag numbers. To avoid mishandling of the personal data, one-way codes must be used and the tag of the passenger should only be activated when the passenger enters the transit hall of the airport at the security or passport check (Bite c., 2008). At the exit doors of the airport, an extra reader could be implemented: in case of leaving the airport after checking in a baggage and not returning on time to reach the gate on time, the system could send an alarm to the flight coordinator.

4.1.2. Reuniting Passengers and their Baggage at the Baggage Claim

Normally, at the exit of the baggage claim, nobody checks if baggage is taken by its owner or another person. Only at some American airports and at the Hanoi airport in Vietnam, dedicated service people check bag tags manually, right before travellers leave the customs area.

Nowadays, at some airports, the passenger-baggage check at the baggage claim is either a totally manual process or does not exist at all. But in case a baggage gets stolen, the airline is responsible for the compensation. It is not possible to manually check if a baggage belongs to a given passenger. It would simply cause enormous queues. There are no security checks of the passengers leaving, so this problem is not dealt with.

If the passenger has an RFID tag containing baggage data, the passenger-baggage check at the customs – before leaving the airport – could be effectively carried out. The possibility that a baggage gets taken away by accident or stolen would be almost zero. It is not manually checked, so it would be quick and it wouldn't affect or slow down the passenger flow.

Implementation of this check depends on whether the RFID tag is a one-time used tag or a reusable one (Bite b., 2008).

In case of a single use tag, the check is very easy: At the exit door, an antenna is placed, which identifies the tags and, in case of a problem, a signal would be forwarded to the security automatically. Of course, a couple of seconds are necessary to complete a check and passengers must walk into a narrow lane in order to do this. However the system to be implemented must be capable of handling all the ways passengers bring their luggage (beside them, pulling behind etc.). It has also to be ensured that the reader is capable of identifying several passengers (and their luggage) exiting at the same time. After leaving this area, the RFID chip should be de-activated to avoid mishandling of personal data and the chip itself.

In case of reusable chips, they must be returned at the airport. This can be processed by means of a box, where passengers have to put their bracelets in a holder at the box, while pulling the luggage through. In the box, the identification can be made and the chip removed. The exit door is opened if everything goes well. If there is a problem, the door stays shut. To save time and space at the airport, this identification procedure could be made at the customs. It is similar to an automated boarding gate but would serve for leaving the airport and matching the passenger and her/his baggage (Bite f., 2008).

Figure 26: Exit with Reusable Chips
(Source: Own Research)

If a passenger has more than one package, this is encoded in the tags so the system knows that several packages are will come through the box (Bite, 2006).

In case a package has not arrived on time, a tag writer could be used at the Lost and Found desk to overwrite the data so that exit problems are avoided.

As an additional service to the passenger, an information appliance (Passenger Information Kiosk) at the arrival side could be used to inform the passenger where his baggage belt is located and other important information such as shops or money exchange, etc.

Figure 27: Simplified Flowchart Diagram for Passenger and Baggage Identification Machine at the Baggage Claim
(Source: Own Research)

4.1.3. RFID Passport Serving as Boarding Pass

The next step in the technology's innovation is the widespread use of biometrical passports with an RFID tag implemented that stores the biometrical information. It would improve the efficiency and the level of automation to use RFID passports as Boarding Pass, too. There are 2 possibilities for using the passports as a boarding pass (Bite a., 2010):

1. Passengers holding their new RFID tagged passports, with the passport having a small display, because then all the boarding information could be automatically stored in the travel documents and no extra kind of boarding pass would be needed.
2. Following the trends of saving costs everywhere where it is possible, another option is that the passport's RFID has all the actual boarding information required, and the passenger simply memorizes or copies it to a small piece of paper if he wants (not necessary), and the boarding procedure would be absolutely paperless. It is necessary to memorize the flight destination and the time only, because with this information any flight information display can provide further important information, or the passenger can proceed to a passenger kiosk proposed above *(see 4.1.1.)*.

At the check-in desk or self check-in kiosk, the data of the flight would be written into the chip (Bite g., 2008). With web-check-in becoming more common, passengers can check-in through the web, and if they have no tag writers at the computer where they had processed the check-in, they just go to the baggage drop (if having a baggage to check-in) and there, they can write it on the passport's chip or simply at the border control as the mentioned *(see 3.6.2.)* solution of Swissair with the improvement that the officer tells and gives information to passengers, and no pick-up of extra papers and queuing is needed.

In case this is too complicated to apply to each person, then it would be definitely feasible to apply this method for diplomats, VIP person, frequent flyers, businesspersons, etc. They would have their chips and their check in would be much quicker. To implement a chip writer at home is just a question of time. As after a long period, CD/DVD and USB drivers and paper printers became widespread and now almost everyone has one, it is just a question of time that the chips get more common and home tag writers can be used. And with the home chip writers, the new problem (and the possibility) of printing boarding passes at home could be solved, too. Around 2015-2020, RFID passports would become widespread worldwide. The advantage of the RFID passport serving as a boarding pass is that passengers do not have to take care of too many documents, and on their passports, they will definitely keep an eye.

4.1.4. Combining Security Check, Border Control and Check-In

The next step is to combine the security check and the border control. As the security check technology can have RFID and biometrical identification integrated, all necessary data could be checked only by passing through the security check. And only those with visa or "black list" problems would need to proceed to an extra check. This could speed the flow within the transit area up: less queuing is necessary. Furthermore, the check-in could be integrated into a united security check and border control as passing through the security check, the RFID reader implemented into the security gate could activate the check-in information and validate it.
In case boarding passes are integrated into RFID passports, passengers without any checked-in baggage could to go through a door like at the automated boarding gate, and wouldn't even have to take out their passports for exiting the terminal.
If passport check is not needed anymore, passengers could receive their boarding passes in the form of bracelets, and would return them at the baggage claim before exiting after the passenger-baggage identification.

In case passports contain passenger-baggage information as well, identification at the baggage claim could be combined with the passport check or simply the exit door would delete the fight data from the passport's chip after identification. The box, mentioned before *(see 4.1.2)*, wouldn't be necessary for the passenger: there is simply a reader, where passengers have to show their chips. While luggage chips are reusable chips, which remain at the airport flow, and, at the exit, the before mentioned box the passenger has to pull his baggage through.
In case of using active tags for passenger monitoring, as soon as the passenger goes on board, RFID tags have to de-activate themselves until disembarkation, where they should re-activate automatically. Or, at the last reading point before the boarding, the reader could de-activate tags, and, at the first point, re-activate them automatically. With this refinement, it would definitely not interfere with the aircraft's technical equipment or endanger flight safety. It is better to use passive tags, especially in case of the application of the RFID Passport as boarding pass, as there is no extra expense on the airline or airport operator because the passengers already dispose of it.

In case of overbooking, when the passenger passes through the combined check-in+security+border control and the check-in identifier while sending the information to the now used DCS realise an overbooking, the system sends an alert to the flight agent and the personnel working at the combined check to ask the passenger to wait there for the flight agent. After discussing the possibilities of a new flight and agreeing the flight agent re-writes the RFID tag with the new flight information.

4.1.5. *Using RFID Tag for Staff*

In the airport's terminal building and outside areas, there are many video cameras recording the movement of the people passing by. On the video screen, it is only possible to see if a person is moving but it is not possibly to identify the person's identity. In the USA, some airports use facial recognizers implemented into video cameras within the airport (especially where passengers are around). This technology is not perfect yet in this regard. If the person who is passing by the camera is not looking directly into it or the total face cannot be seen even with zooming on it, the facial recognizer is unable to identify the person. Even if he/she looks into the camera, but something small has changed on its face (e.g. taking some pills to have the face deformed), or especially with bigger changes, it is unable to identify the person. Even in the best case, when the person looks into it, facial recognizers need to have a very high resolution to identify the person correctly, and the accuracy rate is quite low. The only reason of using facial recognition implemented into the video camera is that it doesn't need any physical contact, and can be implemented in crowd situations (Griffiths, 2009). In the future, ear shape recognition could be combined with facial recognition to identify people from CCTV footage (Bite b., 2010). Ear shape recognition has an accuracy rate of 99%, according to laboratory tests (Griffiths, 2009).

The staff's smart card only shows where a staff member has authorization to enter and has entered, but it doesn't provide information about his/her position continuously. It is very easy to change smart card or to loose it. It is getting more common within the aviation industry that the smart card contains the biometrical information of the employee as well. These may vary from IRIS to facial or fingerprint recognition, or a combination of these methods.

Issuing RFID tags embedded into the badges, combined with biometrical data to workers would secure the system. The video shows movements of employees being recorded, and their tag numbers show who they are and if they are allowed to be there. At the entrance to a restricted area, their authorization and personality is confirmed, too, or not depending if he is the badge's owner or not. Integrated into GIS software, it can visualize differently, and a map of the movement flow can be drawn automatically. It is possible to store the data for a long time. In case of any problem, it is possible to find out who there was at that time. Time measurements can be taken too. For example, if an employee spends too much time at certain package, but he/she turns his/her back to the camera, and later a claim arises that something is missing from that bag, having the bags with RFID BagTags too, it is very easy to find out who had made the crime.

In case of an emergency situation (e.g. pointing out an act of terrorism, putting something into a bag or aircraft), where the security personnel sees the crime in real-time on the monitor, it can overwrite the wrongdoer's tag and cancel his/her authorization for exiting that area and the wrongdoer can be caught. The software can give alarms as well. In an emergency situation, it can automatically map where the alarm is raised and draw the quickest way to that place.

The authorization personnel could change the permissions of each staff member anytime in case of any abuse. For the permanent staff, a permanent card with RFID, storing the owner's biometrical information, will be issued. For people who rarely enter the airport's restricted area, a card would be issued at every entrance, so the information on the cards would be deleted automatically at the exit and the cards could be re-used for a new person. It is thus simpler to identify the violator and to take action immediately. It is much more efficient, less complicated to find out who the violator is.

To enter to the restricted area the RFID tag is used combined with the facial and ear shape recognition placed next to or into the RFID reader as their combination is the most accurate identification.
To access any computer system (or where until now a password or PIN-Code was applied) will be as well by the combination of the facial and ear shape recognition implemented into the closest video camera. The employee might not even realise the identification.

4.1.6. Protection against Baggage Pilferage

In case of baggage pilferage, a damage report must be filled out. The claim department must consult frequently with the security staff to guard against fraudulent claims, summarize the experience, and distribute that summary with an emphasis on where the losses had arisen. At sorting or security check, a picture of each piece of baggage could be taken. In case of any problem it could be seen, how the baggage had really looked like, and in what condition it had been. The airline or operator company can always check the pictures, and are protected if anybody claims any compensation for baggage misuse. Tracking luggage through the whole flight procedure with RFID tags enables to find out where the luggage was stored, and for how long. Besides measuring the airport infrastructure, it is a great method to decide if the airport personnel are pilfering the baggage or not. In case the luggage was stored at such a place for a long time, where nothing was around for a while, and afterwards a passenger reports that something is missing from the bag, the system can automatically track the whole journey of the luggage to find out where it could have been tampered with. But this could be checked much better if the personnel were traced by means of RFID tags as well. A video camera at the baggage sorting, if it is well placed, can show if one of the staff members is responsible for it, but it is not capable to identify that person. With the RFID, the identity would be clear as well. One thing for tracking passengers with RFID tags for flight security reasons is preventing them from taking something suspicious on board; another is to make sure that none of the airport personnel puts something secretly into the luggage of a passenger or into the baggage compartment.

At the security check of baggage, a 3D scanner could be implemented, and this scanner could take a picture of the baggage to show all baggage characteristics. In any case of a customer complaint, if the airline wants to be sure or has any doubts of the customer's complaints, the airline can check the picture taken and can avoid any misunderstanding and any false compensation due to foxy customers. The pictures taken should be stored in the baggage data area of the GIS.

This system avoids the possibility of human errors due to naivety, charity, direct corruption and crime. The system automatically stores and analyses mistakes, and provides new options to avoid them. If an employee is doing any type of crime, the system automatically alarms the higher authorities. In case of any later problem or any capacity problem, the system can track back, whose error the problem has been arisen due to. With this option, human resource allocation and equipment allocation could be coordinated better.

4.1.7. RFID for GSE

The Ground Support Equipment has to be tagged too. It is easier to find the equipment and check in the GIS database, which one is available for a special task.

4.1.8. SECURITY: RFID+VIDEO

Analyzing the biometrical identification technologies *(see 2.),* comparing their most important attributes *(see Table 1.)* the combination of facial recognition and ear shape recognition is the most applicable technology which fulfils all requirements for my system and for a reliable identification without the person itself realising it.

Combining facial recognition and ear-shape recognition could be a reliable identification, without anyone noticing it. The GIS is able to implement video pictures and display them. Zooming is possible too. The camera recognises any type of abnormal events and alerts the other cameras, which turn to that point and zoom in automatically. In case of any problem, it sends an alarm to the supervisor.

Outdoors, this is possible with GPS coordinates and indoors, by the RFID. According to the RFID tag's information, the cameras know where to turn and zoom in. If human personnel monitor any incidences and the life on an airport by a CCTV manually, human errors may happen (e.g. the guard falls asleep, is drinking a coffee, is writing an SMS, etc.), the incident may not be realized. It is better to integrate a special alarm system for alerting by means of a sign and sound in any case of incidence possibility, and then, after analysing the questioned incidence, the employee can decide if taking steps are necessary or not. The system automatically shows the shortest and quickest way to the place of the incident, and in case the employee is equipped with a portable device (e.g. PDA), the map could be displayed on it automatically.

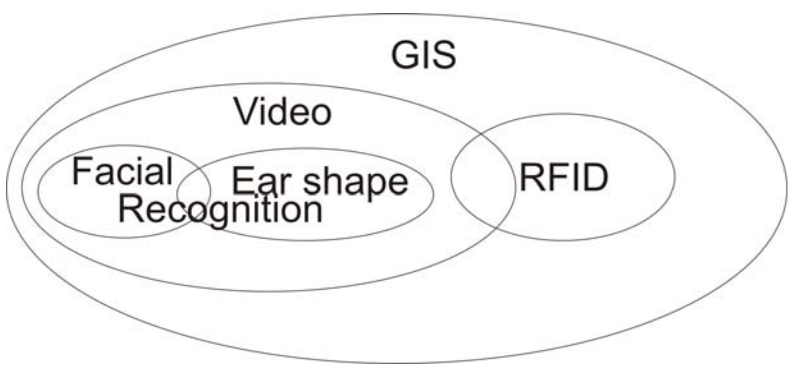

Figure 28: Personal Identification System
(Source: Own Research)

4.2. Integration into GIS

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.

4.2.1. Stable Elements in the GIS

The listed stable elements *(see 3.2.1.)* (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.) (as a simplified example *see App. 8.*) 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.

4.2.2. Moving Elements in the GIS

Moving people and items within the airport *(see 3.2.2.)* 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 a., 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 (for passenger and luggage handling *see Fig. 30*). The interface is converting the RFID signals to able to be captured in the GIS *(see Fig. 29)*.

Figure 29: ***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 (see App. 2., Table 3.*). The gained information can be visualized in different ways in the GIS *(see 1.3.5.)* 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 map's actual video is shown; the video cameras' recordings are integrated into the GIS. These 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 *(see 3.)*, 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 in the appendix *(see Appendix 2.).*

Inpu

x = R

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 *(see App. 2.)* the information on the screen for the authorized person is *(see Fig. 32., App. 7.)*:

- ***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)
- ***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 facilitate the passenger and baggage reuniting before leaving baggage claim exiting to the airport arrival hall and then exiting the airport *(see 4.1.2.*) the relation between the passenger and the baggage RFID tag is the followings *(see Table 3.)*:

A Card (Passenger Card)	B Card (Baggage Card)
1. ID number	1. ID number
2. B ID Number(s)	2. A ID Number(s)
3. Passenger Code	3. Passenger Code
4. Flight Number (s)	4. Flight Number (s)
5. Baggage Code (s)	5. Baggage Code (s)
6. Final destination	6. Final destination
7. Transfer(s)	7. Transfer(s)
8. Family member's (s) B Card(s)	

Table 3: Passenger and Baggage Data Relation
(Source: Own Research)

This information are stored on the same RFID card described above but this kind of information is only appearing at the baggage claim exiting if there is any problem for the authorized personnel. These data is important for the exiting in case of more then one checked-in baggage that the system knows that there are more baggage is following and sending alarm. It enables also the case that family members are carrying each-others luggage and the system does recognize it and is not sending any false alarms. The only extra technical requirement for the exiting baggage claim reuniting infrastructure is to have the waiting time programmed between the following baggage and passengers.
Due to name equality and privacy restrictions the RFID card and Passenger Code is the primary information (Bite d., 2008).

