USE OF NEW TECHNOLOGIES IN THE FIELD OF AIRCRAFT HANDLING

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BACHELOR THESIS

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1. Introduction

Nowadays, the fact that an airport functions fluently is, to a large extent, due to a proper and effective provision of the handling service. This thesis, in the first part, tries to create a general overview of the services provided by the ground handling organizations, discussing the advantages and disadvantages of current practices and techniques used. After having a global view of the topic, an analyses of technology development will be carried in the field of aircraft handling to see how the technology has improved the efficiency and safety in this aviation sector.

In a highly competitive environment, such as air transport, the objective of all airlines is to be efficient and competitive. Their goal is to maximize the use of the aircraft, while trying to minimize the time spent at the airports and the costs that this carries. Hence, the special interest that exists for the study and development of new approaches that can provide more efficient solutions regarding airport handling. In this thesis, some possibilities for introduction of these new approaches will be stated and studied.

Once the theoretical part has been explained, some design changes and process settings will be proposed. In order to know if this changes are suitable for implementation, it is also necessary to do a research on the impact on operations and safety.

The motivation that has led me to choose the topic and scope of this thesis has been, first of all, the curiosity to know a field which is quite unknown to me. For this reason, I strongly believe that this thesis can bring me added value to my studies and can open new horizons and opportunities in other fields that I did not know about. Airport handling is a really important topic which is currently being studied as new resources are being implemented to obtain important and representatives achievements in this field, so that the increasing demand can be satisfied.

The main objectives of this work are the following:

- Analyze the current practices and techniques used, together with the analysis of the technology development in such topic.
- Visualize the handling processes by means of process diagrams to fully understand the sequence of actions.
- Introduction of other approaches to aircraft handling in order to improve the weaknesses on each process.
- Impact of these changes on operations and safety to see if they are suitable.
- SWOT analysis definition of the strengths, weaknesses, opportunities and threats of such new technology.

The previous objectives can be reflected in the structure and planning of the thesis as it is explained below:

- **Chapter 2**: this chapter describes the concept of ground handling to get a general knowledge of the topic of this thesis. All services provided by the handling of an airport are briefly described which include the passenger services and the aircraft ones. Therefore, this section is established as an introduction of the future analysis.
- **Chapter 3:** after a general introduction on the topic, this chapter focuses deeply on the services provided to the aircraft, making a detailed description of each of the services. The procedure followed by each service is visualized through process mapping, which helps identifying the weaknesses of such processes that can be improved.
- **Chapter 4:** once the risks and weaknesses of the different processes have been identified, new technology developments are studied in order to achieve efficient and updated services to the aircraft. In this chapter, several innovations that could be implemented in current airports are described.
- **Chapter 5:** the introduction of new technology leads to the need for the study of the new processes in comparison to the traditional ones. In this chapter, new process maps are developed in order to see the new sequence of actions. The important part of visualizing these procedures is the risk and safety assessment. Every new development comes with some safety hazards that must be taken into account in order to determine whether is feasible its implementation or not.
- **Chapter 6:** Finally, after the safety assessment, a SWOT analysis will be performed in this chapter to identify the strengths, weaknesses, opportunities and threats of each system to conclude the viability study.

2. Airport handling

The concept of aircraft ground handling refers to a whole set of activities and services that take place at the airports and which purpose is to carry out efficiently all relevant activities related to the servicing of arriving and departing flights.

Therefore, the assistance on the ground is of vital importance in order to achieve an efficient operation at the airports. However, there exist varied and diverse activities that form the airport handling which is why nowadays, most airlines decide to outsource these practices. This is the reason why many companies have emerged and they are dedicated exclusively to handling providing their services to various airlines.

The services can vary depending on the level of requirements of the company to which the service is offered, as well as the type of activity that has been contracted since there are basically 3 models for service provision:

1. An airline itself that carries out its handling services.
2. Ground handling at airports is outsourced and performed by a business dependent from the airline.
3. An airline outsources only part of the handling services

2.1 Handling services

One of the main goals of this thesis is to identify the weaknesses of the different processes in order to implement new technology to optimize them. Before that, it is important to get a general overview of the different handling processes for being able to make a further analysis of them.

In this part of the chapter, the different types of the airport handling services are going to be described, starting with the passenger services and finishing with the aircraft ones, which are the main focus of the thesis.

2.1.1 Passenger services

The services to the passenger are all those that the person who is going to travel directly perceives. These services range from check-in processes, to disembarkation and boarding of aircraft. In this section, all these services are going to be described to get a general knowledge of them. [2]

2.1.1.1 Check-In

The check-in process is the first point of contact between the passenger and the airline at airports. This process basically consists of:

- A documentation control, where the identification documents of all passengers are verified. This part of the process could vary depending on the destination and the policies of the companies operating the flight since, for certain destinations, more exhaustive controls are carried out such as, for example, in United States of America.
- Verification of the weight of checked and hand baggage of all individuals, ensuring compliance with company regulations taking into account the rates and classes (Business, first class, tourist etc.).
- Assignment of seats, complying with the restrictions that may exist. However, this step is not carried out in certain airlines.
- Check-in of baggage itself and printing of boarding passes. When obtaining these boarding cards, the passenger is ready to enter the boarding area.
- Finally, the passenger receives information regarding the status of the flight and the boarding area.

This process is fundamental for the airlines or handling agents. This way, the baggage to be loaded is stored in a specific flight and all the passengers expected for a certain plane appear in the information system. Moreover, whether they carry baggage or not is also in the data base. With all of this, there is a better control of the operations carried out.

However, it is important to highlight that airlines also offer the possibility to do an online check-in through the website or through automatic machines located at airports. With this new developments, the waiting times are trying to be reduced at the check-in counters by enabling special counters to check-in only the baggage.

2.1.1.2 Security checks

Security checks separate the land side (check-in counters, ticket sales offices, passenger arrivals…) from the air side (boarding area, transit offices, baggage collection…). This process is of major importance to ensure aviation security at the passenger level. Its function consists of checking the hand baggage of passengers in order to ensure that no object that may threaten the security of other passengers or equipment is transported. Furthermore, the passengers themselves are obligated to pass through a scanner to be checked that no hazardous object or material is hidden.

2.1.1.3 PRM assistance

It is the service responsible for the assistance of people with reduced mobility at the airports. The service basically allows PRMs to travel from a designated point of arrival at the airport of origin to the plane, and from the aircraft to a designated point of departure in the destination airport, including boarding, disembarking, transit and connection operations.

2.1.1.4 Boarding/disembarking

Boarding refers to the airline procedures that process the passengers to allow them onto the correct aircraft for their destination. On the other hand, disembarking refers to leaving the aircraft once it has arrived at the destination.

On the one hand, boarding does not normally begin until a series of ground services have been carried out. It begins with the consultation and agreement with the flight crew when everything is set on board. The time of a boarding can vary depending on the airline´s own policies, the number of passengers to board and the possible setbacks that may appear during this process. After the final boarding announcement is made, various reports and passenger counts are prepared and calculated and are given to the crew and to operations departments.

Regarding the disembarking of the passengers from the aircraft, it is done a sequence of processes including putting the chocks to the wheels of the landing gear, airbridge/stairs connection and other relevant processes.

2.1.1.5 Other assistance

Other assistance that is directly related to passengers are those that are offered to transit passengers. These services include the printing of new boarding passes in the air zone and information regarding the status of flights and the location of boarding gates. Finally, in the baggage collection area, there exist the called "lost and found" offices where claims are made in case of loss of baggage.

2.1.2 Aircraft services

The services to the aircraft are those that does not directly affect the passenger, but which are fundamental to keep the aircraft in required conditions to carry out the flight safely and efficiently. [3]

2.1.2.1 Loading and unloading of baggage and other cargo

The way of loading the baggage can be conditioned depending on the type of an aircraft. In the case of a wide-body aircraft, the cargo hold is conditioned to transport the baggage in "pallets" or "ULDs". Unit load devices are used as containers for baggage and cargo and they are designed to contain and transport baggage and cargo in a modular and standardized way in order to optimize the use of the volume of the hold. The ULDs facilitate the loading, unloading and classification of baggage while maintaining their physical integrity. The elements that make up the ULDs are the following:

- Pallet: platform on which the load is stacked
- Net: ribbon or cord mesh used to hold the entire load on each pallet

- Container: loading equipment that forms a complete closed unit, either by the assembly of individual sub-systems or by an integral construction.

In order to load the containers properly, it is necessary to have a lifting platform that lifts the ULDs and pallets to the level of cargo hold.

Furthermore, in the case of a narrow-body aircraft, it is common to have free bulk baggage loaded, which means that the bags are brought up one by one on a conveyor belt and placed into the hold.

2.1.2.2 Cleaning

This type of assistance covers all cleaning services, both inside and outside the aircraft. Among the most cleaning frequent activities, it is important to highlight the following:

- **General interior cleaning**: This activity is carried out from the end of the disembarkation until the beginning of the boarding and consists of the cleaning of the passenger cabin, the removal of the garbage etc.
- **Change of drinking water**: It involves the filling, by means of a cistern and a pump, of the potable water tank of the airplane.
- **Waste water gathering**: it is an important activity since, during the flight, waste water is stored in a special tank of the plane mostly from the water of the toilets. Thus, once the aircraft is in the parking area, the water is extracted through another tank and a hose connected to the bottom of the fuselage.

2.1.2.3 De-icing process

It is one of the most important processes in certain times of the year and in certain locations where it is common the formation of ice in the wings that prevents the aircraft from flying. Therefore, it is essential to have equipment at airports that can deal with possible freezing by supplying compressed air at high temperatures or other fluids as anti-icing liquid.

2.1.2.4 Catering

This service is usually handled by a company different from the rest of the handling. It is not only responsible for transportation, loading and unloading of food and drinks but also for providing press, headphones, disposable material and even the things that the company sells on board. The catering handling requires a lift truck, which consists of a van that is lifted by a hydraulic system and whose interior is refrigerated to conserve the products.

2.1.2.5 Fuel supply

This handling process is one of the most critical and dangerous, so particular precautions are taken in order to avoid fires. It is frequent that certain airlines, due to their short stopover times, decide to carry out the processes of fuel supply and passenger boarding at the same time. However, for this, previously, the airport firefighters must be informed in this regard, so they can act quickly if necessary.

There are basically three ways on how to perform a refueling process: through a hydrant system, with the tanker or through a supply network, which will be explained deeply in the following sections.

2.1.2.6 Power supply

Once the aircraft has remained with the equipment turned off during the time of scale, it is necessary to provide electrical power to the aircraft systems.

There are several ways how to supply the aircraft with the electrical energy: by means of an auxiliary unit of power of the own airplane, called APU (Auxiliary Power Unit), by means of a mobile equipment that provides the agent of handling which is called GPU (Ground Power Unit) and finally, by means of a fixed equipment of the airport that is attached to the airbridges.

2.1.2.7 Push-back

Once the aircraft is ready to leave the parking area and the footbridge or stairway has been removed, a process known as push-back occurs, which involves pushing the aircraft backwards. This is made by a high-powered tractor connected to the front wheels of the aircraft and starts pushing back, using tow bars or lifting the wheels of the front axle of the landing gear. This is a case only at the stand, which are located next to the terminal building and where aircraft cannot leave the stand using the engines. In case of remote stands, aircraft do not require push-back vehicle and leave the stand by its own power.

3. Analysis of ground handling processes

As it has been previously mentioned, this project is going to focus in aircraft handling in a deeper way in order to seek new developments that could make this type of services more efficient. In the previous section, a general explanation of the aircraft services has been made but, in this section each of the services provided by aircraft handling organization are going to be analyzed, describing the processes, requirements and equipment.

Before analyzing one by one the mentioned services and the ground equipment, it is important to highlight the process followed before arrival and once the aircraft has parked so the whole procedure can be fully understood.

Prior to the arrival of the aircraft, the ground staff must be present and ready approximately 10 minutes before and the following equipment has to be serviceable and available on the stand: chocks, cones, GPU, preconditioned air, headset interphone among others. Furthermore, Foreign Object Debris, named FOD, must be checked and collected, as any objects in the surface apron can damage the aircraft and cause great injury. Regarding passengers, stairs and bridges have to be prepared and cleaned to allow a quick disembarkation.

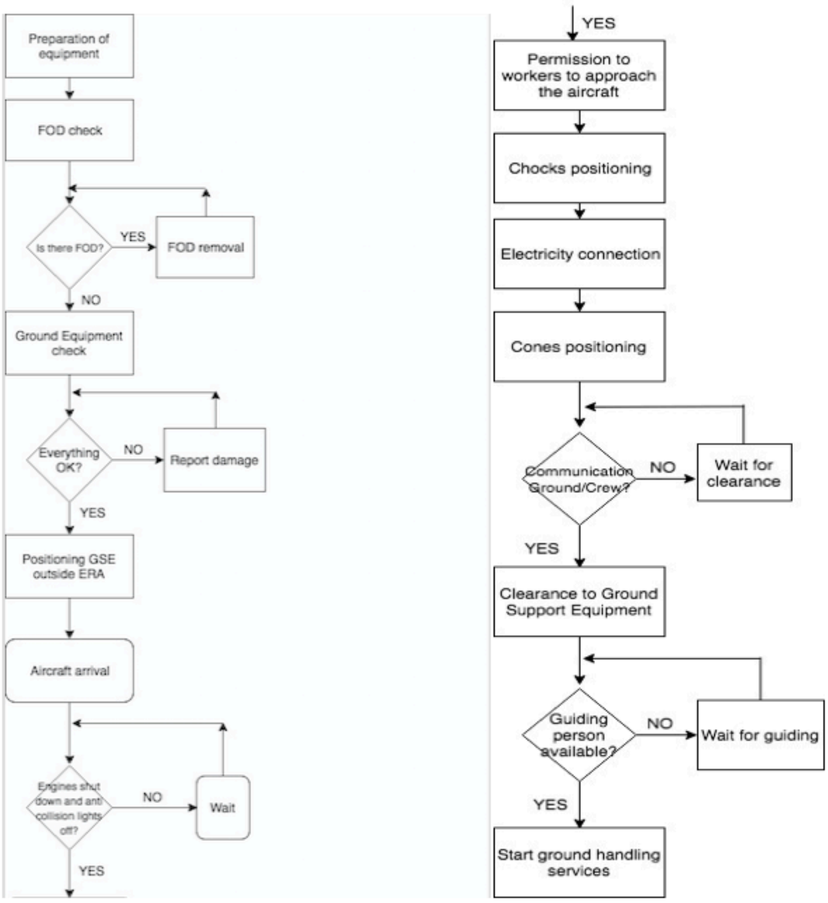
When talking about ground equipment, it is important to clarify that there exists some safety area to prevent any damage to the aircraft during taxiing. This is called Equipment Restraint Area (ERA) and it consists of a closed area on which the aircraft is parked during ground handling and which dimensions are determined by the largest type of the aircraft using the stand. It is defined by the Apron Safety Line, drawn in read on the ground. Vehicles, ground handling equipment and any other object are to keep clear of the ERA while the aircraft is parked. However, they need to be positioned right outside this red line for ready access to the aircraft after it stops.

Once the aircraft has parked and it is completely stopped with the engines and the anti-collision lights switched off, the ramp agent gives the signal to workers to approach the aircraft. Right after that, the next step is the positioning of the chocks. They consist on wooden or metal structures located in front of the wheels of the aircraft to prevent its motion from the ground. They can be short term or long term chocks. In the first type, chocks are placed in the nose gear wheel and the right main gear wheel. On the other hand, in the second type they are located in the nose gear wheel as well but also in both main gear wheels.

Once the chocks have been placed, electricity is then connected and cones must be used to create protective zones around some delicate aircraft areas such as engines or wings to prevent damage or collision by the ground service equipment. They are seen as a caution sign for drivers to maintain the safety requirements.

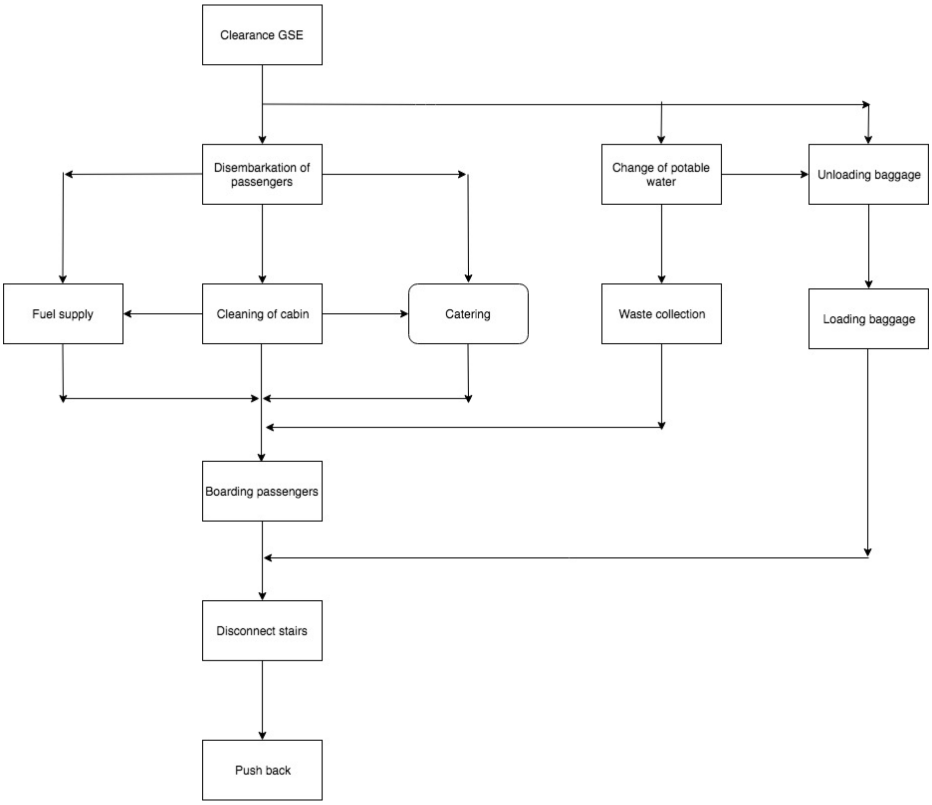
After the preparation of all the equipment prior to the arrival of the aircraft, chocks and cones positioning and electricity connection, Ground Support Equipment is clear to function. However, when moving the ground equipment to their corresponding part of the aircraft, a guide person should be located near the fuselage and should assist to the drivers. For the handling procedures, hand signals are used and it is important that the same person, who must be clearly identified, guides throughout the whole process and keeps a clear line of sight with the vehicle at all times to avoid confusion and mistakes. [3]

A more efficient and understandable way to visualize these procedures prior to technical handling services is to make a process mapping like the following:



Process map 1: Arrival of the aircraft

Once these procedures are known, it is now time to focus on the description of each process and the specific ground service vehicles along with their corresponding diagrams to make a further analysis of their risks and weaknesses. However, prior to this, it results helpful adding a diagram which represents which activities can be carried out simultaneously or what are the precedence restrictions.



Process map 2: Sequence of handling services

It is worth to be noted that not all of these activities are carried out during every aircraft handling. There should be a clearly stated agreement between the airline and the service provider on which services are to be done based on the airline requirements. Some tasks may or may not be done depending on aircraft status, next flight and infrastructure available at the airport.

In the following figure, all ground services provided to the aircraft can be seen along with the location of the corresponding vehicles used.

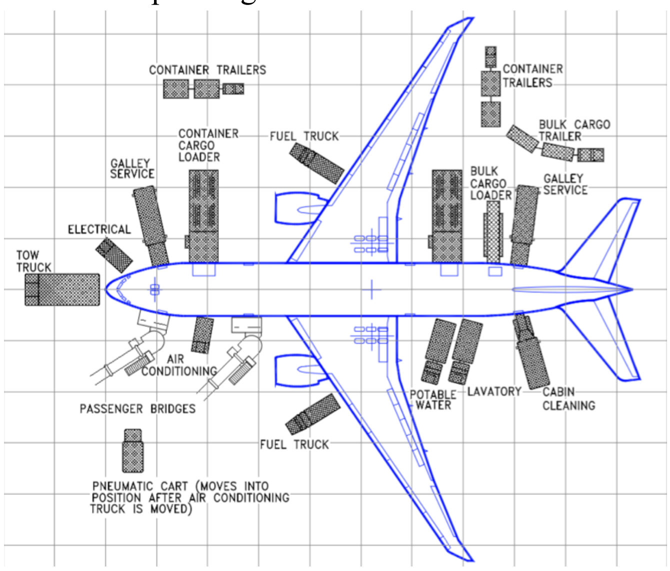


Figure 1: Ground handling services [4]

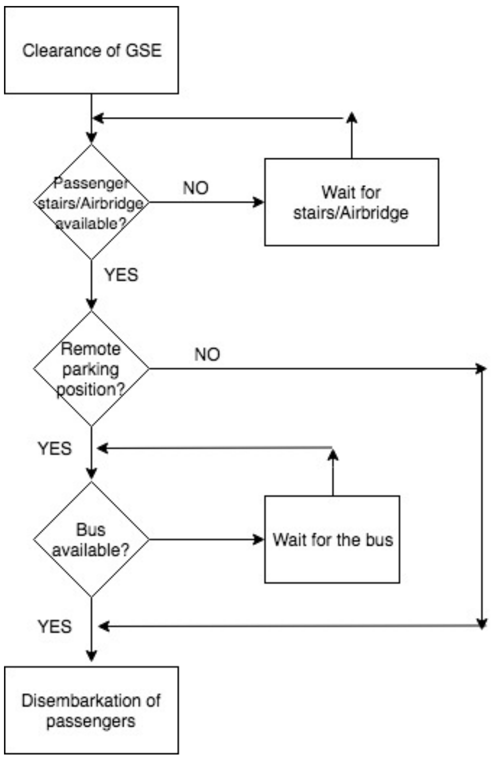
3.1 Process mapping

3.1.1 Disembarkation of passengers

Once all the previous processes at the arrival of the aircraft haven been correctly developed, the disembarkation of passengers begins. It can be done mainly in three ways: through buses in remote stands, through airbridges or by walking from the airplane to the terminal [3]. This last option is only performed in close parking stands to the terminal, typically by low cost airlines.

In the case that the aircraft is parked in a remote stand, buses have to be in the parking stand in order to wait for the flight on its arrival and start the procedure right away. In order to make an efficient and quick disembarkation, enough number of buses for passengers need to be available at such stand. The number of these buses depends on how the airlines would like to offer the service and, therefore, its up to them. Ground handling organization does not have any kind of responsibility in making this decision, but only to provide the number requested as agreed in the service level agreement and have them ready when necessary.

On the other hand, for the airbridge operations, an operator must go to the bridge control panel to position the airbridge following the safety and guiding instructions so that no damage is done to the aircraft. When using this equipment, a bridge operator has to be in the parking stand at least at the moment of the aircraft arrival, but it is advisable to arrive sooner.



Process map 3: Boarding/Disembarkation procedure

3.1.2 Loading and unloading of baggage and other cargo

The process of loading an aircraft needs to be done in such way that maximum allowable weights are not exceeded and the center of gravity remains suitable for the whole operation. It is of major importance for safety that the flight crew are aware of the remaining weight and center of gravity in order to set the aircraft parameters correctly. These includes the reference speed, slat/flap position and pitch trim or stabilizer position. The achievement of the hold compartment loading remains in the creation of a provisional Load Instruction Report (LIR), which is given to a supervisor to certify that loading has been performed correctly. [4]

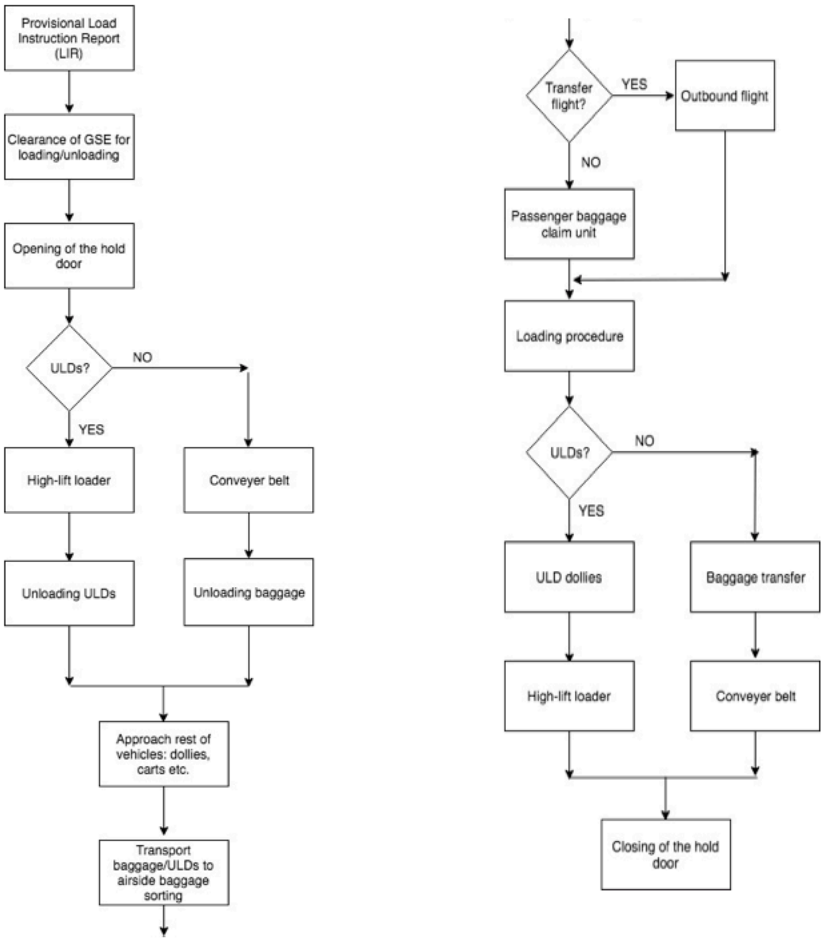
In the loading procedure [3], the first step is to load the forward hold and then the rear one, just the opposite from the unloading procedure. Transfer bags shall preferably be loaded in separate compartment. If this is not possible, at least they should be separated having transfer bags located for easy access. Both cargo holds contain a number of different latches to hold ULDs in position during flight.