Analogously, the cargo can be linked together as well. It is only necessary to include the ID and code of the related shipments on each-others card that belongs to the same owner. This is also enabling to find out where the other (related) shipments are in case of any problem. Analogue to the related industrial items this can be applied for military related items too.

To obtain this information the RFID tag has to fulfil the 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 b, 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 *(see 3.4.3.).* With this system the alerting and problem solving is automated and fast. On the figure below are shown *(see Fig. 30)* all the RFID activation-de-activation points, reading points and their information. Before the RFID at the boarding de-activates itself, passenger and baggage will reconsiliated. 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 baggage only with it's passenger can be loaded to the take off. 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 and App. 2.)*, no extra communication is necessary to be taken.

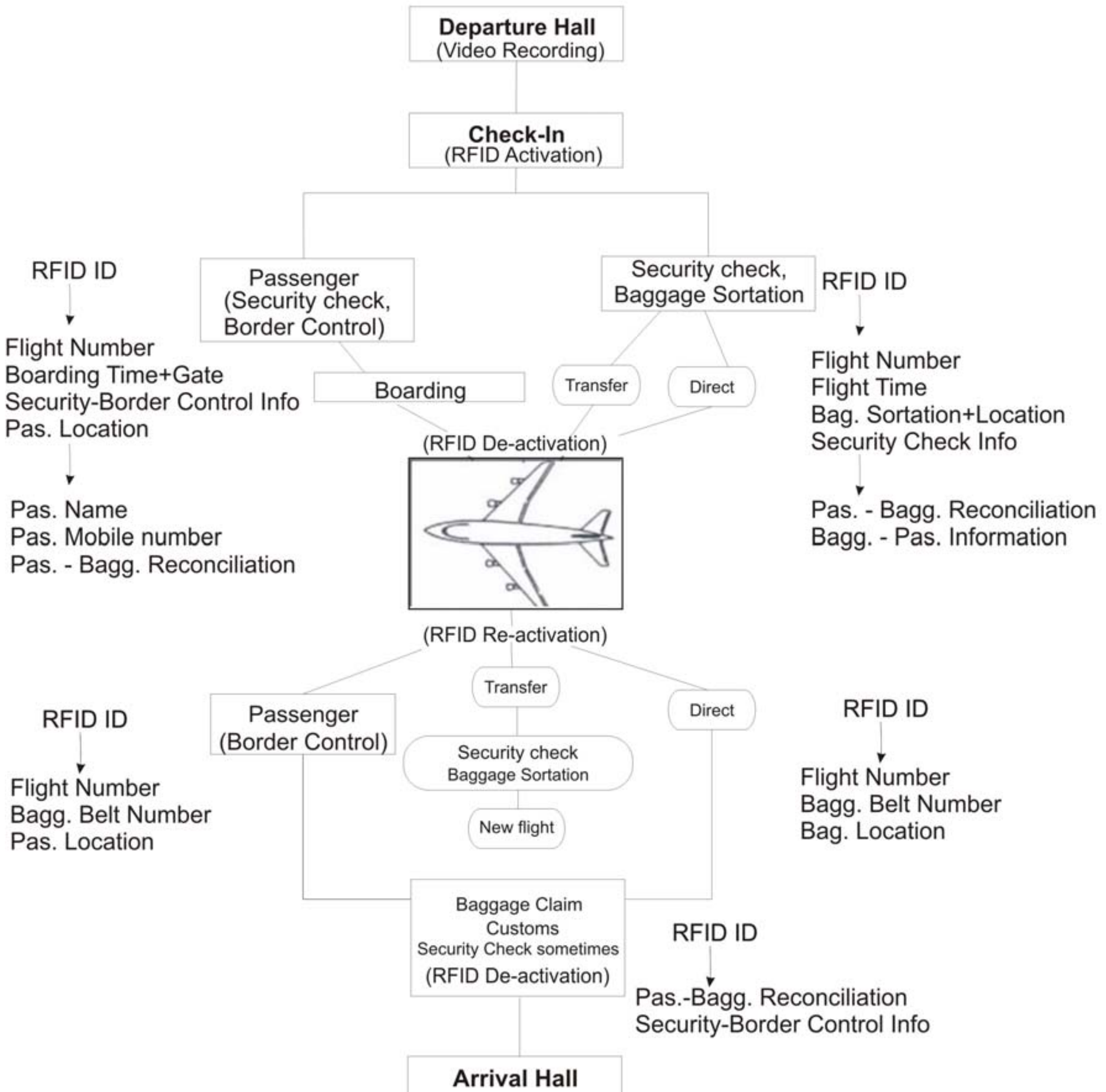

Figure 30: Passenger and Baggage GIS Data Checkpoints
(Source: Own Research)

The below figure *(Fig. 31.)* 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 *(see 4.1.5. and 4.1.8.).* The allowance and task type of information *(see above and App.2.)* 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 is not open for passengers and visitors, etc. *(see 3.2.)*, within 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 all the computer, PC, PDA, etc. and all software that need special allowance to be accessed.

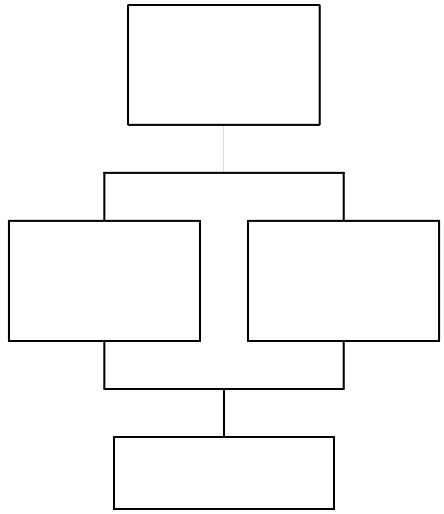

Figure 31: RFID/GIS Data Checks at Access Points for Staff (Source: Own Research)

Analogously, it possible to identify, monitor, manage the staff, cargo and mail, the ground handling equipment alerting in case of process errors or abnormal activities (e.g. entering restricted areas without authorization). It enables 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 type of information is necessary to be on the RFID then for staff, GSE equipment. The cargo and mail handling requires very similar information as the passenger and baggage handling, the difference is their location within the airport, the document 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.

On the screen it using the RFID data structure in GIS and visualising the information on a map, following will be seen (see Fig. 32.) in case of monitoring and layering the passenger and baggage locating. On an analogue way, for monitoring items and vehicles other information is appearing *(see App. 7.)*.

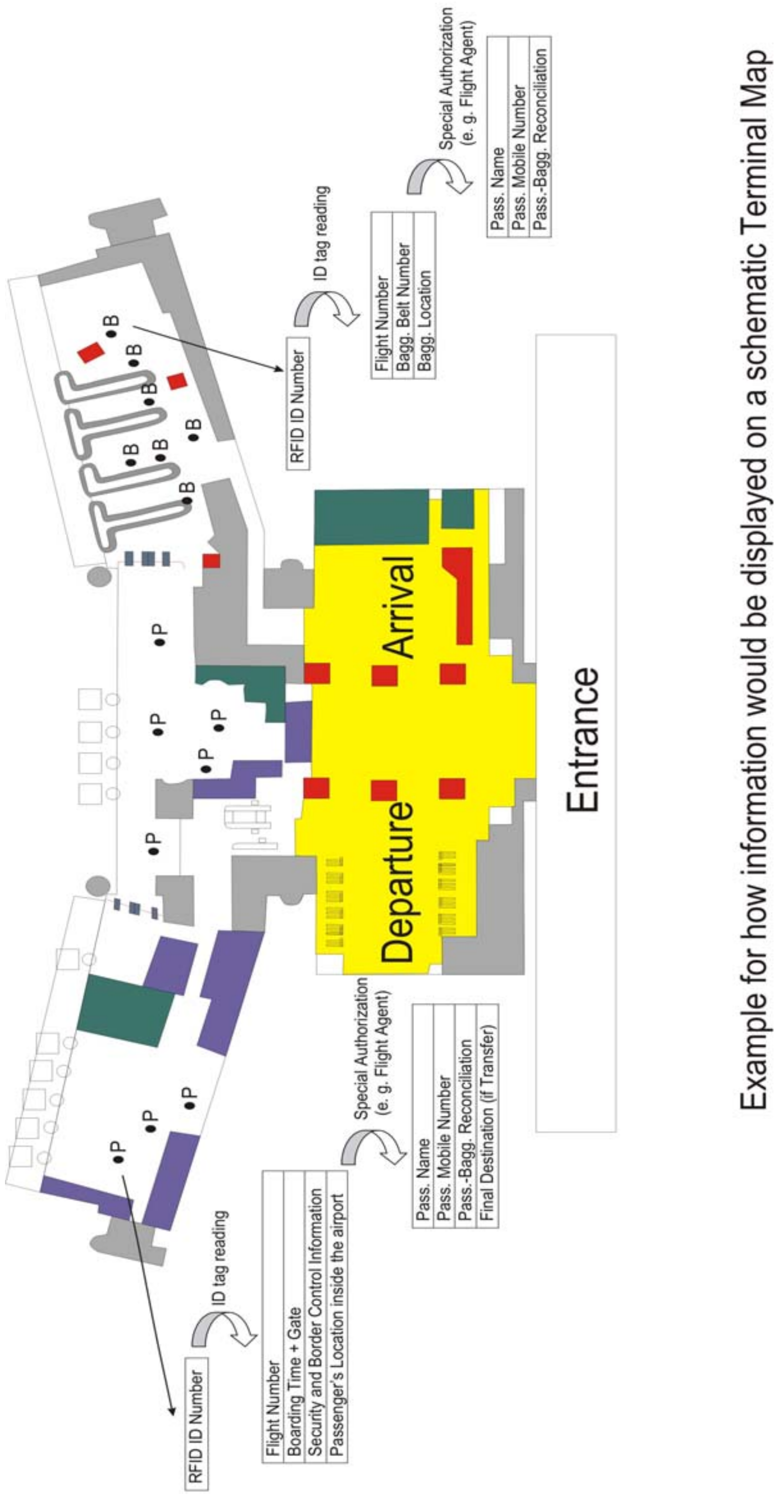

Figure 32: Examples for Tracking Passengers and Baggage in the Terminal Building (Source: Own Research)

4.2.3. Integration into the Local Information System

The above listed information is necessary for security, for traffic and operational management, business processes. All this information is shown in 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 see in that area. Each specific area has its own called 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

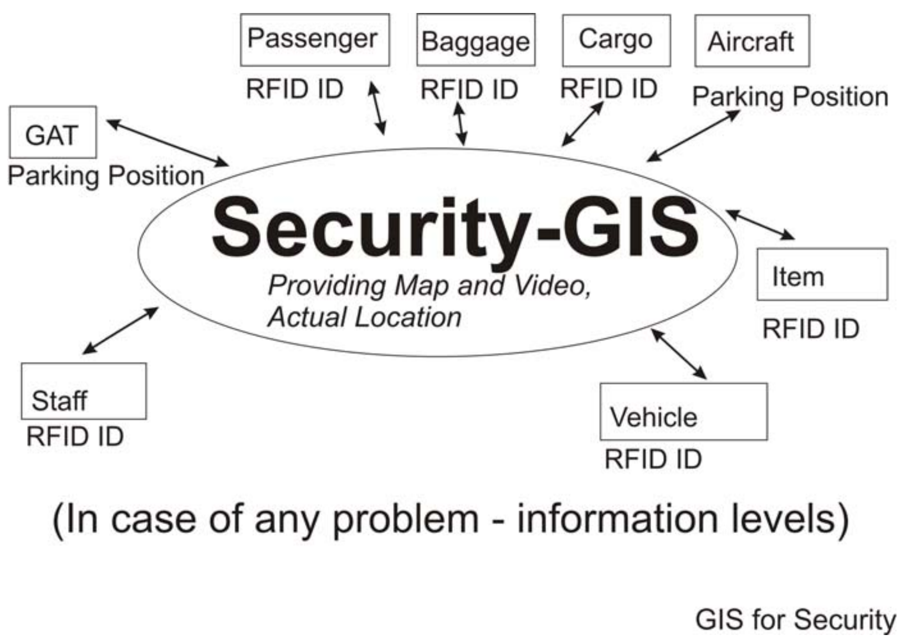

Figure 33: Security-GIS
(Source: Own Research)

The security personnel always receive information on 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 thematic. 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 authorized personnel.
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 personal and authorized personal (e.g. the flight agent to that specific flight).

In any case, the history of a tracked person or item is stored and it is available for the authorized personnel to monitor it. The history can be displayed by movement tracking or shown in table form, at which time where it was and data of its actual task. The history is stored for 30 days.

Employees can request to see the data of a given flight only from the system, or just see a passenger's location of a current flight, or 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 current stage 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.

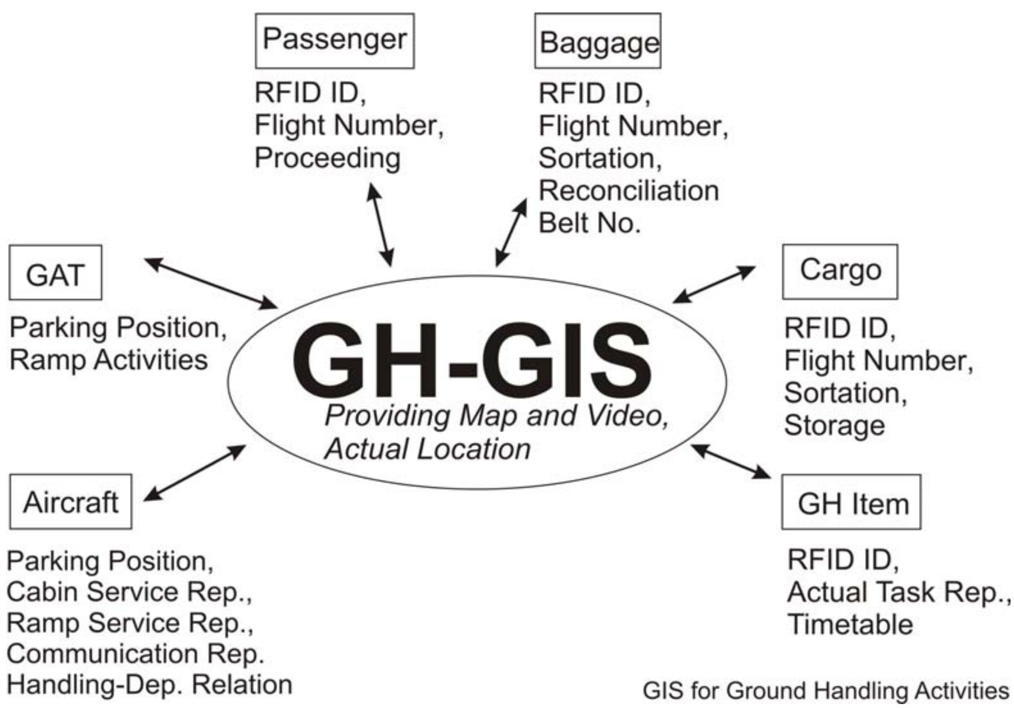

Figure 34: GIS for Ground Handling Activities
(Source: Own Research)

General Aviation is also served by a GH company if requested. As its passengers and baggage are handled differently and by 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 difference principle in tracking view of point, the only difference is the information stored on the tag *(see 4.2.2.).*

Airport – GIS *(see App.5.)*

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, 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. Legend *see App.5*.