Loading and unloading procedure is performed using various Ground Support Equipment. Once this equipment has received clearance to operate, normally baggage-handling vehicles, which are conveyer belts and high-lift loaders, are the first to approach to the aircraft. After these vehicles are in position, tug and carts, container dollies or other equipment carrying baggage, cargo and mail may approach.

On the one hand, conveyer belts are used to move baggage, freight and mail into and out of the aircraft holds. Once the vehicle is parked, the belt can be raised to a height just below the hold doorsill and should be kept on a certain distance away from the aircraft to prevent damage to the aircraft. However, some airlines permit the upper end of the belt to be located inside the hold but only when the belt is in contact use.

On the other hand, high-lift loaders are used to load or unload unit load devices (ULDs) and pallets on wide-body and some narrow-body aircraft. It is very important to align the loader with the aircraft to speed up the handling procedure. These devices should have safety rails on the left side of the forward platform but it should be down before approaching the aircraft. Once the high-lift loader is in position, this safety rail can be raised to start the procedure.

Once the two previous equipment are in position, the other vehicles may approach. In the case of tug and carts, they are used to tow movable stock such as carts, dollies, low profile trailers and some no motorized equipment. Furthermore, carts, which can also be called barrows, are used to move baggage, freight and mail around the airport but never to transport airport staff. This vehicle should be placed immediately behind the tow vehicle but tow vehicles must never tow more than six carts at one time. In addition, dollies and low-profile trailers are used to move unit load devices and pallets.



Process map 4: Baggage handling procedure

Once the ULDs and baggage have been unloaded, it is important to know if they need to go to outbound flights or to the baggage claim unit for the passengers to collect it.

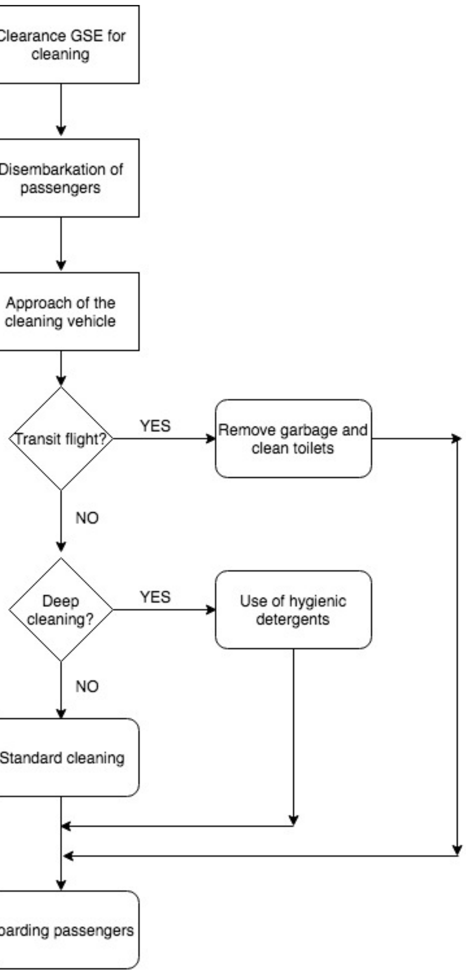
3.1.3 Cleaning service

3.1.3.1 General interior cleaning

Cleaning the interior of the aircraft is mainly to allow passengers to travel in comfortable and clean conditions and it duration is important because unless it is finished, passengers can not start the boarding procedure.

Cleaning service can differ depending on the type of the flight. It can be classified as transit cleaning, standard cleaning and deep cleaning.

In transit flights, cleaning is not a very exhaustive task and only consists on removing the garbage and cleaning toilets in no more than 5 to 10 minutes. However, standard cleaning of the aircraft includes more tasks such as: cleaning toilets, catering boards, removing garbage, vacuum cleaning, cleaning floors and seats, changing sickness bags and head covers, cleaning the windows etc. Finally, when talking about deep cleaning, it means that all the above mentioned services are done with hygienic detergents so it is much more demanding and time consuming task. [3]



Process map 5: Cleaning service procedure

3.1.3.2 Water servicing

The drinking water system stores, filters, heats and supplies potable water under pressure in galleys and toilets.

The equipment required to proceed with the potable water supply consists of a Water Service Unit. Firstly, the operation is performed by storing the water in a pressurized water tank with air from the pneumatic system. Inside this tank, there are levels that indicate its load and it has a safety valve for overpressure. The purpose of the pressurization of the water by means of air from the air conditioning system or even from its own compressor is to make the water available in the tap of the airplane.

Furthermore, the distribution process is made by means of rigid pipes of stainless steel which allow the water to arrive to galleys and bathrooms by connecting a hose to the aircraft through the mentioned Water Service Unit. This system is equipped with its own ultra violet water treatment system to eliminate almost entirely the living microorganisms from the water.

During ground operations, the system can be filled, pressurized or emptied. In order to carry on with filling the aircraft water tanks, there are some specifications that need to be taken into account. It is important that the filling process is done as close to the departure time of the aircraft as possible. Furthermore, prior to connecting the filling hose to the aircraft, the hose must be flushed. [3]

3.1.3.3 Toilet servicing

Usually, the toilet servicing procedure consists of three stages:

1. Draining of the waste tank of the aircraft into the waste tank of the Toilet Service Unit.

2. Flushing of the waste tank twice and then emptying again

3. Pre-charging with the right quantity of water and disinfectant

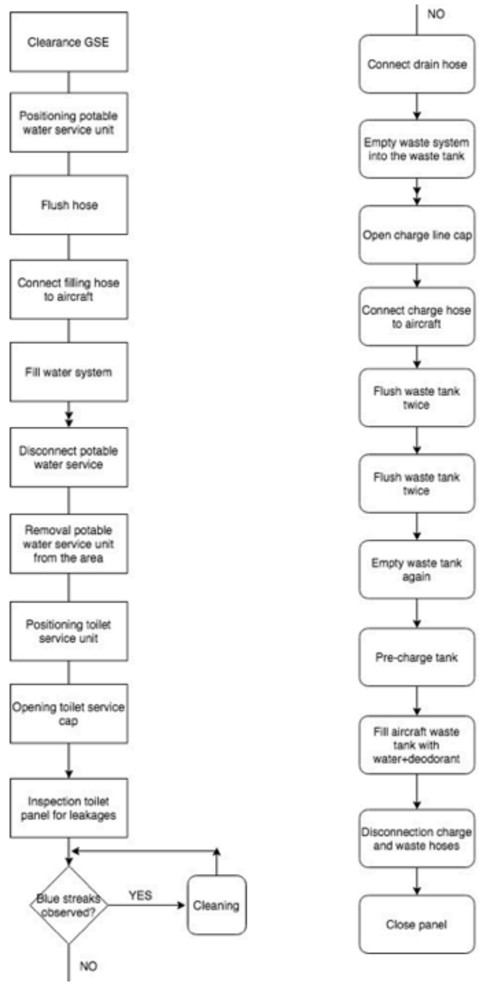
The equipment required to perform this service is the Lavatory Servicing Cart which consists of three or more separate tanks and a pressure pump. These tanks are the waste water tank, the flushing water tank and precharge chemical tank and they are used to accomplish the previous 3 main stages of the procedure.

Prior to toilet service operation, it is necessary to ensure that all attachments on the toilet truck, including the toilet basket, are correctly placed and restrained and valves are closed.

The toilet servicing procedure [3] starts by opening the toilet-servicing panel on the aircraft. Then, the toilet service cap must be opened to connect the waste-servicing hose to the waste connector in order to enable waste discharge until the waste tank is completely empty.

Once the emptying procedure has finished, the charge line cap must be opened so that the hose previously connected to the toilet truck can be connected to the charge line of the aircraft. This way flushing and pre-charging stage can be performed and once the toilets have been pre-charged with the correct amount of liquid the charge and waste hoses can be disconnected and the panel can be closed. It is very important to let the toilet flush port drain completely after flushing to avoid freezing during winter operation.

While activities related to the drinking water supply and lavatory servicing may initially seem insignificant, they can in fact have a real impact on flight safety, in particular because they involve the use of liquid and corrosive products, directly in contact with the aircraft fuselage. These liquids used in the toilets are corrosive and can cause damage to the structure of the aircraft. Even very small leaks must be reported immediately. As a consequence, most products are blue and can be easily detected. It is also important to remark that toilet service must be kept strictly apart from water servicing equipment and the same person who performed one task cannot perform the other one.



Process map 6: Water and toilet servicing procedure

3.1.3.4 De-icing procedure

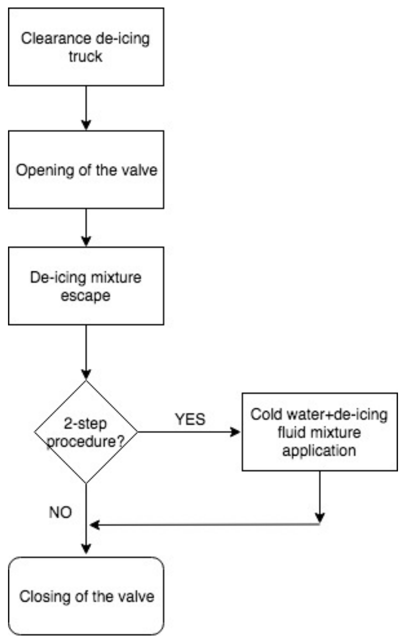
The formation of ice and snow on the wings and fuselage of the aircraft is extremely dangerous and its removal is crucial to prevent accidents. This is because the ice changes the shape of the wings and flaps, thus changing its aerodynamic properties which can make the aircraft uncontrollable.

One of the ways to treat this phenomenon in some parts of the engine is by using the remaining heat from the engine after shutdown. This way, the ice formed in the fan blades and the spinner can be melted.

However, when dealing with the ice and snow in other surfaces, the most effective way to remove it is by using de-icing fluid with a de-icing truck [3]. This vehicle is a truck that has a built-in tank with 5000 liters of water and glycol and a heating boiler.

Subsequently, the operator opens the valve, which allows the liquid to escape at the required pressure. Among this liquid, three types can be found: type I, used for the removal of ice, rime or snow, type II used for protection of surfaces after de-icing and type III which is similar to type II but with longer hold-over time. In addition, the de-icing procedure is divided into one or two steps. One step de-icing is done with de-ice fluid and the two step de-icing is done as follows:

- First, hot water or a mixture of hot water and de-icing fluid is used to de-ice the aircraft
- Secondly, before the mixture freezes, which happens approximately in 3 minutes, a mixture of cold water and de-icing fluid is applied to provide longer protection.

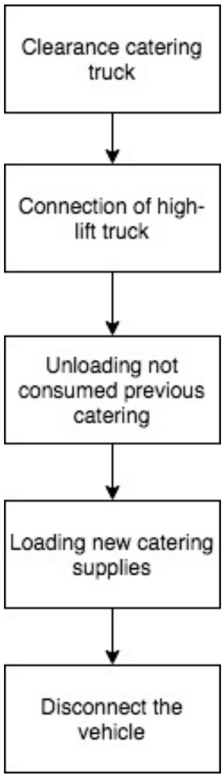


Process map 7: De-icing procedure

3.1.4 Catering

The handling agent in charge of the catering services are responsible for the unloading of food and beverages that were not consumed during the flight to give rise to the new load of food and drinks offered to the passengers as well as to the crew of the next flight. In addition to these services, the catering service also provides press, headphones and also the things that the company sells during the flight.

The equipment used for catering services are high-lift vehicles which usually transport also two members of the staff, the driver and the assistant. They normally consists of a lift truck powered by a hydraulic system, a front end equipped with a platform that accesses the aircraft and stabilizing jacks.



Process map 8: Catering procedure

3.1.5 Fuel supply

The fuel may be shipped directly to an airport storage facility but it is very common that the distribution chain includes one or more intermediate storage terminals. Quality checks must be carried out at every point in the distribution chain to guard against contamination.

Tests are conducted at the time fuel is received into the airport storage in order to confirm the identity of the fuel and check for water and particulate contamination. This process also includes filtering of the fuel when going into storage tanks at the airport and also before being delivered to the aircraft.