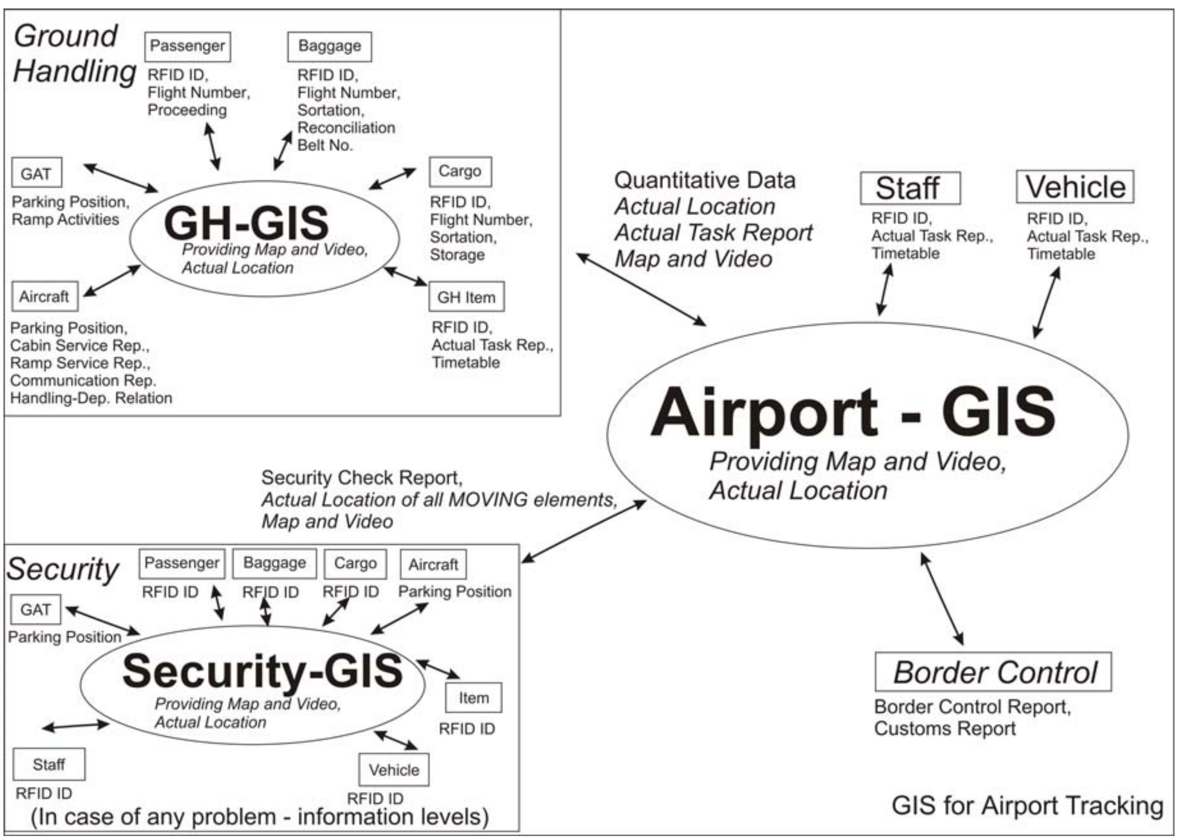

Figure 35: Airport-GIS
(Source: Own Research)

Airport-GIS Integrated into the AODB currently used *(see App. 6.)*

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 if it is already finished, sends an automatic current task report if requested 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 (Bite c., 2010).

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.).

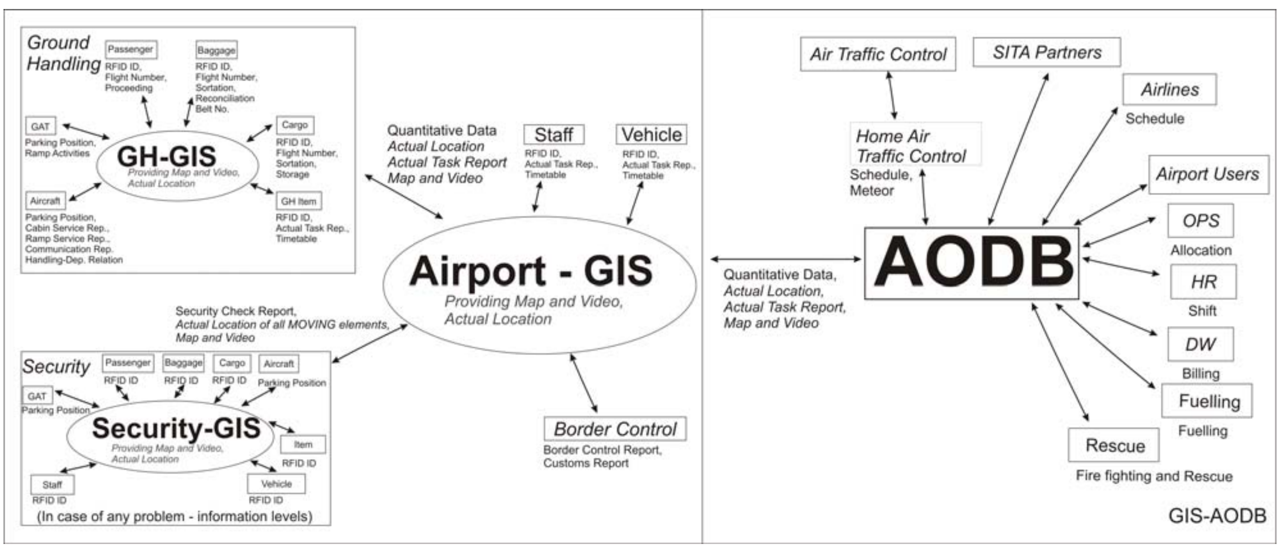

Figure 36: Airport- GIS-AODB
(Source: Own Research)

4.3. Real – Life Application of the Suggested System

The future trend in globalization and mobility freedom indicate rapid increase in needs of public used air transport systems. Such new and further civil aviation requires totally new, innovative ideas and the use of the newest technological achievements to ensure a new, inexpensive, and secure monitor system (Rohács, 2005).

The implementation of this system depends on the local **authorities** and local **law**. If the security administration or the local law reject the system, the benefits cannot be taken. Law and some administrative ordination are necessary.
The system can be installed in parts too: only for baggage handling or just for monitoring of items but not people.

Privacy rights must be protected. Personal information of staff members and their locations should only be accessed by the security coordinator if there is a problem or the system is reporting an emergency situation. To avoid mishandling of the personal data, a one-way code must be used, and the tags of staff members should be only activated when they enter the restricted areas of the airport and areas that require authorization, and de-activated when leaving it.
To ensure the staff's privacy rights apart from the standardization, further disposition can be made:

1. Tracking of workers with RFID tags should facilitate the security tasks of the airport and global industry. For privacy reasons, the system on the monitor would only show RFID tag numbers. There is a need for 2 linked databases. The first database contains the RFID tag numbers and access information, the second the RFID tag numbers and the passengers' personal information. In case of trouble with a worker, the second database opens automatically. The personnel at the monitoring must contact the security agent. Personal information of workers should only be accessed by the security or police coordinator. Of course, only authorized personnel would be able to access the database of RFID tags and the current owner of a tag.
2. Attacks against mishandling of workers' RFID tags can take place by means of decoding the radio signal behind a passenger by another person having a reader. To avoid this, one-way code can be a solution. A one-way code is a code that is non-decodable with decoders that do not know the special airport system code. Hence, a third party cannot retrieve any data from another passenger's tag.
3. Tags should be activated only when they enter a territory, which requires authorization.

From **technical point of view**, the system is feasible in practice. There are some refinements to be taken:

- Configuration for any kind of handicap
- Precise information and educative help during the introduction of the system
- Maintenance
- Educating the personnel using the system
- **GIS Software has to handle:**
    - Real-time, non-real time updating
    - Continuously changing map
    - Large amount of data
    - Interface for channelling the RFID, video, SMR, biometrical signals into the GIS

- RFID signal processing
  - RFID tag passive
  - RFID tag active
  - RFID tag for metal items
  - RFID tag for weather-resistant
  - Protection against any kind of mishandling
- Video signal processing
  - High resolution
  - Zoom in-out
- SMR signal processing
- Biometrical signal processing
  - Facial recognition
  - Ear shape recognition
- Alarm settings (alarm order)
  - Alarm first to Passenger's RFID tag
  - Alarm to Supervisor
- Fast data management and reports
- Information display as it is described (3 steps, with authorization requirements) with a map and video background
- Enabling queries regarding:
  - Elements
  - Flight numbers and times
  - Boarding Gate
  - Employees
  - Authorizations
  - Allocations
  - Etc.
- Managing provision for editing, reading, etc.
- Database management for the proposed information display (steps)
- High levels of system and data storage reliability through system and data redundancy

Environmental aspects are kept and meet the requirements of today's environmental friendly aviation and all types of industry trends (e.g. paperless boarding passes). Another advantage is for the airline and operator, that paper use is minimal.

Passengers **only have to take care of their passports** (in case the passport serves as the boarding card as well) or only of their bracelets. As it is contactless, it is only important that passengers wear them, but doesn't really matter where. In long-term regards, when biometrical identification will be widespread maybe not even a passport will be necessary, an RFID tag will be enough.

The RFID does **not interfere** with the aircraft's navigation system (Mecham, 2005).

Medical effects of the RFID technology: "The World Health Organization's research, as well as many other scientific studies, have shown that EMF exposure below the limits recommended in internationally adopted guidelines has not revealed any known negative health effects. To ensure a uniform benchmark for compliance, EPCglobal recommends adhering to the human exposure limits for EMF as developed by the International Consortium on Non-Ionizing Radiation Protection (ICNIRP) and recommended by the WHO." (RFID Journal a, 2010).

5. Efficiency of the Suggested System

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 of such a system is worth it in many areas such as:

- Less flight delays caused by ground handling activities
- Reduction of Passenger Handling and Baggage Handling time and achieving a higher efficiency (while reducing turn-around times) and automation
- Improving Customer Service and less hassle with late passenger
- Decreasing baggage loss expenses
- Faster location of employees, passengers, ground support equipment, etc.
- Less baggage pilferage and compensation for it
- 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)
- Automated Boarding Gates
- 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
- Environmental friendly (e.g. paperless)
- Improving reputation

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.

5.1. Costs and Expenses due to Lost Baggage

5.1.1. Reasons of Baggage Losses

The World Tracer is an automated service for tracing lost and mishandled baggage, developed by SITA and co-sponsored by IATA. It tracks lost baggage. It is an international lost baggage tracking system in common use at all airlines. A missing bag

is defined as bag, which has not been received from the delivering carrier; a file has to be created in the baggage tracking system (IATA e., 2009). A late or misconnected bag is a bag that has been received from the delivering carrier beyond the Minimum Connecting Time (MCT) and was late to be loaded into the connecting flight; a FWD file will be created in the baggage tracking system (IATA e., 2009).
The reasons for baggage losses during the flight procedure are grouped by IATA and each reason has a unique and world-wide known code listed in the Reason for Loss list (RL codes, or RL list) *(see App. 4)*. Lost and Found employees mark the reason code in the World Tracer.
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.

5.1.2. International Data and Regulations for Baggage Losses

Irrespective of the reasons, losses cost the airline and the airport a lot of money. The airline has to compensate the passenger in some form, depending on whether they find it and forward it to the owner within 24 hours, days or weeks or never, and depending on whether the passenger was arriving at home or not, the compensation is different. The compensation rules are standardized by IATA and airlines.
The retrieval costs of a lost bag are between US$100-150 for the airlines, excluding the possible costs of an airplane being held up because of a mishandled bag (Ground Handling International, October 2006).
Association of European Airlines (AEA) pointed out that these statistics do not distinguish between irrevocably lost baggage and bags later found and returned to their owners (Ground Handling International, April 2007). It doesn't matter whether it is returned or not, it costs the airline time and money and the passenger has a hassle and is unsatisfied. Approximately 1% of the 1.7 billion bags that pass through the system are mishandled every year. Mishandled baggage is an annual US$3.8 billion problem for the aviation industry. In 2007, 42, 4 million lost bags were registered, the estimated costs of which were around US$3, 8 billion.

It also affects about 42 million passengers annually and is the second most important factor in having a pleasant trip, according to the 2009 IATA CATS survey. Between 2005 and 2007, the passenger number has increased by 9% in Europe, while the number of mishandled baggage has increased by 28% (IATA data source) In the USA, passenger numbers grew by 10.5% while the number of mishandled luggage has increased by 27% (IATA data source). According to IATA, the key regions are: Europe, the USA and Latin America. In 2008 the rate of mishandling decreased by around 20%, according to data of the Société Internationale de Télécommunications Aéronautiques (SITA) (Bondarenco & Price, 2009). The reason is the tremendous effort made by airlines and airports and the fewer number of bags per passenger. In 2008 and 2009, low cost airlines progressively introduced to pay extra fees for baggage and the global economy problems led to fewer passengers too. In the following two tables *(see Table 4., see Table 5.)* are showing the real problem expressed in pieces of baggage loss of the previous years.

Carriers	Passenger Checked-in baggage (million)	Mishandled
Airlines of the USA, 2005	440	2.93 million
US domestic airlines	Ca. 600	4.08
Southwest Airline	98	525.000
US Airways	49	420.000
Delta Air Lines	66	456.000

Table 4: Mishandled Baggage in the USA in 2006
(Source: Ornellas, 2007)

Year and Continent	Total passenger Checked-in baggage (million)	Lost luggage rate (bag/1000 passenger)
2006 Globally	N/A	6.73
2005 Europe	346	14.1
2006 Europe, airlines belonging to AEA	357	15.9

Table 5: Lost Baggage Rate
(Source: Ornellas, 2007)

Even if the missing bag and the late or misconnected bag are handled within different files in the baggage tracking system, it costs the same amount of money and energy. For statistic calculations, it is counted in a combined way. A file can contain more than one bag.

5.1.3. Qualitative Measures for the Analysis of Baggage Tracking System

The weak points of the baggage tracking system *(see Fig.37.)* points of the today's infrastructure are shown below, those problems can be minimised with the RFID/GIS integration *(Bite d., 2010)*.

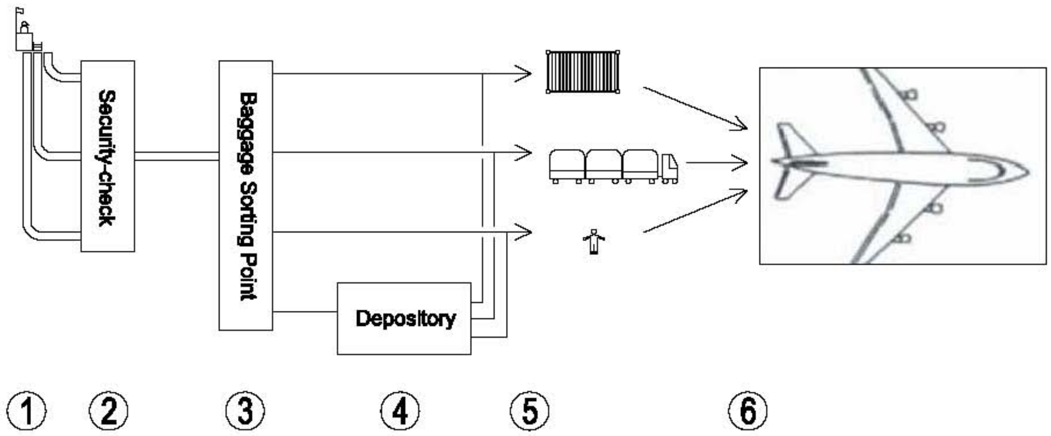

Figure 37: Weak Points of the Baggage Handling
(Source: Own Research)

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,
  - and automated match with the passenger boarding, with the barcode system it is not automatically checked and is more time consuming.

5.1.4. Quantification of Lost Baggage

The exact calculation for lost baggage according to the above *(see 5.1.3.)* 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:

- 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.

The simplified model for the estimation is *(Bite d., 2010)***:**

Estimated number of lost baggage: E_{LB}

$\boldsymbol{E_{LB}} = \boldsymbol{B} * \boldsymbol{R_L} * \boldsymbol{C}$, [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 *(see Table 1.)*

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

- o Available staff working at the check-in
- o Available staff working at the baggage sorting
- o Congestion of the baggage on the belt
- o Airport size (e.g. handled traffic)
- o 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

$E_C = E_{LB} * C_{LB}$, [USD]

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 6, see Fig. 38.):*

N 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	

N 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***

Table 6: Costs Caused by Baggage Loss for a Regional Airport in 1 Year (Source: Own Estimation)

According to the calculation of *Table 6.* 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.