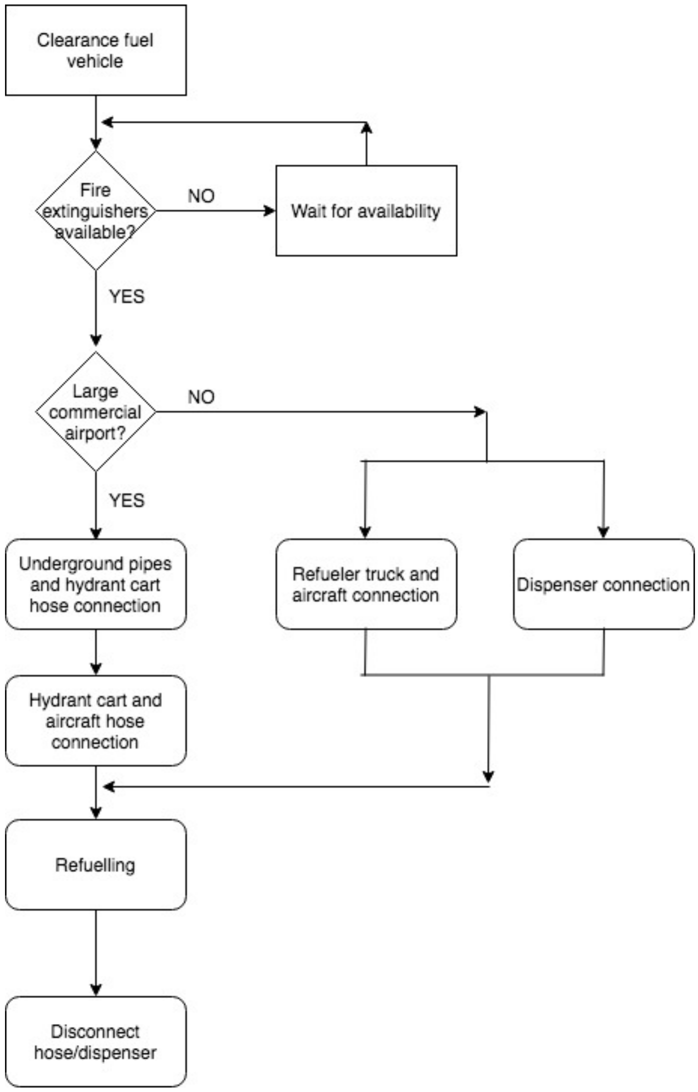
Once the fuel is in the airport´s storage tanks, three ways can be found to deliver it to the aircraft: hydrant system, fuelling truck or a dispenser. [5]

The hydrant system is used to fuel jet aircraft at the largest commercial airports. It consists of a network of underground pipes which connects the storage tanks to each aircraft stand and a hydrant unit. This unit, which can be either a truck or a cart, is equipped with filtration and volume metering equipment. Hose connections are made between the hydrant and the unit, and between the unit and the aircraft. Hydrant trucks are usually equipped with filter or water-absorbing media to provide a final barrier to particulate and water contamination before the fuel enters the aircraft´s tanks.

The fuelling truck and dispenser methods are used at smaller airports. They both have pumping, filtration and volume metering equipment. The first method uses fuelling truck which carries the fuel to the aircraft. On the other hand, a dispenser is a pump placed at a fixed location design specifically to fuelling the aircraft.

When refueling is in process, there is a very important consideration that the handling agent must take into account. All staff working in this process is required to have a good knowledge and be familiar with fire fighting and fire brigade procedures. Right after the fueling vehicle is in position, fire extinguishers must be available in case some safety event occur. It is also important to pay attention to fuel spillage.

It is also important to mention that refueling procedure could be done with passengers on board [3]. When this is the case, it is mandatory to keep designated escape exists, such as bridge into the terminal building, cabin door or passenger stair truck position on an open cabin door clear. Moreover, it must be ensured that all areas below designated escape exists are free of any equipment and vehicles which could be an obstacle to the deployment of escape slides.



Process map 9: Fuel supply procedure

3.1.6 Power supply

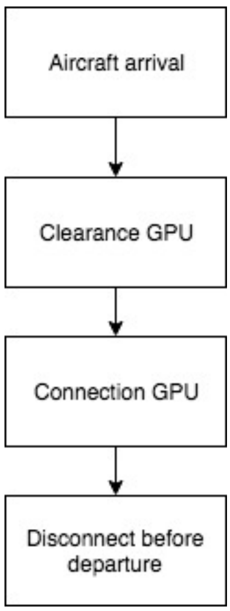
The aircraft requires electrical power for internal and external lighting, operation of the on-board systems, extension of its own stairs and ventilation of the cabin and electronic equipment.

The electrical power supplied is AC three phase current of 120/208V and 400 Hz of frequency. Airplanes work with this frequency to reduce their weight and the size of the electrical components.

There exist different means of power supply: by equipment incorporated in the aircraft called Auxiliary Power Unit (APU), by means of mobile equipment, which can be self-propelled or towed, called Ground Power Unit (GPU) or through fixed power outlet in the parking stand.

The APU is a system that provides energy to the aircraft and allows an aircraft to operate autonomously without reliance on ground service equipment. Therefore, the APU enables the supply by itself of the electrical and pneumatic systems of the aircraft. Excessive use of the Auxiliary Power Unit is increasingly being avoided on both environmental and noise grounds. Many airports ban its unnecessary use for noise abatement reasons and encourage airlines to use Ground Power Units.

GPUs provide DC and AC power to keep the aircraft powered up while it is on the ground and the engines are switched off. It is one of the first things of the process of ground handling and it should be connected until the aircraft is ready for departure.



Process map 10: Power supply procedure

3.1.7 Push-back procedure

Ground time of aircraft is ended by removing the chocks, which is called chock off time. Chocks can only be removed when the pushback is connected to the aircraft, and following the removal of chocks, pushback starts.

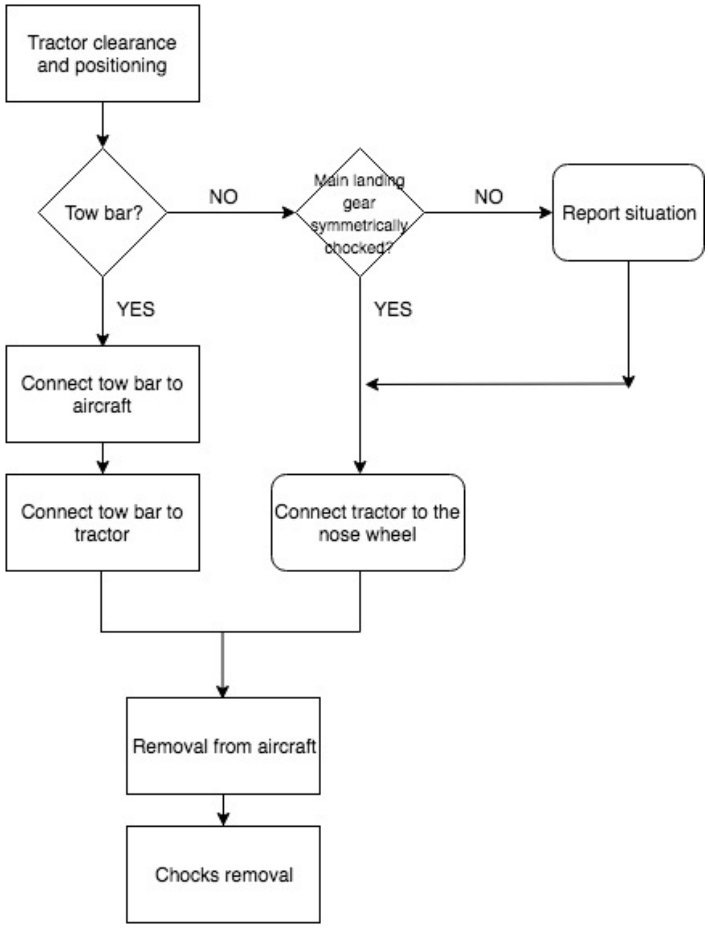
The push-back is the procedure by which the aircraft is towed from the aircraft stand to the push-back position on the taxiway so that it can start the engine and taxi to the runway for take-off, as well as any other movement that the plane must make through the airport. It is necessary in maneuvers in which the aircraft is not autonomous, especially at the exit of the parking lot.

Two types of tows can be found:

- Tow bar→connects the tug to the nose landing gear. It must be approved for use with a particular type of aircraft and clearly marked as such, since there is no universal tow bar specification.
- Tow bar-less→ The tractor locks the front wheel and lift it. When the bar is connected it is necessary to deactivate the steering system of the nose wheel. The maneuver of the tractor ends at the moment when the aircraft can move with its own engines. The tractors are of low height and different powers and weights.

Obstacles in the apron may go unnoticed by pilots during the pushback so operation staff have the responsibility of seeing around to avoid such obstacles. Before starting the push-back operation, a standard inspection around the area must be performed to make sure there are no obstacles.

In order to perform this operation correctly, in addition to the worker in charge of driving the tractor, another person, commonly ramp agent, is needed to establish communication with the pilot.



Process map 11: Push-back procedure

4. Technology development

4.1 Latest technology analysis

Airspace sector is constantly evolving with new aircraft systems and technology. This leads to the introduction of more and more planes into operation, resulting in one of the most prominent problems, the congestion at the airports.

The most common solution to this problem is the expansion of the airfield with the introduction of the new apron, runways and taxiways. However, this fact will increase the complexity of air terminals that will reduce the efficiency of the system. According to IATA [1], it is expected an 80% growth in the area of ground handling in the next decade. The demands of ground operators, therefore, change drastically as airports get overcrowded, while the Ground Support Equipment available in the platforms for them is stuck in the past.

As a consequence, there is an increment on the risk of human error which can result in hazardous situations that can cost lots of money to the companies. The major institutions are already working to address the problem through the introduction of innovations and measures aimed at providing the efficiency of ramp services. [8]

In older planes, damages of the fuselage are basically punctures on the fuselage, which must be repaired following strict specifications. In newer planes made from composite materials, special equipment must be brought to the airplane to test for potential and non- visible damage to the composite structure. As damages caused by GSE may not be visible from the outside, the safety responsibility may shift from pilots to Ground Handling Staff to ensure any incident is reported. Both cases lead to high costs for the airline as the aircraft must be out of service for a considerable period of time.

4.1.1 Baggage handling

On a daily basis, at all airports around the world, large pieces of equipment approach the aircraft for servicing. In the case of baggage handling, a wide scope of ground service equipment is used to load and unload baggage to and from the aircraft. If the loader operator does the task correctly, it is just the regular situation. However, if they collide with the airplane fuselage, operations can be stopped, delaying takeoff times, having a great impact in costs for the airline and frustrating passengers.

When observing, in practice, the ground handling processes, one of the remarkable weaknesses was regarding this issue, but not only with the baggage procedure but with many others such as airbridges, toilet servicing, fuel supply, catering etc. The main objective, therefore, is to make sure the equipment never makes forceful contact with the aircraft in service. In the current practices, the reliability is put in the human perception but this is far from being accurate.

Over the years, almost every aspect of the flight has been automated, making every part of it more efficient, smoother, safer and more reliable, not to mention cost effective. However, much more is to be done in the field of baggage handling. Suitcases are still sometimes handled like in the old days, one by one, piece by piece. Apart from the fact that pulled baggage handling is the most common source of flight delays, around 22 million bags are missing annually. Last year, lost, damaged and mishandled bags cost the airlines in the aviation industry a loan of more than 3 billion dollars and tenths of thousands of occupational injuries from lifting and turning were reported and compensated.

To ensure the safety and accomplish the main goal, it is necessary to start relying in sensors which could prevent the drivers of the aircraft support vehicles from colliding with parked aircraft. The system should use detection and navigation methods as well as analysis software, which together alert drivers of the proximity to the aircraft.

The question now rises on whether implementing fully or nearly fully autonomous vehicles or partially autonomous, which means that technology is used to help the operator and increase safety, but there is still human work required.

4.1.1.1 BBHS system

BBHS (Bulk Baggage Handling Service) has developed and efficient system which has reduced human labor by approximately 95% and consists in linking baggage handling systems with conveyor belts which load and unload baggage into and from the aircraft. [9]

The weak spots are eliminated by using this system, not by replacing existing distance with robots but by smart thinking and a little help from gravity. In BBHS 95% automated baggage handling system, baggage is now handled in one sequential chain from departure to arrival. No shoulders and bags are injured and bags are handled gently. With automated handling control, the baggage is now handled in batches and prioritized according to airline requirements to save time and reduce the size of the fleet of carts on the ramp. Precisely, 1 BBHS cart corresponds to 8 traditional carts. Carts destined for departure are loaded efficiently and in order and upon arrival, baggage is delivered in less than 10 seconds per cart to the arrival belt.

When ready for departure, the baggage is transferred to BBHS make up station, by previously passing through the check-in desk and x-ray scanner. At the make up station, the baggage enters the orienteer unit (1), which ensures that all baggage is perfectly aligned for the onward journey, classified for the most optimal positioning based on the shape and size. This bag-orienter is able to handle approximately 1200 pieces of baggage per hour. Each piece is, then, moved by the mini loader (2) to the level and shelved in the sorting consolidation unit (3), which matches its priority. Baggage is stored until it is consolidated with four other pieces with the same definitions. From the sorting unit, a batch movement made by the BBHS batch mover (4) quickly moves full batches of baggage to the departure consolidation units (5) ready for transfer to the BBHS baggage carts (6). The carts receive the baggage all at once in less than 10 seconds enabling a speedy and safe onward journey to the airplane. They are coupled in pairs, with a total capacity of 60 bags, 30 bags per BBHS cart. Upon arrival, the baggage is unloaded into the carts and quickly makes its way to the BBHS arrival station. The high speed gates open and the carts are automatically emptied all at once. According to priority, the baggage is then moved to the vertical unit, which ensures that the suitcases are gently delivered to the arrival conveyor system.

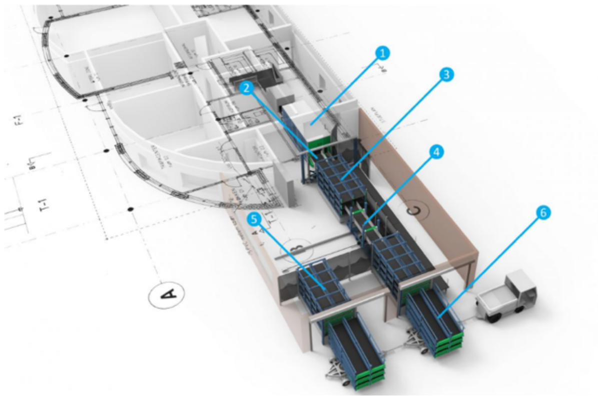


Figure 2: Structure of the BBHS system

In brief, the process is constituted by a chain of BBHS components which work in synchrony to perfectly match between them and obtain the highest performance possible. It is divided into three subsystems. The main one is an innovative baggage cart and it uses Mobile Gravity Feed technology for getting the baggage into the cart and out. The cart is capable of turning around its own axis, which makes it more accessible to loading and unloading procedures. The other parts of the system are departure and arrival consolidation units. On the one hand, the departure unit ensures all the baggage is sorted according to airline specifications and is ready to load and unload the carts. On the other hand, the arrival unit receives baggage from the cart and dispatches it forward to the arrival belt.

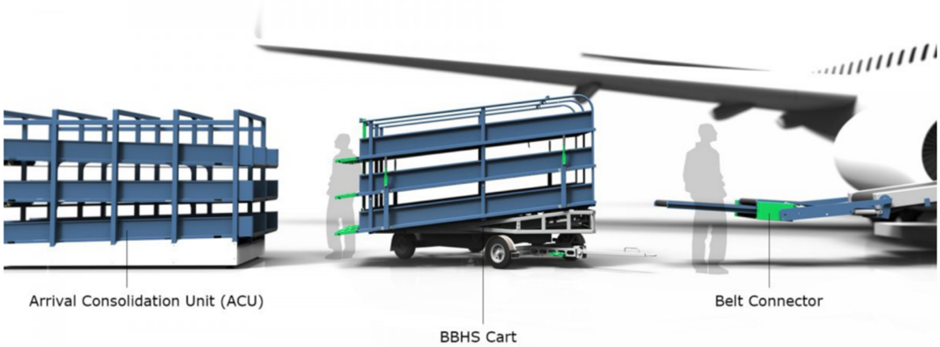


Figure 3: Connection of the BBHS system to the aircraft

In conclusion, what is obtained from BBHS:

- Manual lifting is eliminated since baggage is flashed automatically to and from trollies and belts
- Baggage is handled efficiently, reducing time from bag drop-off to delivery at destination
- Time savings: the automation and optimized flow saves time
- Full traceability: the batching of baggage ensures that it can be traced from drop-off to delivery
- Baggage cart utilization: reduces cart fleet requirements to one fifth
- Gentle handling: the BBHS system prevents rough and abrasive manual lifts and loading
- Aggressive payback: the solution offers a pack back period of only 3 years
- Insurance premiums: the reduction of manual lifts leads to fewer work injuries and insurance claims
- Square meter utilization: the batch approach reduces space requirements to baggage halls

The BBHS system has already been introduced at Billund Airport providing the airport with the Danish Work Environment Award in 2016. In addition, Vojens Airport in southern Denmark has also focused its attention in this system and it is in the process of implementing it as a test and showroom facility while intense negotiations with other airports are already taking place.

4.1.1.2 ASD system

Aircraft Safety Docking (ASD) system is not only a system but a combination of an operational process and an electronic control supervising. This system will limit the risk of damage by the collision between the GSE and the aircraft by supervising the operator during ground services. Other important goal of the system is to ensure that no aircraft should depart with unreported collision. [12]

It prevents a high-speed approach to the aircraft, thus avoiding a great impact on the fuselage. For this, 3 different areas have been established to control the speed. Outside the ERA, all ground support equipment can be driven up to 25 km/h without supervision. However, while approaching the aircraft by entering the safety area, the ground handling operator will start the ASD system by pressing a button, thus reducing the velocity. From this point on the proximity sensor is activated. This sensor consists on a 3D infrared cameras installed in the equipment itself that has the function of detecting any obstacle in front of the GSE up to 7 meters.

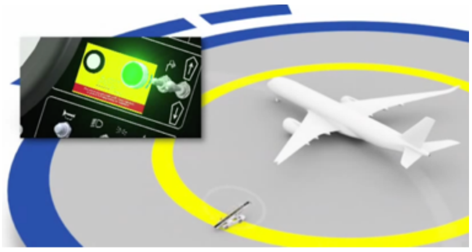


Figure 4: Activation ASD system

The operation limits the speed of the vehicle to 5 km/h at the beginning of the process and it will be indicated by a flashing beacon to let the ramp operators know that the safety mode is activated. As soon as an obstacle is detected by the system, it will force the operator to reduce the speed to 0,7 km/h through a light or a buzzer. If the driver does not react immediately, the system will stop the vehicle automatically. The operator will, then, approach the aircraft with the required speed of 0,7 km/h in a perfectly safe condition and finish the docking process. Even in the case of contact, the kinetic energy created by the GSE can hardly cause any significant damage to the aircraft at this speed.

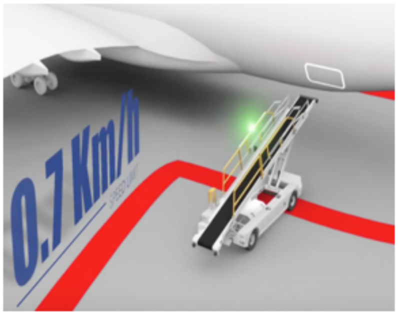


Figure 5: Last ASD approach to the aircraft

The ASD system also includes a collision recorder, similar to a black box. This recorder will measure the impact strength and, in case of impact, stop the unit. The vehicle will be stopped until the responsible manager unlocks the vehicle with a designated key after the fuselage inspection.

The driver, in this case, is still in charge and has the responsibility of performing the operation correctly. Initially, the ASD system is not leading but just supervising the operators´ work and behavior. It only acts when the operator does not respond properly in time to the indications of the system. This has its benefits as the driver is much less exposed to possible technology failure by not relying on a fully automated system. In case of failure of the system, the GSE remains just as safe as in the current situation, so there are no steps backwards.

Other advantage is that the ASD system relies only in a 3D camera rather than a combination of multiple sensors or radars. These are more sensitive to meteorological conditions and the interferences that may come with them. Furthermore, the more amount of sensors, the higher the probability of technical failure. This will create a significant risk as operators can hardly notice the difference between a sensor that is not detecting any object and a non-working sensor. In the case of the camera, if any setback arises, the camera itself detects the problem and automatically positions in the safety mode by lowering the speed of the vehicle.

Finally, one of the most important points to take into account is that the ASD system can be installed, not only in new GSE, but also on operating equipment, with the exception of equipment mounted on commercial chassis.

4.1.2 Intellidock automatic airbridge

Regarding boarding and disembarkation procedure, it is also considered as one of the most critical services for the possible collision with the airplane. In the case of using a Passenger Boarding Bridge, it must be operated by a well-trained employee, which is not that easy to find. It may happen that the trained crewman is not available at that specific time, so this results in delays and therefore, costs for the airline in labor and fuel and discontent passengers.

This operation is really susceptible to human error which can lead to damages in the aircraft fuselage. Due to the limited visibility from the cabin, the airbridge can be unconsciously driven into the structure of the aircraft, so a clear line of sight with the aircraft door is necessary for sake docking of the bridge. Sometimes, adverse weather conditions can obstruct the operator´s view so it becomes even more difficult to have a clear line of sight.

There exists a real need for a passenger boarding bridge that is efficient, reliable regardless the bad weather conditions and does not require human labor susceptible to errors.

There have been some attempts for improving this situation. However, one of the most advanced technology in this topic is the automated airbridge docking system. Intellidock system is a fully automated passenger boarding bridge docking solution. It has a sensor module which is fitted to a passenger boarding bridge connected to a remote intelligent PLC system.

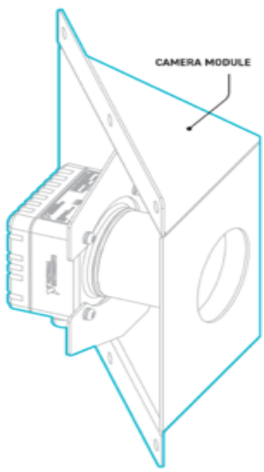


Figure 6: Sensor module automated airbridge

The system is always ready waiting for an approaching aircraft, and as soon as the airplane arrives, it earns the aircraft type and expected location and confirms it visually. It then automatically initiates movement and drives the passenger boarding bridge into its launch position about two meters from the aircraft door. From that point, the sensors work to determine the precise position of the aircraft duel before locking on to it. The passenger boarding bridge is moved towards the aircraft door making constant adjustments in height, lateral movement and rotation to ensure a perfect docking alignment with the door.

Traditional controls can be removed from the passenger boarding bridge, freeing up space for passengers and flight crew. Turnaround times are improved by using Intellidock system with no waiting for crew to take the controls.

Any number of these systems throughout an airport can be monitored remotely by a single centralized control disk. This allows the operator to manually confirm each docking sequence and even override the controls at any stage.

The system does not rely on any guidance systems to operate and reduces the risk of damage to aircraft and apron equipment. It can also be fitted to any existing passenger boarding bridge and all aircraft currently operating.

It has already been installed into one gate of the Wellington Airport in New Zeeland, which is the first airport in the world using this technology. It has been working successfully and it is part of their daily operations. The success is such that the airport is planning on implementing these automated bridges in more gates.

4.1.3 Push-back innovations

4.1.3.1 Aircraft Towing system (ATS)

The push-back process is one of the most important ones. It is exposed to a high probability of human error since several operators are required to carry the towing process out. With the growing expansion of airports and the forecast of more aircrafts in service, the problem of taxiing is aggravated. This leads to greater fuel consumption and a greater number of emissions into the atmosphere. Economic and environmental pressures have prompted the development of new technologies to optimize this process.

One of the most innovative developments is the use of autonomous towing vehicles [13]. By autonomous, it is meant a towing vehicle that will autonomously navigate to a determined aircraft, attach itself, move it to the runway for departures and to the gate for arrivals. Then, the vehicle autonomously detach itself from the aircraft and navigate to its determined position, either its parking area or to service another aircraft.

There is an outstanding system called Aircraft Towing System (ATS) that will maneuver these automated vehicles using underground track mechanisms to perform the movement. As a general idea, once the aircraft has landed, the pilot moves it to the taxiway where the ATS system is installed ready to be used. Later on, the aircraft moves into the ATS pull cart, where it is attached and secured and finally, the engines are shut down saving fuel and reducing emissions. [10]

The system uses a special rail system constructed underneath the taxiway with channels that power, by electrical motors, all the system for the purpose of the aircraft transport. The pull cart has the function of moving each aircraft to the corresponding gate along the channel.

When the process is the opposite, that is from the gate to the runway, the ATS pulls the aircraft along the taxiway until it reaches the runway. Lastly, the pilot starts the engines, detaches from the pull cart and positions the aircraft for take off.

The entire system is 100% automated and it is integrated into the ground control system, ran by the ground control tower personnel. The system maximizes safety by optimizing the traffic in the taxiways of the airport, reducing the number of operators participating in the process and also the ground support equipment around the aircraft and controlling all the movements of the airplane during the operations.

Entering in more detail in the different parts of the ATS system, it can be said that it comprises the taxiway channel, pull cars and software.

On the one hand, the taxiway channel consists of different blocks built into the airport taxiway, more or less 80 cm deep and 120 cm wide. The channel is covered by stainless steel doors by using a brush system used to close the gap between the different doors. These channels are designed with a drainage and heating system to keep the system working even when the weather conditions are adverse.

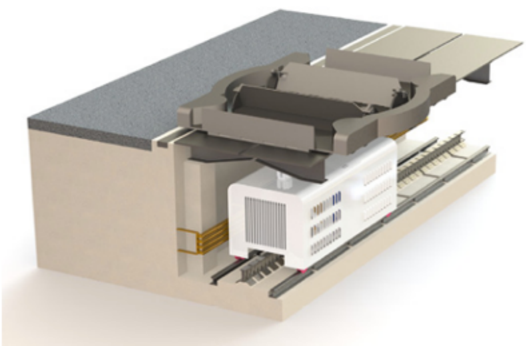


Figure 7: Channel structure

Regarding the channel installation, they are built, firstly, in close site to the airport prior to the installation in the airport itself. The first step is to cut the channel into the taxiway by a concrete cutting vehicle and then build the foundation. Once this is done, the channel module is ready to be put in the corresponding place and secured. As the installation is done section by section, once one is finished, the taxiway can be used for normal airport operations until the entire system is installed.