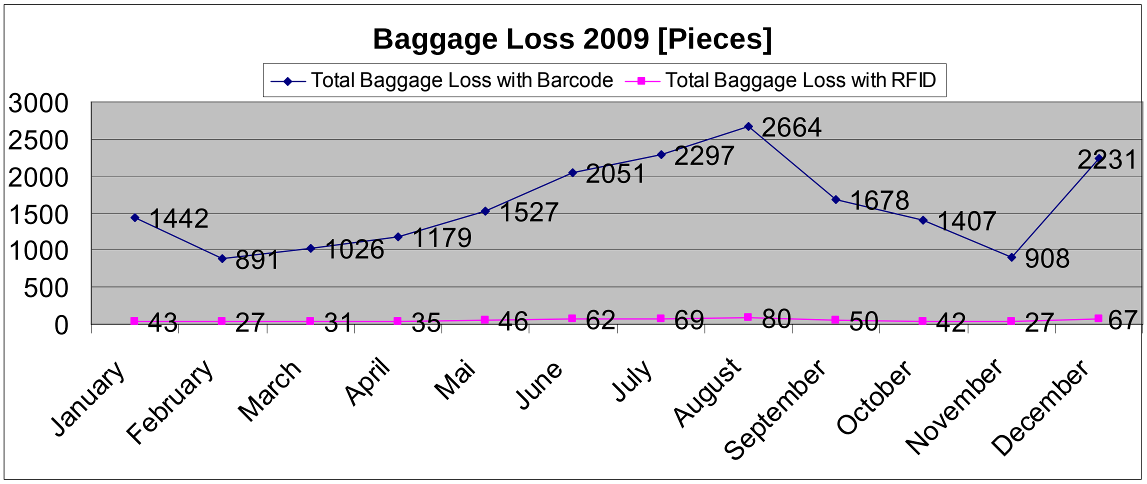

Figure 38: Baggage Loss in 2009 for a Regional Airport (Source: Own Research)

Concerning the different values of the C factors using the same source of data as for the above calculation and based on the above calculation *(see Table 6, Fig. 38)* can change. The C factor can vary in the two independent ways (C_1 and C_2). For example increasing the staff results a reduction to 4, 629 lost baggage, or speeding up the system results a baggage loss of only 3,697 or reducing the congestion at baggage belt results a reduction to 2,976 baggage losses.

The above elaborated model can be analogously applied for passengers *(see 5.2.4.)*, 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.

RFID technology's rate of reliability is 95-99% (in the calculation, 97% was assumed), while the barcode-scanner's is 85%. This already achieves a reduction of **5 times in the costs.**
Applied RFID technology decreases the non-quantifiable costs, which, however, improve the efficiency of baggage handling:

- **Reading speed is quicker** with RFID compared to the barcode-scanner, therefore system throughput is improved and a higher amount of baggage can be handled
- **Data transmission time** between now used DCS to BRS is slow, there is a transmission time about 5-6 seconds, and it can take a minute if there is a communication problem (it is about once a month). Many times, the baggage is already at the sorting area but cannot be scanned because its data has not yet received by BRS. GIS is sending the data automatically and updates it in real-time. Therefore, the data of checked-in luggage can be seen by the stevedore in real-time, and the stevedore need not wait at the baggage belt and the luggage can be identified and sorted immediately.
- GIS combined with RFID always **sees the current place** of the baggage, an alarm signs if the amount of luggage in the DCS is not equal to the correctly sorted and loaded amount.

Baggage handling is more effective and quicker, losses can be minimized.

Forecast

In 2015, the forecast number of passengers will be 1100.6 million in Europe (ATAG, 2000). It means that an estimated 1100.6 million baggage will be handled with the elaborated simplified estimation using RFID/GIS technology the following amount *(see Table 7.)* can be saved:

Forecast for 2015	*Passenger Checked-in baggage [Pieces]*	*Mishandled [Pieces]*	***Cost= EURO 125/Luggage***	***Savings* [EURO]**
With Barcode	1,100,600,000	6,371,055.487	**590,087,404**	
With RFID	1,100,600,000	1,274,211.097	**118,017,481**	**472,069,923**

Table 7: Baggage Loss Forecast for 2015 for a Regional Airport (Source: Own Research)

5.1.5. Effects and Consequences of Baggage Loss

Effects and consequences of baggage loss (extra expenses) for airlines, airports, passengers and for the environment:

- Airline:
  - Compensation to passengers in case of late arrival of more than 24h and not for passengers arrived at home
  - Time, energy and money spent on delivery service and telephone calls
  - Loss of reputation and customers
- Airport:
  - Lost and Found: finding
  - Storage
- Passengers:
  - Missing the appropriate dress (e.g. conference, opera, etc.)
  - Missing the appropriate devices (e.g. documents, etc.)
  - Bad feeling, medical effects, psychical effects
  - Missing medicines
- Environment:
  - Loss of Energy,
  - Extra emission due to the delivery service:
    - Noise,
    - Air pollution,
    - Waste
  - Extra money spent
- Others:
  - Positive effect on:
    - commercial units,
    - service units
  - Negative effect on: tourism

5.2. Costs and Expenses due to Flight Delays caused by Ground Handling Activities and Late Passengers

Increases in the air traffic have been causing more and more flight delays. In 1999, every 5th flight had a delay of 25 minutes. Flight delays and congestions cost 1 billion Euro per year, moreover, they also contribute to pollution. The main reasons for delays are related to problems in airspace capacity and weather. Flight delays caused by ground handling are a very small % of the flight delays due to airspace capacity or weather problems. For this reason, the estimated calculation is in the *App. 9*. EuroControl addresses developing the airspace capacity by several programs (SES, FAB, etc.) (Orlóci, 2006). The suggested technology, however, cannot help airspace capacity problems; it can only reduce delays caused by the airport capacity, ground handling capacity and efficiency.

5.2.1. Reasons of Flight Delays

The reasons of aircraft delays are divided in groups by IATA *(see Appendix 3)*. Each delay is defined by a 2-digit code. These codes are unique and internationally used. After take off, the ground handling company has to mark them in the locally used database (FIDS or AODB, depending on the airport). Each airline has its own in-house developed (3-digit) code, but this is only for the airline, not for other use, and thus it is different with each airline or airline group. Whatever the real reason for a delay might be, it costs energy, time and money for the airline, airport and passenger, and can lead to loss of customers and in long-haul loss of market share.

The Standard IATA delay codes are shown in *App. 3*. Airline related delays, which are relevant for my work are the following: (IATA d., 2009): 11-19, 21-29, 31-39, 51-59.

In addition to the IATA delay codes, further reasons can also be responsible for delays, which GIS/RFID technique may help to minimize. These are delays caused by passengers. 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)

A plane can only take off if the owners of the checked-in baggage are on board.
The steps taken by the airline and the overall waiting time for a lost checked-in passenger at the boarding gate depends on many reasons:

- Does the passenger has checked –in luggage or not:
  - If there is none, and there is no other waiting reason, the airline leaves the passenger at the airport

  - If there is, the airline starts unloading the checked-in baggage as immediately soon as they notice that the corresponding passenger is late
- While the checked-in baggage is being removed, the agent calls the missing passenger by the loud speaker (as soon as the baggage is found, the passenger is left on the airport)
- Methods and times of baggage removal are as follows:
  - *Baggage charts*: **min. 10- 20 minutes** (the last time to know the exact location of the baggage was when it passed the scanning for the baggage chart; maybe the stevedore remembers where he had put the baggage (this can speed it up a little bit)
  - *Baggage charts with sorting*: **min. 5-10 minutes** (some airlines (e.g. British Airways, Lufthansa, etc.) require sorted packing within the aircraft (e.g. priority, transfer passengers and direct passenger's baggage); this can speed up the search for the baggage. (Low Cost or charter airlines do not apply this)
  - *Container loading:* **min. 5-10 minutes** (the stevedore knows the right container and the loading order of the luggage being looked for from the scanner, and he might also remember its approximate location)

Unloading a baggage takes a lot of time (min. 5-20 minutes) and may cause flight delays, which may lead to further problems and delays costing the airline a significant amount of money and efforts.

The waiting time for a late transfer passenger depends on the followings:

- Slot of the flight and the next slot possibility
- How many passengers the flight is waiting for: the airline will not wait for only a few passengers (1, 2 or 3) but only for a bigger amount of passengers, depending on the destination (e.g. if the next flight is not scheduled within hours or one or two days, depending on the schedule of the aircraft, due to economical reasons, it is better for the airline to wait for those transfer passengers than pay their stay and compensation at the transfer city).
- Aircraft's daily time schedule
- Ad hoc decisions on the spot, depending on the circumstances

5.2.2. RFID Integrated into GIS Reduces Flight Delays

The RFID technology can speed up the procedure of finding a luggage being searched for, but, most importantly, it speeds up the search for a passenger. Nowadays the search for a passenger is made only by loudspeaker. The passenger might hear it or not. The **searching time** is between **5 – 20 minutes**, while the checked-in luggage will be removed. The GIS shows the agent the missed passenger and integrated RFID shows where that passenger is, and starts immediately sending an alarm to the passenger's tag and reminding him of being late. In the meanwhile, the agent can see in the GIS, if the passenger has started to move to the boarding gate or not. RFID as a boarding pass or RFID as a boarding pass integrated into the passport reduces the time of **finding a passenger to 1-5 minutes.** Connected to the GIS, the flight agent sees immediately the place of the RFID ID being looked for, and sends an alarm signal to it, this way the passenger notices it. It wouldn't be necessarily starting unloading its baggage as it is quicker finding him.

Another issue that makes the search for a passenger more difficult is that the flight agent only sees in the information of having been checked –in (and having a checked-in luggage) or not. Today's DCS site at the boarding gate is not connected to the security check or to the border control (if available, because for domestic flight and Schengen type of community, there is no passport check at all). Therefore, the flight agent doesn't even know if the passenger being looked for has entered the transit hall or not. Furthermore, nowadays, the security check does not register passengers, and the border control is checks only if a passenger can enter or leave the country, but neither of them registers passengers (only in its own system). The flight agent does not even have the right to ask for any information of a passenger being looked for at the border control.

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.

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.

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.

5.2.3. Quantification of Flight Delays

The simplified model for the calculation of the errors of baggage handling *(see 5.1.4.)* can be only limited applied in an analogue way for the flight delays due to ground handling mistakes. The exact calculation of the flight delays are depending on much more factors then the baggage handling or the passenger handling, the defining of the C factor is too complicated to establish a general model. The cost estimation is also very different between airlines and international organisation. The compensation to the passenger for baggage problems due to the mistake of the airlines is defined internationally and is standardized. In case of the passenger handling the model can be applied in the analogue way. The model can be applied for the limited differentiated areas as delays only coming from passengers, or ground handling equipment problems, or cargo and mail handling, but it cannot be applied in complex way for flight delay as there too many factors to valuate. But it must be emphasized that the RFID/GIS integration even if it difficult to estimate without having the proper data available, it is very much increasing the efficiency and the allocation of people and equipment.
The following aspects are examples that airlines take in account by calculating the delay costs:

- Type of the Aircraft
- Seat number
- Schedule of the Crew and Aircraft (= Network Reactionary Delay)

- Regional Airline or Intercontinental Airline
- Hub and Spoke System
- Time:
    - Short-delay: x < 15 Min (can be made up leeway)
    - Long-delay: x > 65 Min (the delay costs starts legging)

Because the exact calculation is not possible, an estimated calculation based on the data of that regional airport where the source is not allowed to be published can be found in the *App. 9.* Though the calculation is not accurate it gives a good estimation of the expected results in case of a proper calculation.

5.2.4. Quantification of Flight Delays only due to Late Passengers

The elaborated model for the baggage handling *(see 5.1.4.)* 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. 39)*. Those points can be speed up and their problems minimised by using the RFID/GIS technology.

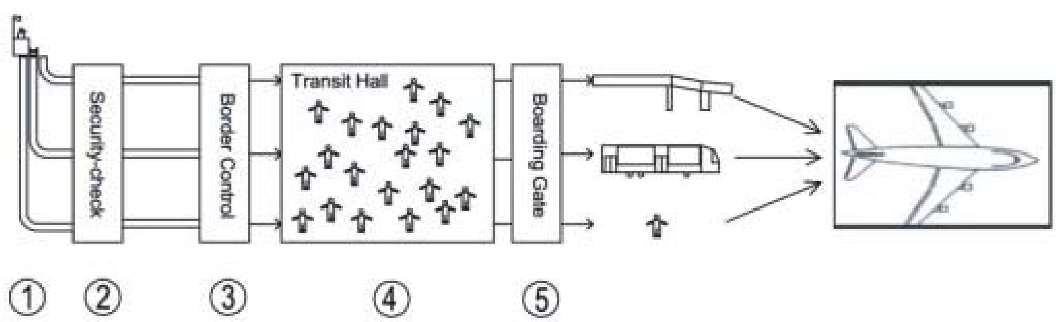

Figure 39: Weak Points of the Passenger Handling before Departure (Source: Own Research)

- **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 the RFID Passport *(see 4.1.3.)* 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** *(see 5.2.1.)*
- **5. Boarding:**
    - queuing
    - by manually check of boarding cards, the proceeding is slowly

The order of proceeding concerning security check and border control depends on the airport. Uniting the check-in, security and border control check *(see 4.1.4.)* would reduce the queues and waiting time and increase the service level for passengers.
The system may also be applied, in a differentiated way, only for passengers to reduce waiting time and time to find late passengers.

The waiting time for a passenger as described in detail above *(see 5.2.1. and 5.2.2.)* is **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.

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 *(see Table 1.)*

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.

$$C = \prod_{i=1}^{m_1} C_{1_i} + \prod_{j=1}^{m_2} C_{2_j} = \sum_{k=1}^{2} \prod_{l=1}^{m_k} C_{k_l}$$

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 8, see Fig. 39.).* The shown data are taken as a part of the delay times of the *App.9* related to late passengers*:*

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**

Table 8: Costs Caused by Late Passengers for a Regional Airport in 1 Year (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 8.)* 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.

5.2.5. Effects and Consequences of Delays

Extra costs and expenses of delays occurring at the airlines, airports, passengers, and for the environment are the following:

- Airline (Kővári, 2005):
  - Fleet Re-Allocation:
    - Aircraft: Fuel, Parking, Tube, Maintenance, Change, Stand by aircraft
    - Crew: Cabin, Cockpit, Ground, Change, Stand by crew
  - Slot Time Request or not
  - Depending on the reason of the delay: aircraft and crew changes
  - Passenger: food-drink (after 1-2 hours of delay), compensation, change to another flight, accommodation
  - Transfer: reduction of efficiency, cancelled flights
  - Long-term expenses: loss of market share, loss of reputation
  - Paying a higher fee to the airport (parking fee, using airport capacity more and dampening the airport facilities) and ground handling company (e.g. longer use of GSE)
- Airport:
  - Longer occupied airport capacity: dampening the airport facilities
  - Re-Allocation of facilities used
  - +: Higher charges for the late departing plane and occupied facility
  - +: If the delay is longer than 1 or 2 hours (e.g. missing a slot): passengers will not be boarded or they have to de-boarded and they can leave the separated boarding area (if available), it means more income increases for the airport's:
    - commercial units
    - service units

- Ground Handling:
  - Re-Allocation of :
    - Ground Support Equipment, Facilities
    - Staff.
- Passenger costs:
  - Missing the connection flight
  - Losing time
  - Business passengers:
    - Being late to meetings
    - Losing a business opportunity
    - Missing a presentation (e.g. on a conference, etc)
    - Etc.
  - Leisure travellers:
    - Less vacation time
    - Missing already pre-paid programs (e.g. hotel, rent a car, programs, etc.)
    - Etc.
  - Passengers arriving at home:
    - Missing connection to a further destination (e.g. countryside, etc)
    - Missing planned programs and day schedule (e.g. business or other, etc.)
    - More parking fee
    - Money and energy spent on informing the pick-up person
- Environmental effects:
  - Longer use of the engine:
    - producing more air pollution (Rohács J., 2005)
    - producing more noise and waste (Markovits-Somogyi, & Sobor, 2005)
  - Emission of harmful substances
- Other:
  - Less income for tourism (Selymes, 2009)
  - Less income for commercial units
  - Less income for service units

5.3. Return on Investment

Today, the technological advancement is developing very rapidly. The new technologies and their application effect on the economy in very complex way (Rohács, 2006).