Furthermore, the pull car has the objective of transporting the aircraft from the runway to the airport gate and the other way around. This autonomous vehicle gets around the taxi channel, moving the aircraft in a safe way. As it has been previously stated, the car system, including its connection with the nose wheel of the aircraft, is fully automated. Once the aircraft is attached to the pull car, no further action from the pilot is required, but the pilot can disconnect from the vehicle at all times if an emergency happens.

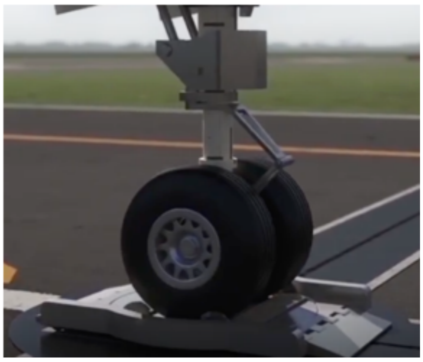


Figure 8: Pull car connection

Just like the channels, the pull cars are built outside the airport, at a permanent manufacturing facility and then delivered and placed into the channel sections as they are being installed.

Figure 9: Representation ATS system

Finally, once the physical installation of the system is completed, it is time for the software integration to be planned in the project in order to minimize the disruptions to the airport operations. It can be said that the system is equipped with a fully integrated software that eliminates, mostly, the human error. All the possible movements from different aircrafts are totally coordinated from the taxiway to the gate and back to the runway.

The ATS Worldwide will partner with the airport to determine the optimal taxiway layout of the system and upload the software suite for ground traffic controllers to operate the entire system. For operating the system, an array of training options is offered to the personnel at the airport which include a customized simulated system, onsite ATS expertise and classroom training.

To sum up, from this innovative system, many benefits can be extracted:

- Optimization of the traffic in the taxi-lanes by stacking aircrafts closer together as the engines are shut off during the aircraft movement. This way, the system enables an airport to service more aircrafts simultaneously.
- Reduction of the transport time of aircraft between the runway and airport gates by approximately 30%, thus increasing the capacity of the airports. Normally, by using the traditional way, the push-back procedure is done in an average of 4 minutes, which are to be avoided when using the ATS system. It immediately starts moving the aircraft throughout the channel and does not need to stop until the aircraft reaches the runway.
- Removal of collisions among ground support equipment: the pull cars are equipped with a radar that analyzes all possible collision areas. In case of emergency, the vehicle will automatically stop and report the situation to the pilot, traffic control and other aircraft, adjusting their movements accordingly.
- Reduction of ground equipment and operators in and around aircraft operations to overcome the initial costs of the construction of the system.
- Reduction of fuel emissions: the engines are powered off while taxiing to the runway or to the gate, which results in less impact in the environment.

It may seem that this system is not suitable to implement in the airports due to its installation in the different airports. However, the company will collaborate with each airport interested in order to design a proper layout for the ATS system to maximize the airport capacity and the aircraft movement flow.

The installation is thought to be done by using a modular strategy for minimizing airport downtime. The channels in the taxiways are designed to be built in 8-hour increments, installing 250 meters in each one of them, and allowing the taxiways and gates to get back to normal operations in between increments. Other solution that has been stablished is that disruptions to airport operations are even more minimized by working in the installation of the taxi channels at night.

However, it is also important to talk about some set backs. The main disadvantage is the installation cost of the ATS system. It will require initial investment and maintenance operating costs. To be precise, 1 meter of the installation costs approximately 3121 $ and one pull car 78026 $, so it is a great amount of money to cover the entire airport.

One option to recuperate the initial investment is to charge usage fees to airlines, which are less than the cost of the fuel burned using the traditional push-back service.

Regarding operations and maintenance, more or less 10 workers are required to operate the whole system and an additional 10 employees to maintenance duties. They are responsible for maintaining the system in air traffic control tower, monitoring software and hardware functionality, maintaining the necessary equipment, that is the channel and pull cars and also detaching the aircraft from the pull car whenever is required. It is a big number of employees, but still less than the required in the traditional service.

4.1.3.2 Electric push-back vehicle

The previous system is really expensive to integrate and the infrastructure of the airports need to be modified in order to use it. In order to make it simpler, when focusing only on the push-back process, without taking into account the taxiing movement to or from the runway, one possible solution could be the introduction of an electric robot. There already exist a couple of versions of a remote-controlled device developed by a company named Mototok [11], which are the so-called Spacer 8600 that is able to push up to 90 tons and a larger version called Spacer 195 that can handle up to 195 tons.

Figure 10: Electric push-back vehicle

Safety is the main priority in ground handling. In order to prevent damages on the nose gear while attaching the vehicle with the aircraft, it has been developed the Intelligent Oversteering Protection System (I-OPS). It is composed by numerous sensors that measure the forces and torques on the nose gear. Once the torque reaches a certain stablished limit, the counter steer algorithm automatically starts, so damages are nearly impossible to happen.

Among the benefits of the electric vehicle, the following can be stated:

- Very low maintenance costs: the electric drive has the characteristic of having less moving components so all important electrical and hydraulic components are located into the same compartment, making the maintenance procedure simpler.
- No fuel costs and consumption as there is no waiting time for a traditional truck to arrive.
- 100% Green energy: less emissions of carbon dioxide to the atmosphere as it is fully electric.
- Savings on staff and personal costs: normally, in the traditional push-back procedure, two operators are required: a wing-walker in contact with the pilot and a specialized pushback operator riding the vehicle. With this new vehicle, only one person is needed to maneuver the aircraft standing far away from the engines thanks to the wireless remote control. This operator is always connected to the pilot via the headset.
- Convenient, quick and easy: the attachment process to the nose gear will start automatically by pressing a button on the remote controller. It will take no more than 15 seconds.
- No driving license required: only a training of 2-3 hours is enough for a crew member to be able to push back the aircraft.
- Short recharging time: batteries are fully charged within only 3 hours so after its use, it can be placed in the recharging station to be ready for the next aircraft.
- Great amount of pushbacks with only one Battery Charge: 30-50 pushbacks can be carried out.
- Compact design: the reduced dimensions allow the vehicle can be parked anywhere in the stand without disturbing the rest of the processes of the ground handling.
- No change in the pushback procedure from the view of the pilot.
- Elimination of delays as the tug and the driver are always available.
- Complete and circumferential view of the entire aircraft by the operator in the entire process.

Figure 11: Remote control procedure

4.1.4 Other services

Nowadays, aviation industry has been facing a rigid design and arrangement of the platform area at airports, where an optimal use of the ground support equipment can not be achieved. It actually consists on a clutter of hoses, cables and vehicles acting around the parked aircraft that consequently cover most of the apron around the aircraft. The traditional way of thinking restricts the improvement of vital systems of supply for the aircraft, so they often remain unchanged for decades.

However, with the advances in airport technology and with the constant growth of aircraft dimensions, it is required to use flexible systems. For example, with the entry into operation of new aircraft such as the Airbus A380, some of the current supply systems can no longer perform their work, so the equipment and procedures in use must adapt to overcome this challenge.

In the case of Airbus A380, traditional supply systems would need to be duplicated, which would consequently create more problems in terms of space, cost and efficiency. In order to supply fuel, electric power, water and air conditioning to the aircraft on the ground, huge tankers, heavy diesel generators and cables and hoses covering the whole platform are commonly used.

4.1.4.1 Underground system

As a solution to this saturation in platforms, there has been made plenty of developments along these years. One of the most outstanding innovations is the revolutionary underground system [14], which provides utility services to aircraft using retractable equipment on the platforms. After providing the service, this pop-up equipment is retracted, completely hiding when it is at the level of the platform, so that it remains clear of obstacles for the free circulation of aircraft. By using this technology, all essential ground support equipment is available very close to the aircraft, providing not only operational efficiency but also the possibility of significantly reduce the carbon footprint. There already exist retracting pits which can be configured at the will of the customer, to provide different services needed.

Figure 12: Retracting pit

Other variant to address the problem of overcrowded platform with vehicles is the use of hatch pits. It is very similar to the pop-up pit but the opening is simpler, with only a single touch. All the required ground cables will be, then, available so that the aircraft can be connected to the services as soon as possible.

Figure 13: Hatch pit

The main services that this system can provide are the following:

- Collection of waste water
- Clean water service
- Electric power, 28 Volts of direct current at 400 Hz
- Fuel supply
- Other auxiliary services

There also exists the possibility of installing a complete tunnel system allowing easy access and maintenance to all installations.

Figure 14: Tunnel system distribution

On the one hand, the sewage collection service and the supply of clean water is offered by hoses wounded in drums located in the retractable units. When fully extended, the drums are released allowing their connection to the hoses of the aircraft.

In addition, the electrical energy (28V/400Hz) is supplied by flexible cables and connectors. Each cable is equipped with a connector to the aircraft, which is, at the same time, composed by pushbuttons for switching the power supply on and off after the connection to the aircraft has been made. If it has been done correctly, then a LED with the inscription “Pilot Contact” is displayed. Among the other auxiliary services include, for example, pressurized air, electric power, electrical ground and cables for communications and information transfer.

The fuelling offering includes design capabilities for a complete fuel farm. The refueling system include components such as loading arms, tank farm systems, floating suction arms and truck loading systems which enables the safe transport of the fuel to the aircraft.

Some of the main benefits of the tunnel system with retractable or hatched intakes are the following:

- Reduction of the risks of accidents: once the system has finished supplying the aircraft, it is lowered back into the ground so collisions with ground support vehicles or to the aircraft are to be avoided.
- The life of the equipment is considerably longer than that of the mobile vehicles.
- Maintenance costs of the tunnel system are much lower than those associated with maintaining a fleet of vehicles that provides the service.
- Smaller number of personnel required in the operations.
- Easy access to all utilities at a reasonable working height of the pop-up pits.
- Ready to use immediately the equipment has been raised or opened, thus resulting in time savings.
- Safe and easy opening, closing and raising through an adjustable counterweight mechanism.
- The pollution around the airport is drastically reduced, since none of the equipment installed in the tunnel system uses diesel engines.
- The system can service any type of aircraft regardless of its dimensions.

The technological solution through a tunnel system has been quite successful at the Dortmund International Airport in Germany. In this place, the underground tunnel in the platform area has a length of 40 meters, a depth of 2,5 meters and a width of 3 meters.

The frequency converter at 400 Hz is located inside the tunnel, together with the air conditioning modules. There are up to four electric power cables at 400 Hz and 28 Volts mounted in each well. They are connected, on the one hand, to the frequency converter and, on the other hand, to connectors for coupling to the aircraft.

The clean water service reaches the tunnel through a pipe system which ends in a hose on the back of the mounting plate of the retractable unit to supply water to the aircraft. Another part of the system consists of a suction hose to remove the waste water from the aircraft toilets, which is housed in a drum.

5. Safety analysis

In the field of commercial aviation, damage caused during the ground handling has severe economic consequences for all organizations involved. A new set of technological solutions also trigger new potential and inherent hazards and risks. For this reason, it is highly important to analyze the possible safety hazards that come with the implementation of the new technology exposed in the previous chapter.

Due to the insufficient data on the costs and implementation methods of the described innovations, as most of them have not been implemented yet, a basic safety assessment will be done instead focusing mainly on the hazard analysis and impacts in the existing operations.

Regarding the safety assessment, there exist several methodologies on how to perform it accurately. Organizations like Eurocontrol have published their own risk assessment methodologies, which in this case is called SAM. This tool consists basically in identifying the possible hazard, assessing the severity of the risk and making the necessary changes on the system to prevent it. This is achieved by using FHA and PSSA analysis. [15]

On the one hand, the purpose of the Functional Hazard Analysis (FHA) is oriented towards the consequences and corresponding severities of the possible failures. It identifies the functional safety hazards through the evaluation of the functions of the different systems. For each potential hazard, the risk is evaluated as a combination of the frequency of failure and the severity of such failure.

Firstly, the new process mappings will be done to visualize the improvements of the new technology and see how the process changes after such implementation. In such processes, the structure change has been marked to clearly see the differences. After that, by following the changes in the process steps, it is then possible to clearly identify the possible safety hazards that come with it to evaluate if the systems are safe enough to consider them through possible hazardous scenarios.

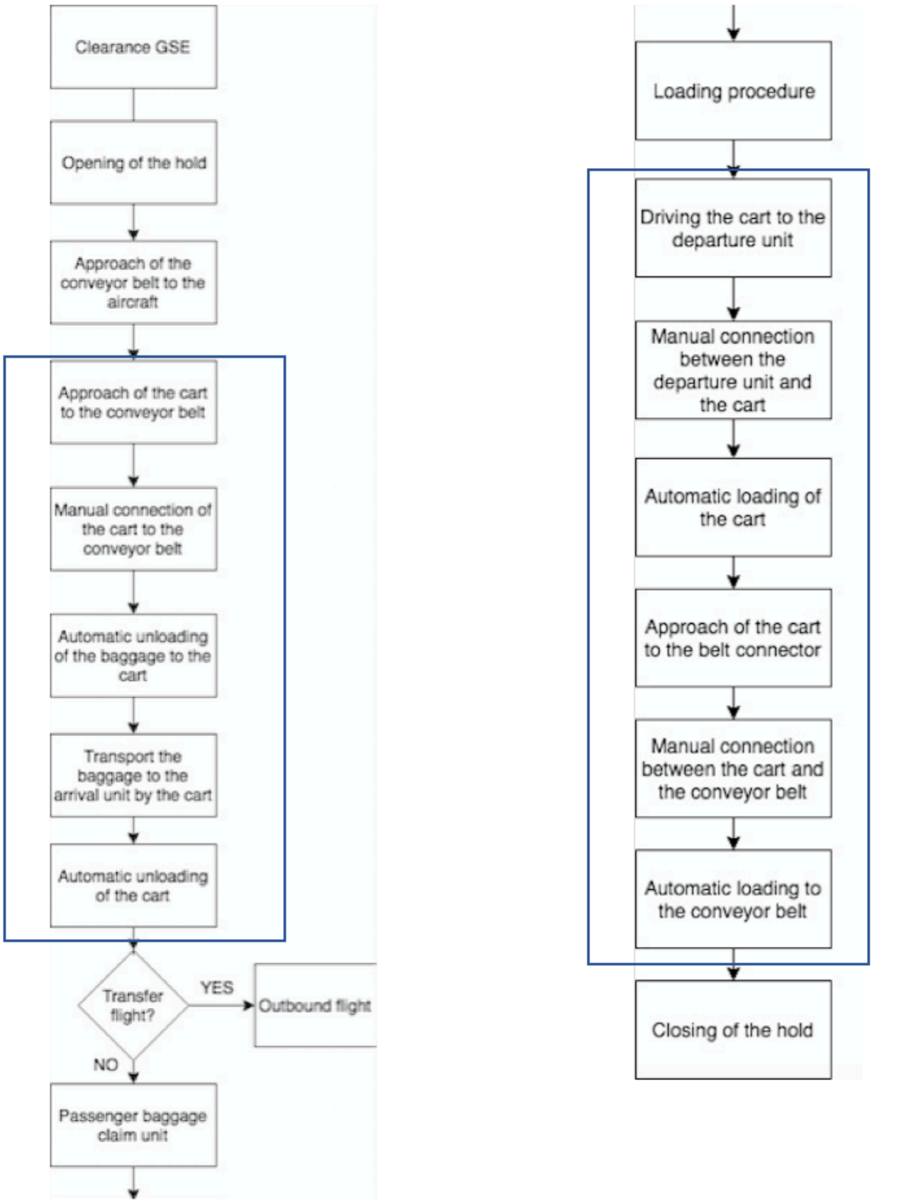
After this evaluation, the Preliminary System Safety Assessment (PSSA) is performed to ensure that the requirements identified in the FHA analysis are satisfied.

5.1 BBHS system

The main achievement for the baggage handling of the BBHS system is oriented towards the reduction of the cart fleet in the apron and the savings in the time required to load and unload the baggage instead of reducing the collisions of the vehicles with the fuselage of the aircraft.

The procedure of loading and unloading the aircraft using this system slightly differs from the traditional one. On the one hand, as it was previously explained, the original process consists of approaching the belt loader or conveyor belt to the aircraft and then the cart fleet which transports the baggage and is manually transferred to the belt. On the other hand, the procedure using the BBHS is the same in the first stages but the way the baggage is transported and transferred from the sorting unit to the belt is different. In this case, there is no distinction between ULDs and bulk loading as the baggage is transferred piece by piece automatically.

In the following process map, the sequence followed by this system can be visualized along with the differences with the original one.



Process map 12: BBHS system procedure

In brief, as it can be seen, this new procedure changes, not only in the sequence followed by the carts but also in some of the responsibilities of the operators. In this case, the workers are needed for connecting the carts to the departure and arrival units and to the belt connector for loading and unloading the aircraft. Furthermore, the responsibility of both the driving of the carts and the conveyor belt remains the same.

Regarding the requirements of the airport and the operators, on the one hand it can be said that no special training for the operators is needed as they are experienced enough to perform their duty in this system. On the other hand, the airport needs to set a whole new area for the arrival and departure units, so perhaps some design issues are to be considered.

Once the new process has been analyzed, there exist some safety hazards that may arise in the implementation of such technology, which need to be taken into account.

Firstly, the original problem regarding the conveyor belt is not solved. In this case, the BBHS system is not taking into account the risk of collision of the conveyor belt with the fuselage of the aircraft, as it is not part of the system.

Furthermore, the possibility of human error remains as operators are needed not only for driving the carts but also for connecting the components of the system to the optimal functioning. This is linked with the fact that if one component of the system fails, then the entire process is disturbed. There always exists the risk of failure in the automation which can affect the safe operation of baggage handling. If this happens when transferring the baggage from the cart to the conveyor belt in the apron, it could lead to a high risk of collision and injury of the operators.

The following table identifies the possible hazards that may arise as well as the root causes, which are the initial factors that influenced the hazards and their realization, therefore the causes of such risk.

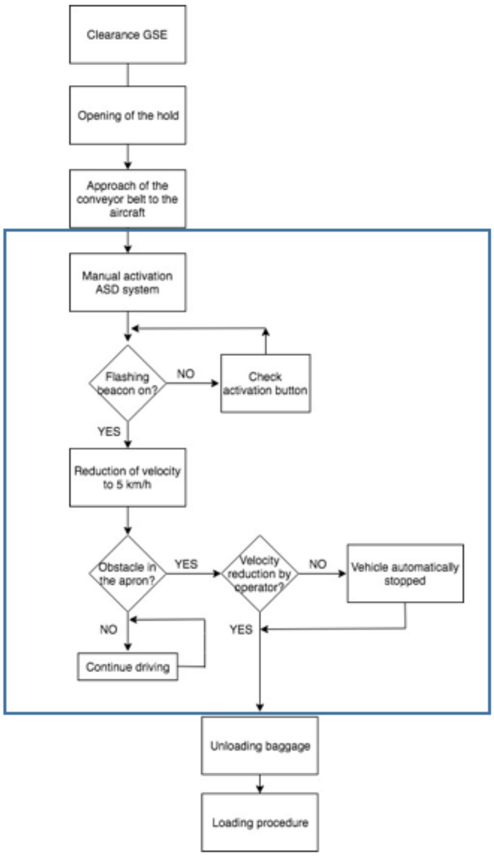
Hazard	Potential root cause
Collision with the aircraft	- Inadequate separation of the GSE with the aircraft - Failure of the guidance system - Error in human perception of proximity
Collision with other GSE	- Human error when driving the vehicles
Failure in automation of the system- Improper functioning of the new integrated system	- System used erroneously - Insufficient knowledge of the tasks of the operators

Table 1: Identified hazards and root causes for the potential BBHS system implementation

5.2 ASD system

Unlike the BBHS system, the ASD system focuses mainly in increasing safety in the baggage handling process by using a sensor for perceiving the proximity to the aircraft and avoid a possible collision.

The procedure, in this case, barely differs from the original one, as the sequence of events remain the same. The only thing to be added is the activation of the system by pressing a button when approaching the conveyor belt to the aircraft.



Process map 13: ASD system procedure

The previous diagram has been simplified in the last stage because it does not change from the original map. The only thing that has been done is adding the part where the operator has to activate the system in order to start working. Once the system is activated, the operator needs to check if the flashing beacon is on to confirm the correct activation and then reduce the velocity according the specifications. Once the vehicle has reached the aircraft with the desired velocity, the normal baggage procedure is performed.

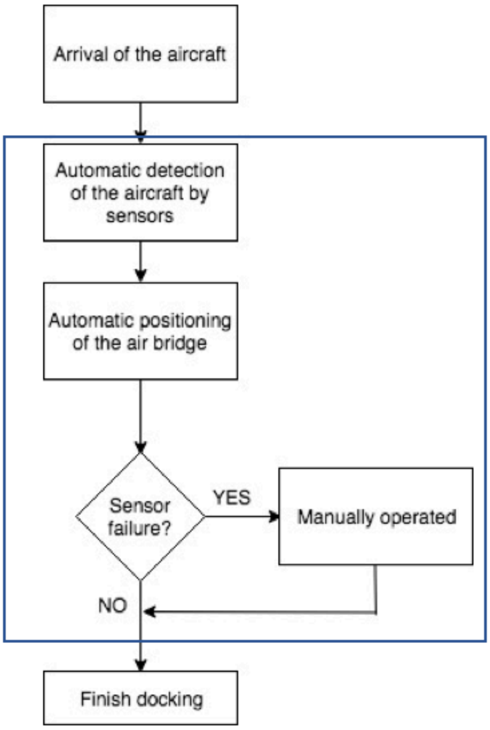
As in the previous case, when using new technology, there is always a risk of failure of the sensor that may lead to wrong measurement of the distance of the vehicle to the aircraft and resulting in collisions. For this reason, it is also highly important the task of the operator. Nevertheless, the reliability in human responsibility can lead to human error. It may happen that the operator driving the vehicle pays less attention to the procedure due to excess of reliability in this new technology so if it fails, it may go unnoticed.

Hazard	Potential root cause
Collision with the aircraft	- Inadequate separation of the GSE with the aircraft due to wrong distance measurement of the sensor - Failure of the guidance system in detecting near objects - Excess reliability of the operator on new technology
Collision with other GSE	- Failure of the guidance system - Excess reliability of the operator on new technology
Installation errors- Improper functioning of the new integrated system	- System used erroneously - Excess of reliability of the operator on new technology - Camera sensor failure - Incorrect functioning of the collision recorder - Lack of experience

Table 2: Identified hazards and root causes for the potential ASD system implementation

5.3 Intellidock automated airbridge

The biggest achievement of this airbridge docking system is its complete automation by means of several sensors that detect the aircraft and establish the route for a safe docking. In this new process, there is no need for a well-trained employee which may not be easy to find available at the time of the aircraft arrival to establish a clear line of sight. All the work is done by means of a set of sensors and in case something goes unexpected, an operator can take the control of the airbridge manually.



Process map 14: Intellidock automated airbridge procedure

The major safety risk relays on the failure of the sensors. The fact that several sensors constitute the system leads to an increase in the probability of error. To overcome this problem, the system can be remotely controlled by an operator but this is also a source of risk due to human factors.

The operator responsible for supervising the correct functioning of the airbridge needs to familiarize with the remote controls of the cabin in case the control is switched towards human work. There could be an insufficient training of the operator in such a new system that leads to potential risk of collision.

Furthermore, the installation of this module of sensors is quite innovative and there are not many references. Due to this, the lack of experience of the operators is a considerable risk to be taken into account.

Hazard	Potential root cause
Collision with the aircraft	- Failure on the distance measurement of the sensors - Failure on detecting the approaching aircraft - Use of a combination of sensors - Lack of concentration of the supervisor - Lack of experience of the operator - Improper training of the operator

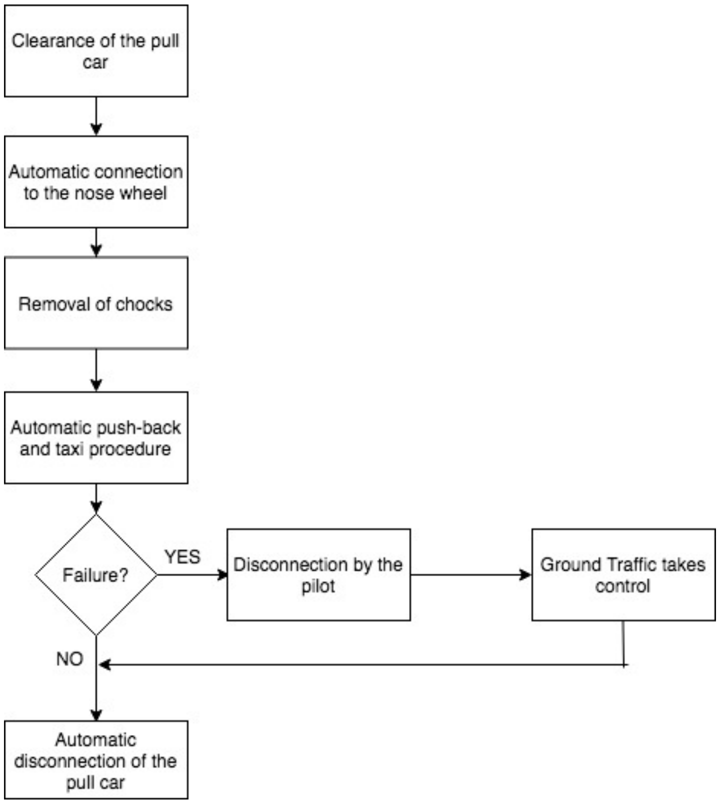
Table 3: Identified hazards and root causes for the potential Intellidock automated airbridge implementation

5.4 Aircraft Towing System (ATS)

The process of the Aircraft Towing System completely differs from the original one so a new map should be done. This system does not only imply the push-back procedure but also the taxiing to the designated point of the runway. However, focusing only in the push-back, the main difference with the traditional procedure is the automation of the vehicle which moves the aircraft towards an entire channel installation.

Furthermore, in the traditional procedure, two operators are needed, one for driving the vehicle and another one for communication with the pilot. With this new technology, these two workers are no longer needed and the full responsibility relays in the pilot in case something goes wrong.