An important question is: who should implement the new investment and pay for it?

The line-up is:

- Airport owns the infrastructure

BUT

- Airline and airport are saving costs by reduction of baggage loss and the delays, on the other hand, the airport is able to increase its capacity.

The infrastructural costs are built into the airport charges (Kővári, 2004) and air traffic control charges (TNC and En-Route Charge). Compared to the other transportation methods, air traffic specifically belongs to the group (category) of person and freight transportation modes with the highest social costs (Bokor & Tánczos, 2003). Consequently, any measure directed at improving efficiency yields significant savings (Legeza & Török, 2009).

The investment and operation costs of the suggested technology could be implemented into:

- Airport charges

AND

- Airline can decide whether including the increased amount into the airfares or not.

The reduction of other costs achieved with this system can compensate for the increased airport charges. Good customer service, customer satisfaction and may attract new passengers.
Airports are categorized according to their sizes and the installation price mainly depends on the size of the airport.
The size and configuration of the terminal building and observed area specifies the amount of the followings to be used for the complex system:

- RFID gate readers,
- Card readers,
- Cameras needed,
- Software,
- Educating the staff authorized for using the technology
- Maintenance
- *See App. 10.*
- *See 4.3.*
- Etc.

Another important decision to be made:

- Whether use more RFID gate readers or use RFID active tag: the accuracy rate of reading is about the same, but, in the terminal building, a couple of metres are not counted for.
- Either RFID passports or RFID bracelet, or both combined, depending on whether passengers already own RFID passports or not.

It is very difficult to do a concrete calculation, as the above-mentioned factors only estimate the total installation costs. I calculated a minimum and maximum value.

An exact calculation is not possible without taking a concrete airport and minimum all the above mentioned factors which are necessary to implement the suggested technology. Therefore I made rough estimations for the minimum and maximum amount of the technology equipment necessary for the implementation and according to it I made a rough estimation of the return on investment. Though the calculations are not accurate they give a good estimation of the expected minimum investment costs, possible return-times of accurate results in case of a proper calculation. The details of the rough estimation can be found in *App. 10.,* their summary follow below is a good base for informational data in preparation for a real calculation. The rough estimation is calculating with the saving results of *Table 6*, *Table 8* and *Table. 9.*

The system may be implemented in parts as well in the area of:

- ***Baggage Handling:***
    - The investments' main area and the highest increase_in reduction of baggage loss,
    - Highest reduction in costs can be generated here,
    - A 5-time reduction of lost baggage and costs may be reached in an ideal scenario.
    - This means that the payback period of the partial investment is just 2 years, and subsequently profit could be expected after the 4th year.
- ***Flight Delays caused by Ground Handling:***
    - Efficiency increases in many areas but the quantification would be very difficult
    - Payback period of the partial investment 6 to 7 years in ideal scenario
- ***Passenger Handling (Late Passengers) :***
    - Applying the partial system only here the estimated payback period in ideal scenario is 21 years
    - Efficiency increases in airport automation and security but the quantification would be very difficult
    - It is better to be considered as a sub-system, a part of a greater system instead as a separate system on its own

In case of an **integration of the whole *Complex GIS/RFID System***, the profit can be estimated around the 7-8th year when assuming an ideal situation and an efficiency of 30%.

6. Future Perspectives

RFID implemented into a passport with biometric data as a boarding pass could be used beyond the aviation sector as well. A boarding pass can be lost easily but everyone takes much more care of his/her passport. Extendable to other means of transportation separately (road, railway, navigation), or to a common unified ticketing system for all transportation systems, Separately no more tickets would be needed, as it would be enough for everyone to refresh his/her original one, unified ticket.

The GIS can not just handle airport processes, their elements, operation and organization but it can also be extended to maintenance, development tracking, etc.

Furthermore, beyond the realm of transportation, it can be applied to the monitoring of hospital equipment and processes for instance and other applications too.

The integrated RFID/GIS should be implemented into the university curriculum related to aviation studies.

7. Statements

1) **I found that geographical information system (GIS), information technology (IT) and modern radio frequency identification (RFID) together integrated into a common system can identify and track moving elements (e.g. people, luggage, ground handling, mail and cargo) in a restricted space (e.g. airports). *(Bite a., 2010, See 4.)***

1.1 The airport infrastructure management uses geographical information system extensively for tracking stationary objects (e.g. property, property-registry and management), and with additional information (primary and secondary radar, GPS), for tracking moving elements (airplanes, airport vehicles). *(Bite c., 2010,* See *1.4.7.)*

1.2 Currently, the management described in point 1.1 does not include tracking passenger, baggage, staff and ground handling units, due to the lack of information and proper technical elaboration. *(*Bite *a.*, 2010, S*ee 1.4.7.)*

1.3 I found, that radio frequency identification (RFID) can be channelled into geographical information system through an interface system, which should be installed based on the requirements for handling processes, business processes and security requirements. *(Bite c., 2010*, See 4.2.2.)

1.4 Tracking of moving elements (e.g. people, *ba*ggage, ground handling equipment, mail and cargo) enables the operative management of business processes, and alerting in case of process errors or abnormal activities (e.g. entering restricted areas without authorization). *(Bite a., 2010, See 4.2.2.)*

2) Based on the analysis of information required for the traffic and operational management and monitoring of airports, I defined the proposed data structure and content for an RFID enabled architecture. (Bite c., 2010, See 4.2.2.)

2.1 I specified the technical requirements for using RFID on airports (minimal memory, data transfer time, reading time and distance). *(Bite a., 2010, S*ee 4.2.2.*)*

2.2 The proposed information content of the RFID tag includes the information required for traffic, operational management and monitoring. *(Bite c., 2010, S*ee 4.2.2.*)*

2.3 I proposed data structures for linking passenger to its baggage, marking cargo belongings together (e.g. industrial, military use). *(Bite d., 2008, S*ee 4.2.2.*)*

2.4 The proposed structure can possibly result in 80% reduction of lost baggage for a regional airport handling 3,006,199 pieces of luggage in a year period. *(Bite d., 2010, See* 5*.1.4)*

3) **I was the first one to propose the integration of the tracked processes into the integrated operational information systems of airports. *(Bite c., 2010, See 4.2.3.)***

3.1 I proposed the integration of the airport operational information system and tracked processes through a geographical information system. *(Bite c., 2010,* See 4.2.3.*)*

3.2 I extended the use of RFID technology that was originally proposed for passenger and baggage tracking to include other processes with similar characteristics (logistics and transportation). *(Bite c., 2010, See 4.2.3.)*

3.3 I showed the benefits of such an integrated system. *(Bite c., 2010, See 5.)*

3.4 As part of the planned integrated operational information system I proposed the automation of traffic and business processes, using RFID and combined biometric identification and image processing. I proposed to display information gathered by identification and tracking in geographical information system. *(Bite a., 2010, See 4.2.2.)*

4) I elaborated a simplified method for the comparison and evaluation of the air passenger and baggage tracking systems that were created using GIS and RFID. *(Bite d., 2010, See 5.1.)*

4.1 I defined qualitative measures for the analysis of the efficiency of air passenger and baggage tracking systems. *(Bite d., 2010, See 5.1.3.)*

4.2 I built a model for quantitative analysis based on multi-factor statistical methods. *(Bite d., 2010, See 5.1.4.)*

4.3 I tested the model with statistical data collected from an existing barcode-based system. *(Bite d., 2010, See 5.1.4.)*

4.4 I performed sensitivity-analysis using the model. *(Bite d., 2010, See 5.1.4.)*

4.5 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. *(Bite d., 2010, See 5.2.)*

5) I used the simplified calculation method for a regional airport, and I found that the integrated use of GIS and RFID improved efficiency. *(Bite d., 2010, See 5.1.4.)*

5.1. In case of a regional airport, a reduction of 21,104 lost luggage and 29 flight delays caused by late passenger can be expected, as shown by the simplified calculation method. *(Bite d., 2010, See 5.1.4.)*

5.2. Cost savings of up to 1,954,550 Euro/year are expected for a regional airport due to the reduction of lost luggage and 350 Euro/year of flight delays due to lost passengers, as shown by the simplified calculation method. *(Bite d., 2010, See 5.1.4.)*

5..3. The expected break-even time is 1-2 years for a regional airport from reduction of baggage losses, as shown by the simplified calculation method. *(Bite d., 2010, See 5.1.4.)*

Conclusions

Nowadays, airports, airlines, operators, handling companies, etc. are facing unprecedented challenges to provide an improved customer service for their passengers (e.g. less queuing, more automation, more efficient information display, less paper, less delay, less baggage losses), more efficient handling of their aircraft, and better use of airport capacity and facilities, while fulfilling all security requirements. Airlines want to use less space and less infrastructure of the airport to save costs. Airports are tending to use more space for retails, bars & restaurants or other facilities for customers.

An integrated Geographical Information System (GIS) could manage all these in one, and ensures map visualization, data querying and analyses in either real-time or non real-time, with point and continuous tracking. GIS can play a pivotal role in airport organization and operation, while reducing costs and improving service. GIS data integration capabilities can help to leverage existing systems by enabling access to all data from one place with authorization request. Furthermore, it provides important visualization and mapping capabilities that gives a common operational image of all facilities and a greater power to effectively control operations.

Radio Frequency Identification (RFID) is an extremely powerful technology enabling and serving to improve the level of the efficiency for identification, tracking, locating and monitoring, security against terrorist attacks, safety against general hazards, error prevention and data capture and to remove tedious tasks. both people and items in- and outdoors. As the costs of RFID technology have begun to fall, currently baggage tracking is the field in the aviation sector where RFID has been proven the most useful, and is becoming widely adopted.

The suggested system follows the trends of today's international innovation for identification, tracing, security, airport automation, less human operators, and space, reducing costs and time, less maintenance costs, environmental and customer friendliness (paperless and using already necessary resources). GIS and RFID technology is totally adoptable in currently industrial trends. Into any kind of check-in desk, boarding gate or security screening, it can be integrated. It is fast and reduces queuing times and congestions.

Using RFID for passenger and baggage handling can make the processes fully automated and minimise the manual tasks made by assistants, reducing costs for airlines, airports and operators. As the system enhances efficiency and service level, unnecessary costs of the paper-based technology can be minimised, and the return on investment will be paid back. The system is faster, needs less manpower, the maintenance is cheaper and the resources can be allocated elsewhere.

Integrating RFID tool into a GIS system allows for a very good visualization and mapping of the passenger and baggage flow and any handling operation and employee, their connectivity, their ways within the terminal, and places where they have spent much time. Many automatic recordings, reports, maps and statistical data information for further improvement can be generated from the GIS software, emphasizing the strength and weak points of the infrastructure. Emergency alarms can be sent, and later analysed and visualised. In an emergency situation, a map also helps the staff to find the place.

The GIS system shows and tracks RFID tag information of moving elements (whether a person or an item). The RFID technology can be implemented into the GIS through an interface system, which enables the integration of the airport operational processes, and complex Airport GIS could be developed. The individual subsystems of an airport GIS system can be accessed with the correct authorization only. Access is granted and displayed to the relevant parts of the system and information only, each subsystem need its own authorization. The RFID reader can be integrated into the configuration of the security check device, the unification and automation of the check-in, security check and border control (if necessary) can be achieved. This way the process achieves a faster progression or flow of passengers to the transit area, due to less queue up and waiting times. The combination of different biometrical identifications, RFID, image processing enables a safer control of personnel authorization security, baggage protection against pilferage and the total airport monitoring and security.

The RFID integrated into GIS made it possible to elaborate a data structure which facilitates the traffic and operational management and business processes, enables the operative management of business processes, and alerting in case of process errors or abnormal activities (e.g. entering restricted areas without authorization).

By giving all moving elements an RFID tag, their tracking and tracing during the whole flight procedure can be visualized by map and video. For example: the way of the baggage or ground support equipment and staff is seen: the weak points of the used infrastructure and resource allocation can be recognised (e.g. congestions) and corrected. Seeing the passenger flow within the transit hall, the airport can see what type of shops, bars, services passengers like and where they spend their time while waiting for the plane. All data are stored in a database; any type of queries and reports can be automatically made. The suggested GIS/RFID system can be integrated into the nowadays applied and continuously developed integrated IT system of an airport.

The RFID integrated into GIS made it possible to elaborate a data structure which facilitates the traffic and operational management and business processes, enables the operative management of business processes, and alerting in case of process errors or abnormal activities (e.g. entering restricted areas without authorization).

I processed and analyzed available statistical data on lost baggage and flight delays I made recommendations on their causes, amounts and long-term cost reductions with the RFID/GIS technology. I analyzed the weak points of the processes and emphasized the points or areas where the RFID/GIS can improve the weak points. I estimated the return on investment by costs savings.

The main area on return on investment is at the reduction of baggage losses, approximately it reduces the costs 5-times. The delays caused by the error of the ground handling can be decreased in ideal conditions 30%.

The goal is to provide a better travel service, use airport capacity better, decrease turn-around times, decrease compensation to be paid to passengers, and provide a safe and secure flight.

Abbreviations

AEA	Association of European Airlines
AIP	Aeronautical Information Publications
AODB	Airport Operational Database
ATC	Air Traffic Control
AUTOMAP	Automatic Mapping System
BagTag	Baggage Tag
BCBP	Bar Coded Boarding Pass
BRS	Baggage Reconsiliation System
CAD	Computer-Aided Design
CCTV	Closed Circuit Television
CGIS	Canada Geographic Information
CIA	Central Intelligence Agency
DCS	Departure Control System
DLG	Digital Line Graph
DME	Distance Measuring Equipment
DNA	Deoxyribonucleic Acid
EASA	European Aviation Safety Agency
EGNOS	European Geostationary Navigation Overlay Service
ERTS	Earth Resources Technology Satellite
ESRI	Environmental Systems Research Institute
ETM	Enhanced Thematic Mapper
FAB	Functional Airspace Block
FIDS	Flight Information Display System
GAT	General Aviation Terminal
GBF/DIME	Geographic Base File, Dual Independent Map Encoding
GH	Ground Handling
GIA	Geographic Information Analysis
GIS	Geographical Information System
GISP	General Information System for Planning
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRASS	Geographic Resources Analysis Support System
GSE	Ground Support Equipment
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ICNIRP	International Consortium on Non-Ionizing Radiation Protection
ID	Identification
ILS	Instrumental Landings System
IRS	Indian Remote Sensing Satellite
MCT	Minimum Connecting Time
MIMO	Map In-Map Out
MLS	Microwawe Landing System
MMS	Multimedian Message Service
MSAS	Multi-functional Satellite Augmentation System
MSL	Mean Sea Level
NASA	National Aeronautical and Space Administration
NASDA	National Space Development Agency
NCGIA	National Centre for Geographic Information and Analysis
PC	Personal Computer

PDA	Personal Data Assistant
PP&M	Process, Power & Marine
RFID	Radio Frequency Identification
RL	Reason for Loss
SAS	Scandinavian Airlines
SES	Single European Sky
SG&I	Security, Government & Infrastructure
ShoCon	Short Connection
SITA	Société Internationale de Télécommunications Aéronautiques
SMR	Surface Movement Radar
SMS	Short Message Service
SPT	Simplifying Passenger Travel
SRA	Security Restricted Area
StB	Simplifying the Business
SYMAP	Synagraphic Mapping Sytem
TIGER	Topologically Integrated Geographic Encoding and Referencing
TNC	Terminal Navigation Charge
URISA	Urban and Regional Information Systems Association
USGS	United States Geological Survey
VIP	Very Important Person
VTIS	Vehicle Telematics Information System
WAAS	Wide Area Augmentation System
WGS-84	World Geodetic System — 1984
WHO	World Health Organisation

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Appendix

Appendix 1: Definitions Related to the Airside of an Airport

(Source: ICAO, 2004)

Airside definitions according to the ICAO Annex 14 I. chapter:

Aerodrome: is a defined area on land or water (including any buildings, installations and equipment) intended to be used either wholly or in part for the arrival, departure and surface movement of aircraft.

Aerodrome certificate: A certificate issued by the appropriate authority under applicable regulations for the operation of an aerodrome.

Aerodrome elevation: The elevation of the highest point of the landing area.

Aerodrome identification sign: A sign placed on an aerodrome to aid in identifying the aerodrome from the air.

Aerodrome reference point: The designated geographical location of an aerodrome.

Aerodrome traffic density: The number of movements in the mean busy hour is the arithmetic mean over the year of the number of movements in the daily busiest hour. Either a take-off or a landing constitutes a movement.

- *Light*: Where the number of movements in the mean busy hour is not greater than 15 per runway or typically less than 20 total aerodrome movements.
- *Medium:* Where the number of movements in the mean busy hour is of the order of 16 to 25 per runway or typically between 20 to 35 total aerodrome movements.
- *Heavy:* Where the number of movements in the mean busy hour is of the order of 26 or more per runway or typically more than 35 total aerodrome movements.

Aircraft stand: A designated area on an apron intended to be used for parking an aircraft.

Apron: A defined area, on a land aerodrome, intended to accommodate aircraft for purposes of loading or unloading passengers, mail or cargo, fuelling, parking or maintenance.

Apron management service: A service provided to regulate the activities and the movement of aircraft and vehicles on an apron.

Certified aerodrome: An aerodrome whose operator has been granted an aerodrome certificate.

Clearway: A defined rectangular area on the ground or water under the control of the appropriate authority, selected or prepared as a suitable area over which an aeroplane may make a portion of its initial climb to a specified height.

De-icing/anti-icing facility: A facility where frost, ice or snow is removed (de-icing) from the aeroplane to provide clean surfaces, and/or where clean surfaces of the aeroplane receive protection (anti-icing) against the formation of frost or ice and accumulation of snow or slush for a limited period of time.

De-icing/anti-icing pad: An area comprising an inner area for the parking of an aeroplane to receive de-icing/anti-icing treatment and an outer area for the manoeuvring of two or more mobile de-icing/anti-icing equipment.

Geodetic datum: A minimum set of parameters required to define location and orientation of the local reference system with respect to the global reference system/frame.

Geoid: The equipotential surface in the gravity field of the earth which coincides with the undisturbed Mean Sea Level (MSL) extended continuously through the continents. The geoid is irregular in shape because of local gravitational disturbances (wind tides, salinity, current, etc.) and the direction of gravity is perpendicular to the geoid at every point.

Geoid undulation: The distance of the geoid above (positive) or below (negative) the mathematical reference ellipsoid. In respect to the World Geodetic System — 1984

(WGS-84) defined ellipsoid, the difference between the WGS-84 ellipsoidal height and orthometric height represents WGS-84 geoid undulation.
Landing area: That part of a movement area intended for the landing or take-off of an aircraft.
Manoeuvring area: That part of an aerodrome to be used for the take-off, landing and taxiing of an aircraft, excluding aprons.
Movement area: That part of an aerodrome to be used for the take-off, landing and taxiing of aircraft, consisting of the manoeuvring area and the apron(s).
Obstacle: All fixed (whether temporary or permanent) and mobile objects, or parts thereof, that are located on an area intended for the surface movement of aircraft or that extend above a defined surface intended to protect aircraft in flight.
Road: An established surface route on the movement area meant for the exclusive use of vehicles (beyond aircraft).
Road-holding position: A designated position at which vehicles may be required to hold.
Runway: A defined rectangular area on a land aerodrome prepared for the landing and take-off of aircraft.
Take-off runway: A runway intended for take-off only.
Taxiway: A defined path on a land aerodrome established for the taxiing of aircraft and intended to provide a link between one part of the aerodrome and another, including:

- *Aircraft stand taxilane:* A portion of an apron designated as a taxiway and intended to provide access to aircraft stands only.
- *Apron taxiway:* A portion of a taxiway system located on an apron and intended to provide a through taxi route across the apron.
- *Rapid exit taxiway:* A taxiway connected to a runway at an acute angle and designed to allow landing aeroplanes to turn off at higher speeds than are achieved on other exit taxiways thereby minimizing runway occupancy times.

Taxiway intersection: A junction of two or more taxiways.

Appendix 2: Security Steps (Data Allowance)

(Source: Own Research)

GIS data for all MOVING elements, Tracking and Security Information on screen after getting the proper allowance:

Passenger (P):

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

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

Baggage (B):

Departure and Transfer Baggage:

RFID ID Number

ID tag reading

Flight Number
Flight Time
Security Check Information
Baggage's Sortation and Location

Special Authorization
(e. g. Flight Agent)

Pass.-Bagg. Reconciliation
Bagg.-Pass. Information

Arrival

RFID ID Number

ID tag reading

Flight Number
Bagg. Belt Number
Bagg. Location

Special Authorization
(e. g. Flight Agent)

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

Cargo (C):

Departure and Transfer Shipment:

RFID ID Number

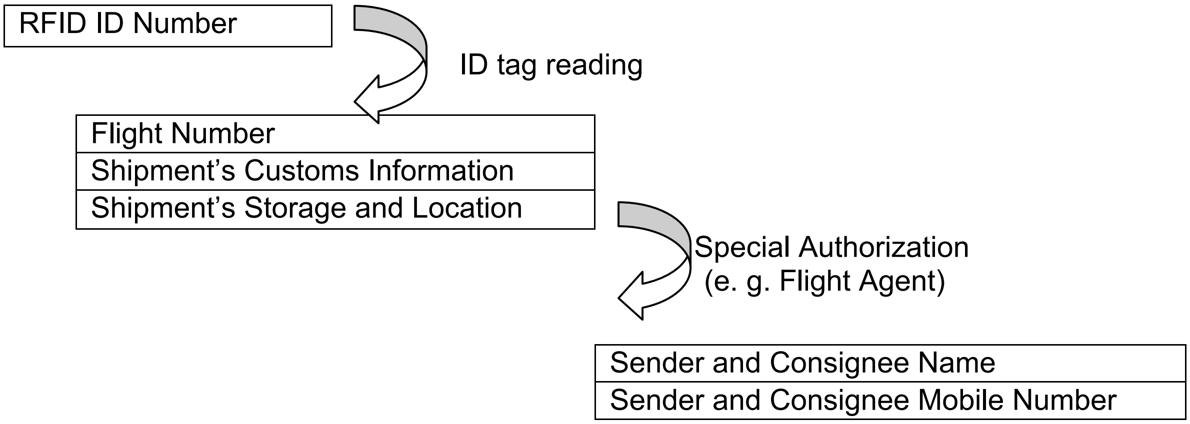
ID tag reading

Flight Number
Flight Time
Security Check and Customs Information
Shipment's Sortation, Storage and Location

Special Authorization
(e. g. Flight Agent)

Shipping Documents Reconciliation
Sender and Consignee Personal Information

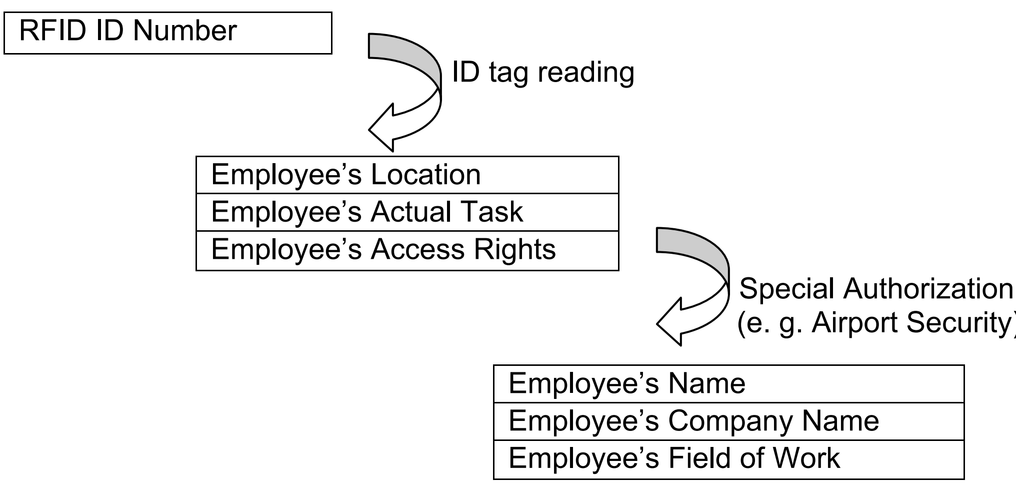
Arrival



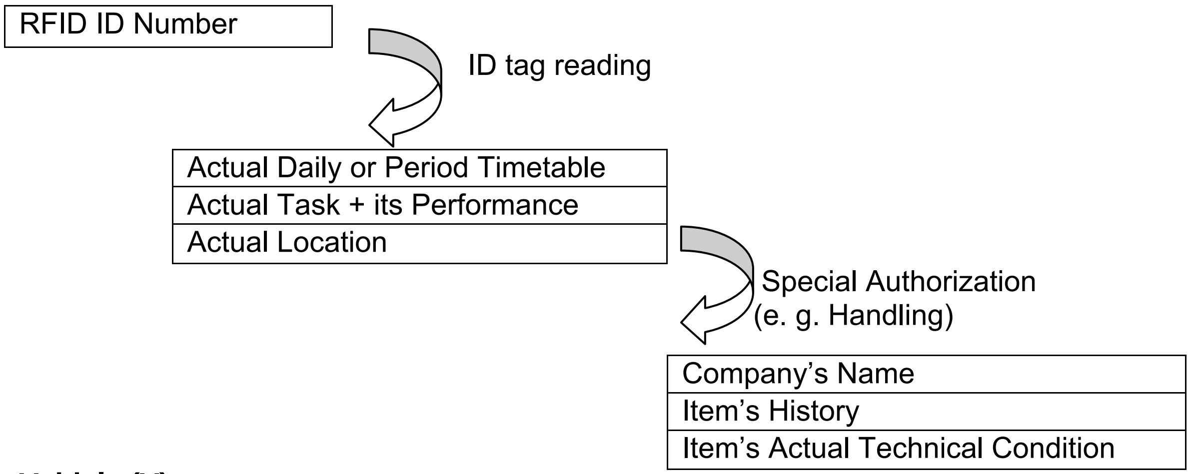
GAT (General Aviation Terminal):

No need for special RFID tagging for GAT passengers as they are accompanied during their statement at the airport by the handling company.
Technical staff is the chosen Handling Company (*see under staff*).

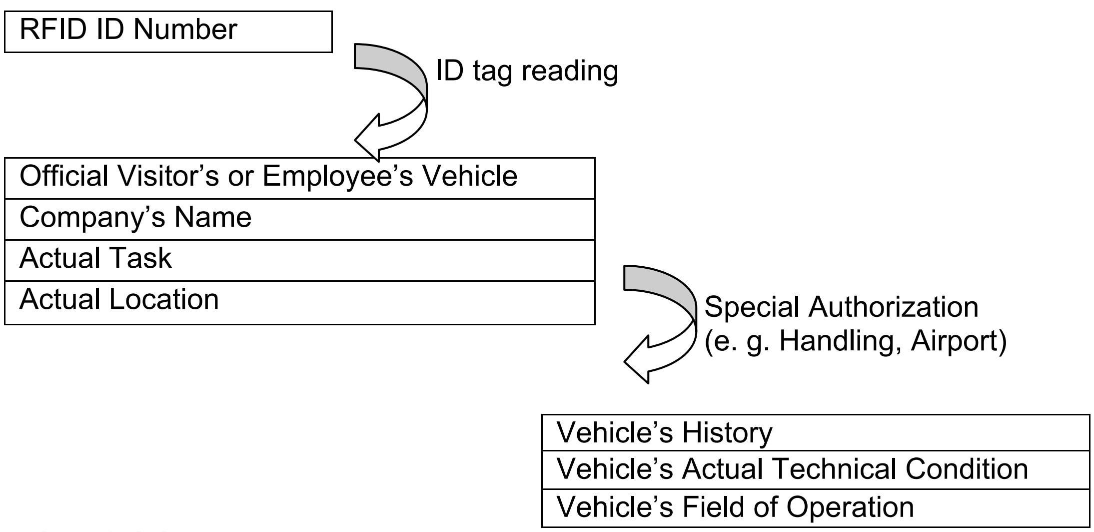
Staff (S):



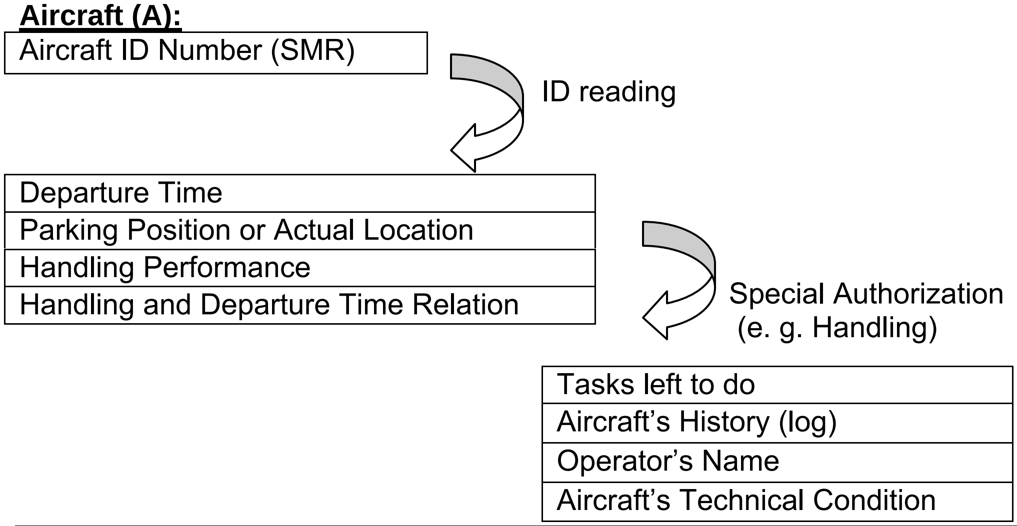
Item (I):



Vehicle (V):



Aircraft (A):



Appendix 3: Standard IATA Delay Codes

(Source: IATA Manual)

		Standard IATA Delay Codes
		Others
00-05		AIRLINE INTERNAL CODES
6	OA	NO GATE/STAND AVAILABILITY DUE TO OWN AIRLINE ACTIVITY
9	SG	SCHEDULED GROUND TIME LESS THAN DECLARED MINIMUM GROUND TIME
		Passenger and Baggage
11	PD	LATE CHECK-IN, acceptance after deadline
12	PL	LATE CHECK-IN, congestions in check-in area
13	PE	CHECK-IN ERROR, passenger and baggage
14	PO	OVERSALES, booking errors
15	PH	BOARDING, discrepancies and paging, missing checked-in passenger
16	PS	COMMERCIAL PUBLICITY/PASSENGER CONVENIENCE, VIP, press, ground meals and missing personal items
17	PC	CATERING ORDER, late or incorrect order given to supplier
18	PB	BAGGAGE PROCESSING, sorting etc.
		Cargo and Mail
21	CD	DOCUMENTATION, errors etc.
22	CP	LATE POSITIONING
23	CC	LATE ACCEPTANCE
24	CI	INADEQUATE PACKING
25	CO	OVERSALES, booking errors
26	CU	LATE PREPARATION IN WAREHOUSE
27	CE	DOCUMENTATION, PACKING etc (Mail Only)
28	CL	LATE POSITIONING (Mail Only)
29	CA	LATE ACCEPTANCE (Mail Only)
		Aircraft and Ramp Handling
31	GD	AIRCRAFT DOCUMENTATION LATE/INACCURATE, weight and balance, general declaration, pax manifest, etc.
32	GL	LOADING/UNLOADING, bulky, special load, cabin load, lack of loading staff
33	GE	LOADING EQUIPMENT, lack of or breakdown, e.g. container pallet loader, lack of staff
34	GS	SERVICING EQUIPMENT, lack of or breakdown, lack of staff, e.g. steps
35	GC	AIRCRAFT CLEANING
36	GF	FUELLING/DEFUELLING, fuel supplier
37	GB	CATERING, late delivery or loading
38	GU	ULD, lack of or serviceability

		Technical and Aircraft Equipment
41	TD	AIRCRAFT DEFECTS.
42	TM	SCHEDULED MAINTENANCE, late release.
43	TN	NON-SCHEDULED MAINTENANCE, special checks and/or additional works beyond normal maintenance schedule.
44	TS	SPARES AND MAINTENANCE EQUIPMENT, lack of or breakdown.
45	TA	AOG SPARES, to be carried to another station.
46	TC	AIRCRAFT CHANGE, for technical reasons.
47	TL	STAND-BY AIRCRAFT, lack of planned stand-by aircraft for technical reasons
48	TV	SCHEDULED CABIN CONFIGURATION/VERSION ADJUSTMENTS.
		Damage to Aircraft & EDP/Automated Equipment Failure
51	DF	DAMAGE DURING FLIGHT OPERATIONS, bird or lightning strike, turbulence, heavy or overweight landing,collision during taxiing
52	DG	DAMAGE DURING GROUND OPERATIONS, collisions (other than during taxiing), loading/off-loading damage,contamination, towing, extreme weather conditions
55	ED	DEPARTURE CONTROL
56	EC	CARGO PREPARATION/DOCUMENTATION
57	EF	FLIGHT PLANS
		Delays to Air Transport in Europe- EUROCONTROL / ECAC **21** CODA
		Flight Operations and Crewing
61	FP	FLIGHT PLAN, late completion or change of, flight documentation
62	FF	OPERATIONAL REQUIREMENTS, fuel, load alteration
63	FT	LATE CREW BOARDING OR DEPARTURE PROCEDURES, other than connection and standby (flight deck or entire crew)
64	FS	FLIGHT DECK CREW SHORTAGE, sickness, awaiting standby, flight time limitations, crew meals, valid visa, health documents, etc.
65	FR	FLIGHT DECK CREW SPECIAL REQUEST, not within operational requirements
66	FL	LATE CABIN CREW BOARDING OR DEPARTURE PROCEDURES, other than connection and standby
67	FC	CABIN CREW SHORTAGE, sickness, awaiting standby, flight time limitations, crew meals, valid visa, health documents, etc.
68	FA	CABIN CREW ERROR OR SPECIAL REQUEST, not within operational requirements
69	FB	CAPTAIN REQUEST FOR SECURITY CHECK, extraordinary
		Weather
71	WO	DEPARTURE STATION
72	WT	DESTINATION STATION
73	WR	EN ROUTE OR ALTERNATE
75	WI	DE-ICING OF AIRCRAFT, removal of ice and/or snow, frost prevention excluding unserviceability of equipment
76	WS	REMOVAL OF SNOW, ICE, WATER AND SAND FROM AIRPORT
77	WG	GROUND HANDLING IMPAIRED BY ADVERSE WEATHER CONDITIONS

		ATFM + AIRPORT + GOVERNMENTAL AUTHORITIES
		AIR TRAFFIC FLOW MANAGEMENT RESTRICTIONS
81	AT	ATFM due to ATC EN-ROUTE DEMAND/CAPACITY, standard demand/capacity problems
82	AX	ATFM due to ATC STAFF/EQUIPMENT EN-ROUTE, reduced capacity caused by industrial action or staff shortage, equipment failure, military exercise or extraordinary demand due to capacity reduction in neighbouring area
83	AE	ATFM due to RESTRICTION AT DESTINATION AIRPORT, airport and/or runway closed due to obstruction, industrial action, staff shortage, political unrest, noise abatement, night curfew, special flights
84	AW	ATFM due to WEATHER AT DESTINATION
		AIRPORT AND GOVERNMENTAL AUTHORITIES
85	AS	MANDATORY SECURITY
86	AG	IMMIGRATION, CUSTOMS, HEALTH
87	AF	AIRPORT FACILITIES, parking stands, ramp congestion, lighting, buildings, gate limitations, etc.
88	AD	RESTRICTIONS AT AIRPORT OF DESTINATION, airport and/or runway closed due to obstruction, industrial action, staff shortage, political unrest, noise abatement, night curfew, special flights
89	AM	RESTRICTIONS AT AIRPORT OF DEPARTURE WITH OR WITHOUT ATFM RESTRICTIONS, including Air Traffic Services, start-up and pushback, airport and/or runway closed due to obstruction or weather2, industrial action, staff shortage, political unrest, noise abatement, night curfew, special flights
		Reactionary
91	RL	LOAD CONNECTION, awaiting load from another flight
92	RT	THROUGH CHECK-IN ERROR, passenger and baggage
93	RA	AIRCRAFT ROTATION, late arrival of aircraft from another flight or previous sector
94	RS	CABIN CREW ROTATION, awaiting cabin crew from another flight
95	RC	CREW ROTATION, awaiting crew from another flight (flight deck or entire crew)
96	RO	OPERATIONS CONTROL, re-routing, diversion, consolidation, aircraft change for reasons other than technical
		Miscellaneous
97	MI	INDUSTRIAL ACTION WITH OWN AIRLINE
98	MO	INDUSTRIAL ACTION OUTSIDE OWN AIRLINE, excluding ATS
99	MX	OTHER REASON, not matching any code above

Appendix 4: Reason for Loss List (RL list)

(Source: IATA Manual)

IATA Reason for Loss (RL list):
PRIMARY CODES

NON-STATION TARGET
-------------- ------------------
10 - ORIGIN STATION CHECK IN 60 - AIRPORT - GENERAL
20 - ORIGIN STATION FAILED TO LOAD 70 - MISCELLANEOUS
30 - ANY STATION - LOADING/OFFLOADING 80 - DAMAGE
40 - ARRIVAL STATION 90 - PILFERAGE
50 - TRANSFER STATION

SECONDARY CODES

NOTE P - PRIMARY CODE S - SECONDARY CODE

P - 10 ORIGIN STATION CHECK IN
S 11 INCORRECT OR NO ENTRIES ON TAG
12 NOT CHECKED TO FINAL DESTINATION
13 CHECKED TO FINAL DESTINATION - 2 SEPARATE CONTRACTS
15 WRONG BAG LABELED - FOR EXAMPLE - TAG SWITCH
16 BAG RECEIVED TOO LATE FROM CHECKIN
17 OLD TAG NOT REMOVED
18 BAG NOT AUTHORISED TO LOAD.

P - 20 ORIGIN STATION FAILED TO LOAD
S 21 BAG LEFT AT STN OF ORIGIN/ CORRECTLY LABELED
23 STANDBY BAGGAGE LEFT BEHIND
25 GATE CHECKED BAGGAGE LEFT BEHIND
26 OFFLOADING DUE SPACE/WEIGHT RESTRICTIONS
27 LOCAL PASSENGER REROUTED / BAG NOT REROUTED

P - 30 ANY STATION LOADING / OFFLOADING
S 31 SORTING OR LOADING ERROR - WRONG AIRCRAFT
32 OFFLOADED BY ERROR
33 NOT OFFLOADED
35 SORTING OR LOADING ERROR-WRONG CONTAINER / WRONG COMPARTMENT / BEHIND CARGO.

P - 40 ARRIVAL STATION
S 41 DELIVERED TO WRONG AREA
42 DELAYED DELIVERY TO CLAIM AREA
43 DELAYED DELIVERY OF OVERSIZED/ODDSIZED BAGGAGE TO CLAIM AREA

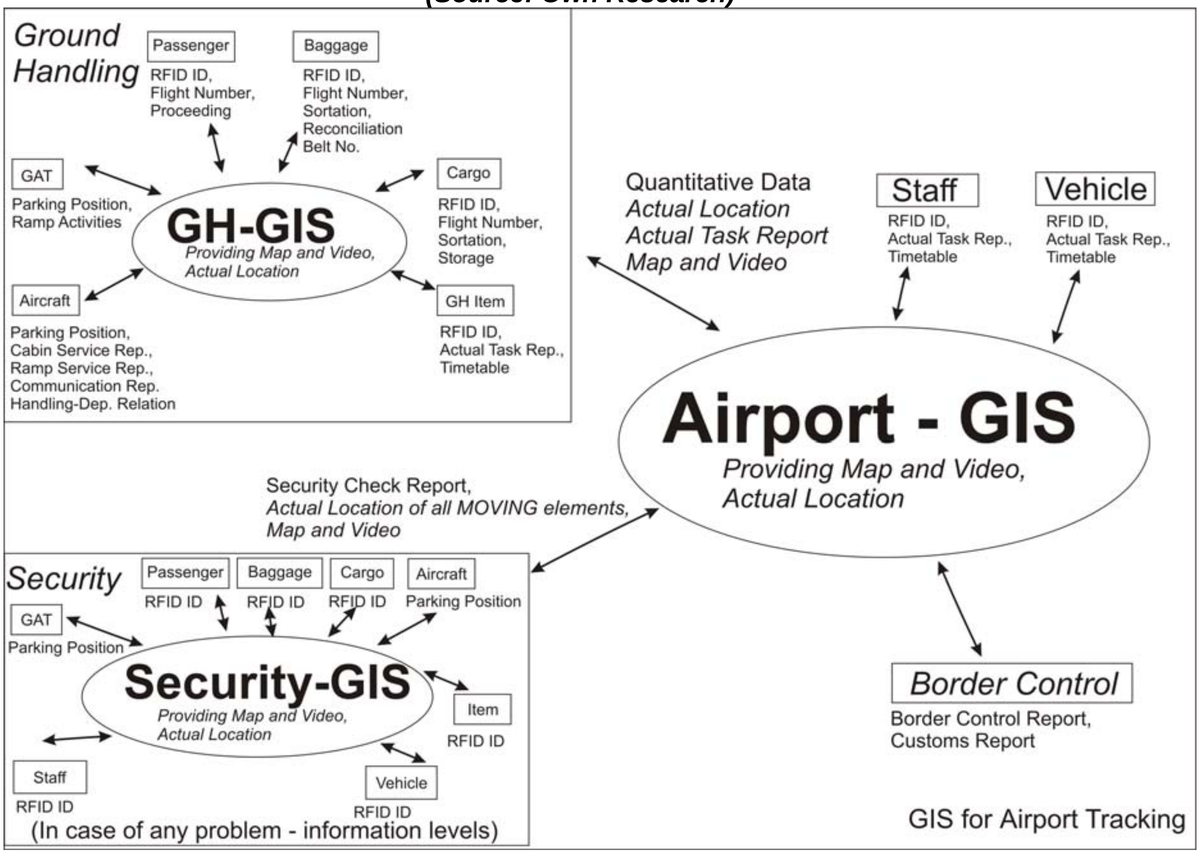
P - 50 TRANSFER STATION
S 51 PASSENGER REROUTED/BAG NOT REROUTED
52 INTERLINE MCT -MIN CONNECTING TIME- AVAILABLE
53 INTERLINE MCT NOT AVAILABLE
54 INTERLINE BAGS NOT MADE AVAILABLE BY INBOUND CARRIER PER LOCAL AGREEMENT
55 ONLINE -OWN CARRIER- MCT AVAILABLE
56 ONLINE -OWN CARRIER- MCT NOT AVAILABLE
57 ALLIANCE PARTNER
58 CODESHARE PARTNER
59 BAG NOT AUTHORISED TO LOAD.

P - 60 AIRPORT - GENERAL
S 61 INDUSTRIAL DISPUTE I.E. STRIKE
62 OTHER REASONS I.E. METEOROLOGICAL
63 AIRPORT SECURITY
64 UNSERVICEABLE EQUIPMENT /BELT/SORTATION SYSTEM/ETC
65 SPACE/WEIGHT RESTRICTIONS DUE WEATHER CONDITIONS
66 ERROR BY NON-AVIATION CARRIER FOR EXAMPLE-CRUISE OR GROUND TRANSPORTATION
67 CUSTOMS/POLICE/IMMIGRATION ACTION

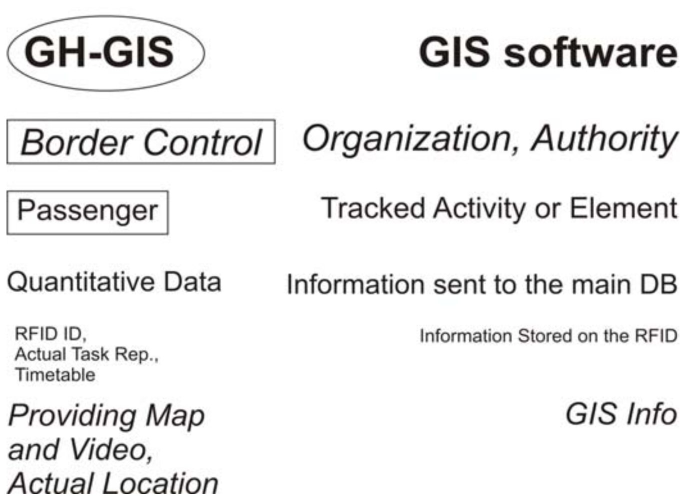
P - 70 MISCELLANEOUS
S 72 PASSENGER OFFLOADED / BAG NOT OFFLOADED
73 BAG NOT CLAIMED BY PASSENGER WHERE REQUIRED
74 BAG SWITCH E.G. PASSENGER TAKES WRONG BAG
75 NOT IDENTIFIED BY PASSENGER AT SECURITY CHECK
76 FOUND WITHOUT TAG
77 ERRORS BY OTHER CARRIER E.G. TAGGING ETC.
78 REASON FOR MISHANDLING NOT DETECTABLE
79 REPORT CREATED IN ERROR

Appendix 5: Airport – GIS, Legend

(Source: Own Research)

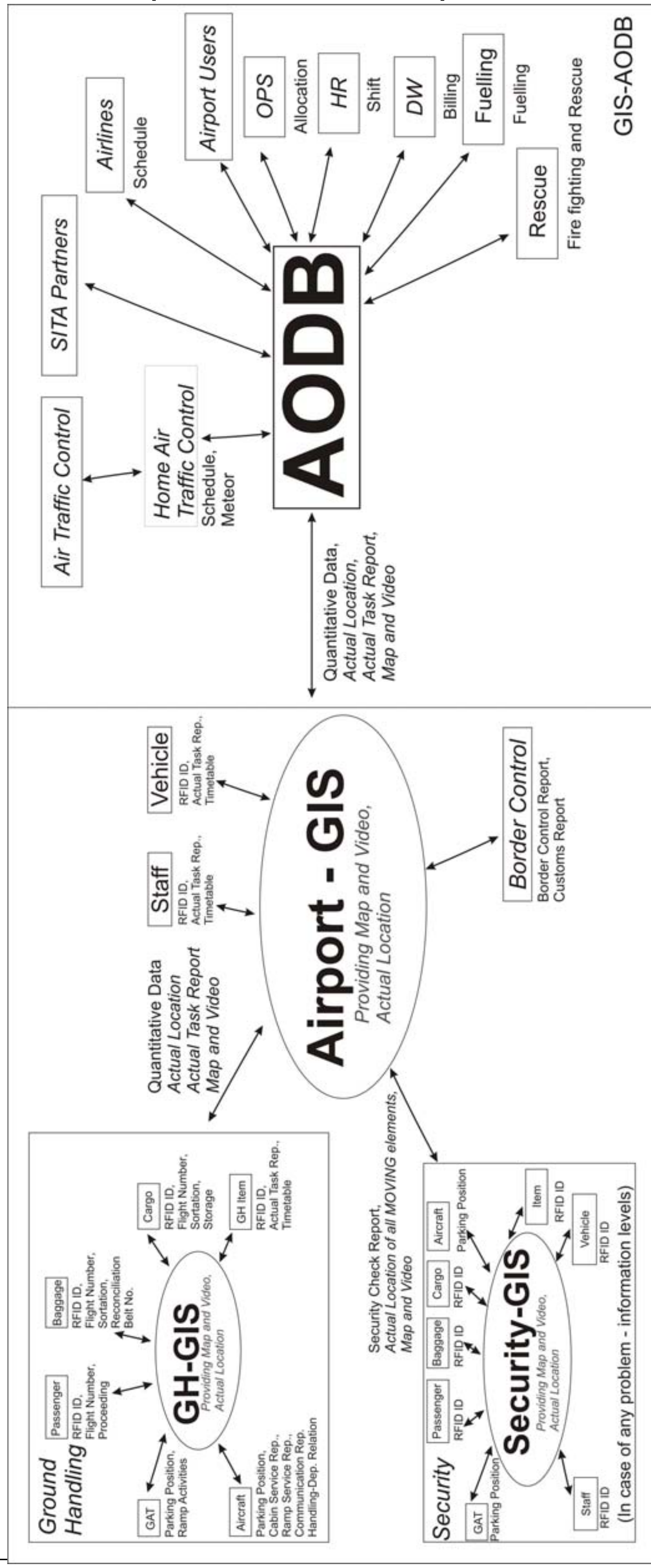


Legend



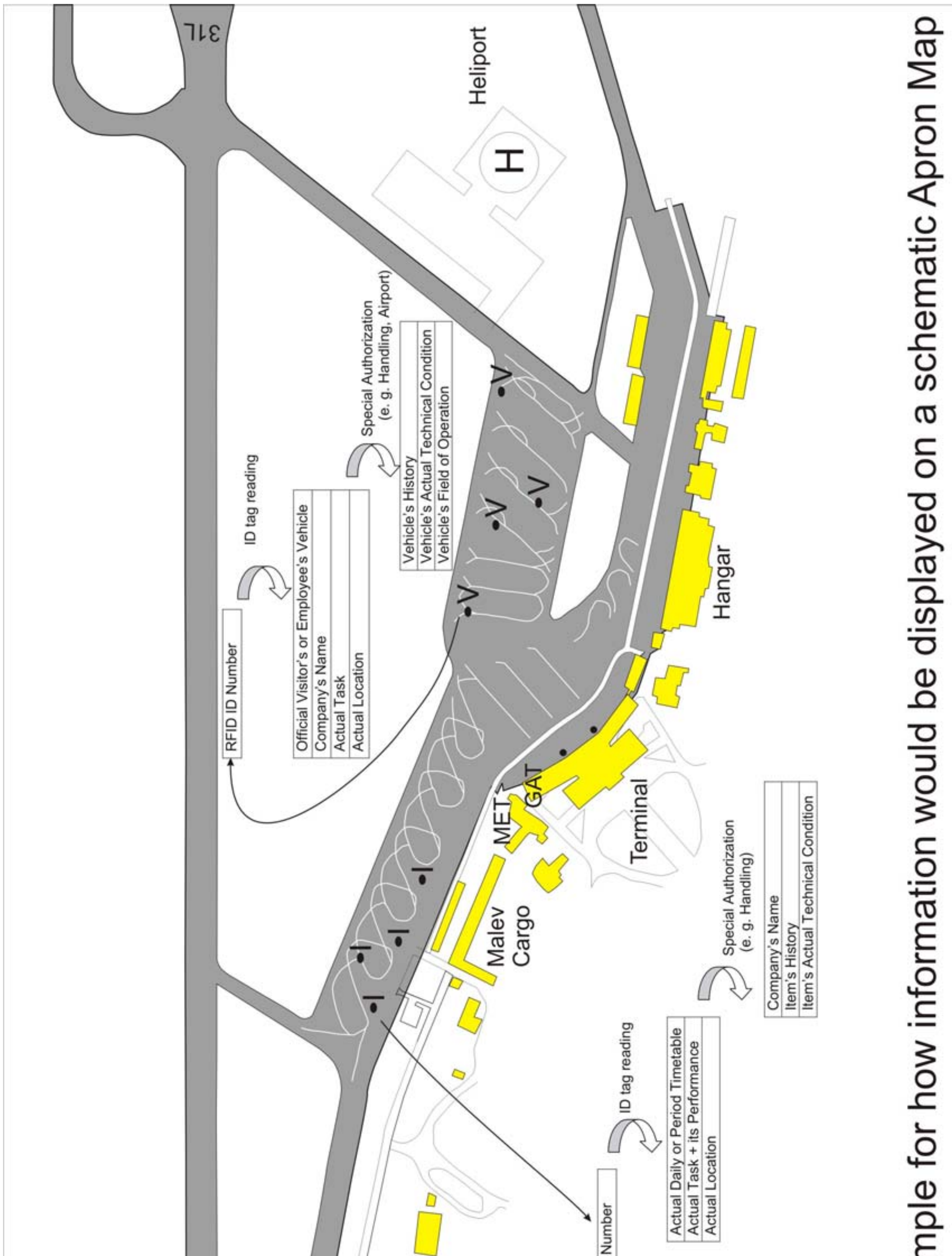
Appendix 6: Airport GIS Integrated into AODB

(Source: Own Research)

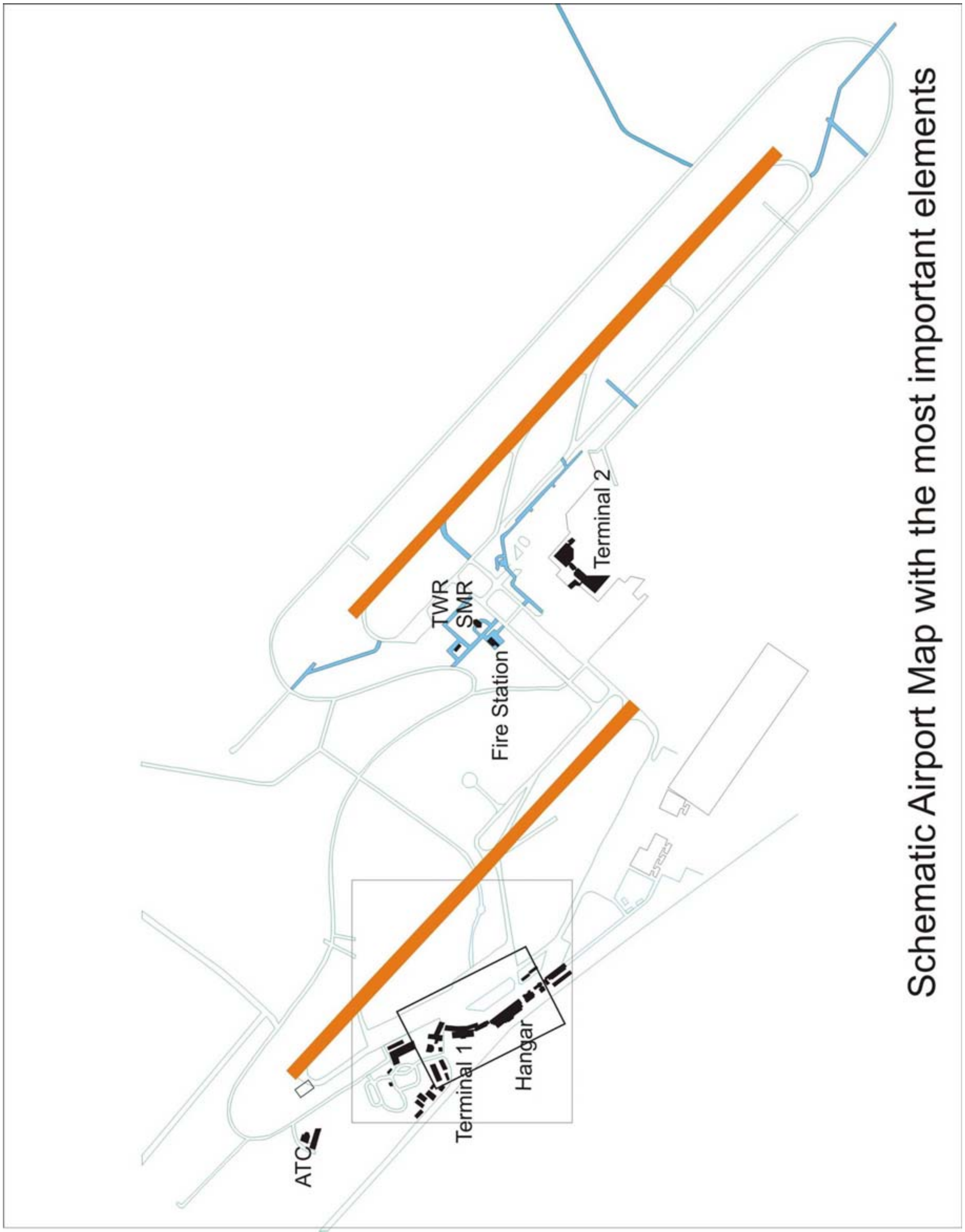


Appendix 7: Tracking on the Apron

(Source: Own Research)



Appendix 8: Most Important Elements of an Airport



Appendix 9: Estimated Flight Delay Calculation

Equation for the delays caused, expressed in time and costs are as follows:
Estimated value of delay: E_D

$$E_D = \sum_{i \geq 15} P_i * i, \text{ [Minute]}$$

where: P_i = Probability that a flight will be delayed by i minutes, formally:

$$P_i = \frac{\textit{No. of flights delayed with i minutes}}{\textit{All flights}}.$$

Estimated value of costs: E_C

$$E_C = E_D * C_D, \text{ [Euro]}$$

where: C_D= the cost per minute at the company for a delayed flight.
For an airline 1 minute of delay costs 50 Euro (calculated based on that: for a regional airline delay means 30Euro/Min., and for an international airline it means 70Euro/Min.)

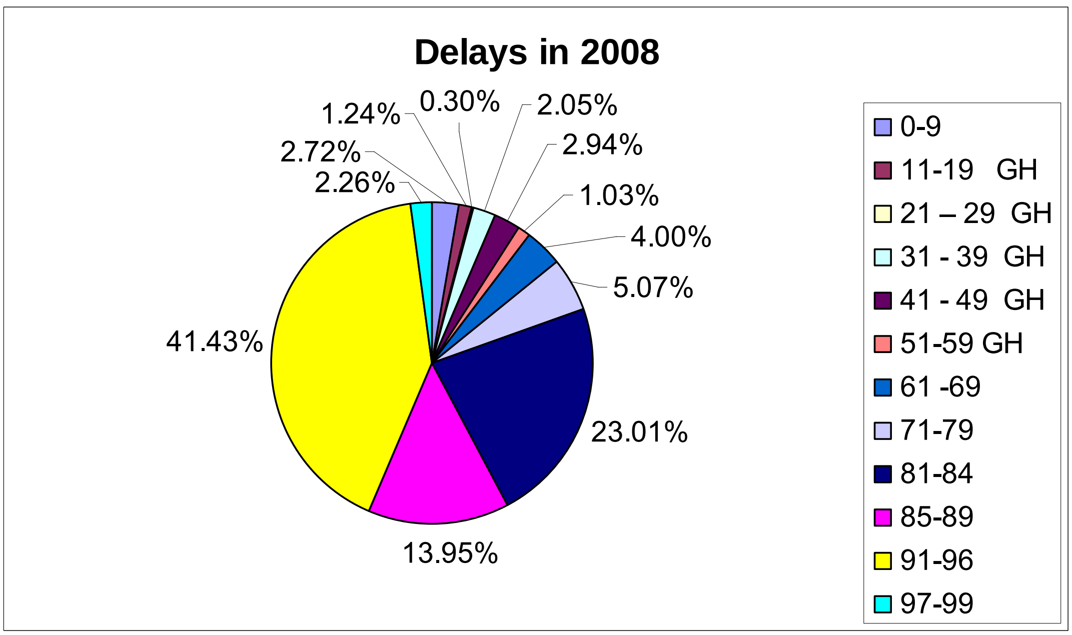


Figure 40: Delays in 2008 at a Regional Airport, Based on Number of Flight Delays (Source: Own Estimation)

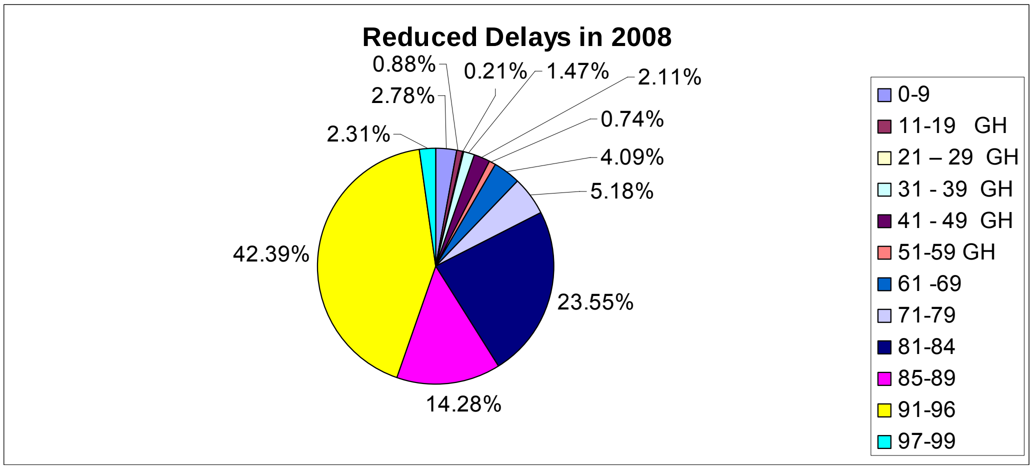


Figure 41: Reduced Delays in 2008 at a Regional Airport, Based on Number of Flight Delays (Source: Own Estimation)

The system can reduce the number and costs of flight delays due to airport capacity or ground handling capacity by the supposed 30% maximum time reduction in ideal conditions. The delays expressed in the table below *(see Table 9)* are the delays valuated in minutes related to the previous figures *(see Fig. 40, Fig. 41.)* where the delays are shown based on number of flights in pieces. The flight delays due to late passengers (*see 5.2.4, see Table 8.)* is incorporated in following estimation.

Quantified that means for 1 year (continuing the previous example):

Delay Codes	Present Delay times (hh:mm)	Reduced Delay Times (hh:mm)
0-9	43:17	43:17
11-19	**29:02**	**20:19**
21-29	**10:08**	**7:06**
31-39	**59:35**	**41:43**
41-49	**354:53**	**248:25**
51-59	**38:23**	**26:52**
61-69	133:37	133:37
71-79	293:21	293:21
81-84	828:04	828:04
85-89	292:14	292:14
91-96	3010:04	3010:04
97-99	181:00	181:00
Total Delay Time [hh:mm]	**5273:38**	**5126:03**
Total Delay Time [Min]	**316440**	**307560**
Costs 50Euro/Min [Euro]	**15,822,000**	**15,378,000**
Annually saved [Euro]		**444,000**

Table 9: Delay Times and Costs for a Regional Airport in 1 Year (Source: Own Estimation)

Appendix 10: Estimated Comparison of the Return on Investments

(Source: Own Estimation)

Equipment	Complex				Delays				Baggage				Passenger			
	Min		Max		Min		Max		Min		Max		Min		Max	
	Pieces	Euro	Pieces	Euro	Pieces	Euro	Pieces	Euro	Pieces	Euro	Pieces	Euro	Pieces	Euro	Pieces	Euro
RFID Passive Tag	1000	300	10000000	3,000,000	1000	300	10000000	3,000,000	1000	300	10000000	3,000,000	-	-	-	-
RFID Gate	10	1,370	40	5,480	10	1,370	40	5,480	3	402	15	2,055	4	548	24	3,288
RFID Hand Reader	2	4,052	12	24,300	2	4,052	12	24,300	2	4,052	12	24,300	-	-	-	-
RFID Reader Secu.	4	548	24	3,288	4	548	24	3,288	-	-	-	-	4	548	24	3,288
RFID Card Reader	50	6,800	150	20,400	50	6,800	150	20,400	-	-	-	-				
RFID Software	1	6,300	1	6,300	1	6,300	1	6,300	1	6,300	1	6,300	1	6,300	1	6,300
Video Camera	50	125,000	250	375,000					-	-	-	-	-	-	-	-
Biometrical ID Software		5,000		5,000					-	-	-	-	-	-	-	-
GIS Software	1	3,000,000	1	3,000,000	1	3,000,000	1	3,000,000								
Total Costs [Euro]		**3,149,370**		**6,439,768**		**3,019,370**		**6,059,768**		**11,054**		**3,032,655**		**7,396**		**12,876**
Min. Savings [Euro]		**444,000**		**444,000**		**444,000**		**444,000**		**1,954,550**		**1,954,550**		**350**		**350**
Return in Time [Year]		**7.09**		**14.50**		**6.80**		**13.65**		**4Months**		**1.60**		**21.13**		**36.79**