As for the requirements, in the case of the airport, a partnership with the provider of the system is established to determine an optimal taxiway layout of the system and implement the software for ground traffic controllers. Moreover, a whole set of training options is offered to the personnel of the airport to efficiently operate the system.



Process map 15: Aircraft Towing System procedure

From the safety perspective, the bigger concern is focused on the installation of the infrastructure. Night shifts are frequent among workers for the minimum disturbance of the normal functioning of the airport. This results in a deterioration of the working conditions of the operators, which can easily lead to human error.

In addition, automation is linked to the possibility of failure that can result in collisions with the aircraft or other ground support equipment. In this particular system, the reliability in technology is such that no operator is required in the process.

Safety risks are a major concern because if something goes unexpected, the normal functioning of the airport can be altered, thus resulting in congestion, delays and the possibility of collision with other aircrafts in the taxiways.

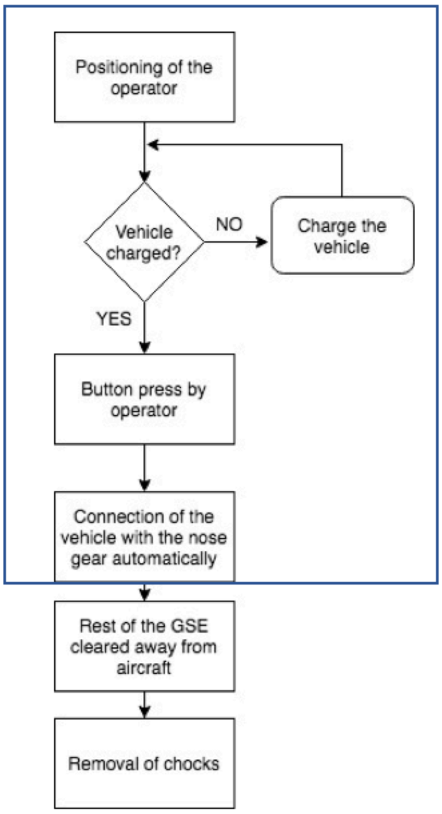
Hazard	Potential root cause
Collision with the aircraft	- Failure of the pull car sensors - Error in the pilot´s perception of proximity in case the pull car fails - Lack of experience with the new software of the Ground Traffic control

	- Insufficient training of the pilot and the Ground Traffic control on the new system
Collision with other aircraft	- Failure of the system in the taxiways - Wrong performance of the pilot or Ground Traffic control
Improper installation	- Insufficient knowledge of the tasks of the operators - Lack of experience of the operators - Increased workload during the procedures - Coordination between operators - Deterioration of the work conditions of the operators
Alteration of the normal operating functions of the airport	- Incorrect installation of the system - Failure in the automation of the pull tug
Detachment from the tracks-front wheel damage	- Blockage or detailing of the system - High speed operations

Table 4: Identified hazards and root causes for the potential Aircraft Towing System implementation

5.5 Electric push-back vehicle

The push-back procedure using the traditional tractor or the electrical vehicle are quite similar. Both of them consists in connecting a vehicle with the nose wheel of the aircraft to start the procedure. However, the way it is done is what makes them different.



Process map 16: Electric push-back vehicle procedure

While in the traditional procedure the operator is responsible for driving the tractor and connecting it to the aircraft, in this new procedure the responsibility changes. The operator remotely controls the movement of the vehicle and presses a button to start the attachment, which is performed automatically by the vehicle. Once the connection with the aircraft is made, the normal operation begins.

The innovation of the use of remote controllers leads to a process of familiarization and training of the operators due to the lack of experience in the matter. This constitute one of the main safety hazards as the less experience, the more risk of failure.

Furthermore, as in the previous cases, the use of robotics comes with a risk of error of the sensors, which should be taken into account.

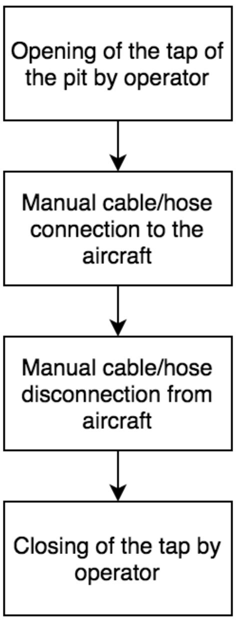
Hazard	Potential root cause
Collision with the aircraft and other GSE	- Failure on the distance measurement of the sensors - Use of a combination of sensors - Lack of concentration of the operator controlling remotely the vehicle - Lack of experience of the operator - Improper training of the operator

Table 5: Identified hazards and root causes for the potential electric push-back vehicle implementation

5.6 Underground system

The implementation of the underground system is based on the removal of the vehicles around the aircraft. This way, a free apron is obtained and the risk of collision to the aircraft and among vehicles is eliminated.

The procedure followed by the underground system completely differs from the processes explained in previous chapters, so a new process map must be done. The operator is responsible for opening the platform and connecting the corresponding cables and hoses for servicing the aircraft. Once the service has finished, the operator disconnects such cables and hoses and closes the pit.



Process map 17: Underground system procedure

Safety is highly incremented as there is not risk for collision. However, it is important to notice that this underground system required an installation, which may lead to human errors and injuries.

Furthermore, the blockage of the retractable and hatch pitch it is also likely to happen due to the failure on the opening and closing system.

Hazard	Potential root cause
Blockage of the retractable and hatch pits	- Failure of the opening system
Improper installation of the underground infrastructure	- Lack of experience of the operators - Deterioration of the work conditions of the operators - Wrong maintenance procedures

Table 6: Identified hazards and root causes for the potential underground system implementation

6. SWOT Analysis

The SWOT analysis is a technique used for assessing the performance, competition, risk and potential of a particular system by means of identifying strengths, weaknesses, opportunities and threats. Using internal and external data, the technique can guide the new systems towards strategies more likely to be successful. [17]

In this chapter, a SWOT analysis of each of the new technology systems is going to be performed in order to conclude with the viability analysis for implementation of these innovative solutions.

6.1 BBHS system

6.1.1 Strengths

One of the most important advantages of the BBHS system is the savings in turnaround time which also reduces costs to the airlines. This is achieved by means of automation of the baggage handling services that permit an efficient operation from bag drop-off to delivery at destination. This operation is done in batches for full traceability and in just 10 seconds, the carts are filled and ready to supply the aircraft. This batch approach also reduces the space requirements to baggage halls. Furthermore, the cart fleet is reduced as 1 BBHS cart contains the amount of baggage that can be transported in 8 traditional carts. All of this contributes to performing the service safely and quickly.

Regarding the operators, manual lifting is eliminated since the baggage is automatically transferred to and from carts and belts. This results in fewer work injuries and insurance claims. By lowering the responsibility of operators, the transfer of the baggage is done gently preventing rough and abrasive manual lifts that can damage the baggage.

6.1.2 Weaknesses

The implementation of the BBHS system requires a high initial investment for the construction and maintenance of the infrastructure, ground service equipment and staff employment. The system required a high initial investment for installation of the infrastructure, due to the usage of conveyor belts, sensors, X-ray screening machines among others. In addition, the operational and maintenance services of the baggage handling system are to be added to the initial cost of the system, which include the cost of maintenance, staffing and electricity.

The system is based on a chain procedure which means that it follows a sequence of events dependent on each other. This could be detrimental because the failure of one component of the system leads to the failure of the entire system.

Other important weakness of the system is the fact that the conveyor belt follows the traditional process. Therefore, the risk of collision with the aircraft remains the same. This particular system only takes into account the improvements of the carts, leaving aside the last stage of the process.

Finally, operators are part of the process, so the system is susceptible to human error. They are required for connecting and disconnecting the components of the system, so any mistake could result in the failure of the entire baggage handling.

6.1.3 Opportunities

The global airport baggage handling system market is mostly driven by anticipated growth in the air travel, modernization of new airports and technological advancements. Some of the critical factors such as customer satisfaction, improvements in turnaround time, airport´s operational efficiency and the need for automation of the baggage services are fostering the growth of baggage handling segment.

As a result, airports and airlines invest heavily in baggage handling technology with the increase in the number of air passengers so BBHS system can clearly benefit from the current situation of the market.

6.1.4 Threats

Competitors have arisen presenting alternatives for improving the baggage handling system which do not require such high costs of infrastructure and maintenance.

SWOT analysis diagram 1: BBHS system

6.2 ASD system

6.2.1 Strengths

The ASD system consists of a combination of a traditional procedure and new technology development which has the function of supervising human performance. This is considered as a benefit because there is no complete reliability in neither of them. If one part fails, the other one can manage the situation. Sensors are used to help the operators not replace them so by working together, the risk of collision with the aircraft fuselage is almost eliminated.

As soon as the sensor detects an object in the apron, which could be other ground vehicle or the aircraft fuselage itself, it will force the operator to immediately reduce the speed. In case there is a human error and the order is not achieved, the system will automatically stop the vehicle and avoid the collision.

Even though the system fails and there is a collision, the force created by the vehicle to the fuselage can hardly cause any significant damage. This is possible because the system functions at a very low speed at the final stage of the approach.

It is clear that the fact of using new technology such as sensors comes with the possibility of failure. The more sensors a system uses, the more probability of error. However, the ASD system only uses a camera sensor, which is less sensitive to interferences and meteorological conditions.

In addition, other benefit is the existence of a collision recorder which will lock the vehicle in case of a collision until the inspection of the fuselage is done.

Finally, the system can be installed, not only in new ground support equipment, but also in existing ones, reducing the costs of introducing a whole new fleet.

6.2.2 Weaknesses

The main weaknesses of this system are related to the human error and the failure of the sensor. Both have a very important role to play in the performance of the system but they are susceptible to error.

6.2.3 Opportunities

As previously mentioned, baggage handling industry is constantly growing and there is a clear interest among market players in investing in research and development. The recent technological advancement in the aviation industry and the development of robotics and digital communications are expected to positively influence the growth of this sector.

6.2.4 Threats

As in the case of the BBHS, there always exist the threat of competitors. In such a wide field, many alternatives are presented in the market.

SWOT analysis diagram 2: ASD system

6.3 Intellidock automated airbridge

6.3.1 Strengths

The automated airbridge docking system is fully automated and relies on a sensor module connected to a remote system.

One of the main benefits is the availability. In the traditional system, a well-trained employee is required and may not be available at the specific time of the aircraft´s arrival. However, this automated airbridge is always available to be used even though the weather conditions are adverse, therefore reducing turnaround times. It does not require a clear line of sight with a guiding person for docking the airbridge to the aircraft since that responsibility relays on the sensors.

The risk of collision with the aircraft is highly reduced, and in order to make sure everything works perfectly, the operator can manually confirm the sequence and override the controls if necessary, in case the sensors fail.

Finally, the installation of such sensors can be done in existing airbridges, so there is no need to install new ones.

6.3.2 Weaknesses

Regarding the possible problems of the automated airbridge, as in the previous cases, all automation comes with the price of the possible failure of the sensors in measuring the distance to the aircraft or even in detecting the approaching aircraft. In this particular case, a set of various sensors are used so there is a higher possibility of error, as the failure of a single sensor affect the whole system. To overcome the situation, human responsibility is added, which also come with the risk of error for the lack of concentration or experience of the operator.

6.3.3 Opportunities

In the case of the airbridges´ market, the competition is scarce. It is common knowledge that an automated airbridge is necessary but there has not be much progress. However, technological advancements are being made in ground handling and the research on sensors for automation is currently taking place.

6.3.4 Threats

The possible threats of the automated airbridge are linked with the safety hazards identified in the previous chapter. Training of the operators in such new technology is of major importance for the correct performance of the system.

SWOT analysis diagram 3: Intellidock automated airbridge

6.4 Aircraft Towing System

6.4.1 Strengths

The aircraft towing system has many innovative solutions to the process of push-back and taxi to the runway.

Firstly, a reduction in the push-back time is achieved. By using this system, the aircraft is immediately transported through the channel by the pull car and does not stop until it reaches the runway. As the engines are shut off during the movement of the aircraft, they can be placed closer together in the taxi-lanes for optimization of the traffic. As a result, more aircrafts can be moved simultaneously and the capacity of the airport is increased.

Furthermore, the pull car contains a set of sensors which analyze the possible objects surrounding the aircraft, thus reducing the possibility of collision with other ground support equipment.

As the process is fully automated and electric, ground equipment and operators are no longer needed. Emissions to the atmosphere are reduced and there is less impact to the environment as fuel consumption is diminished. Engines are powered off during the entire process resulting in savings for the airlines.

6.4.2 Weaknesses

The installation of the infrastructure requires a high initial investment and maintenance operating costs, which lead to the need of operators to do it. Human factor is then added to the system. Long and night shifts are done by the operators in order to reduce the impact on the normal functioning of the airport, but the alteration can not be avoided completely. This results in increased workload of the operators and in the deterioration of their working conditions, leading to an improper installation of the system.

6.4.3 Opportunities

Airport authorities are moving away from fuel-burning ground vehicles to electric propulsion whenever feasible. The industry incorporates considerable opportunities for future growth owing to increasing capacity of the airports. Rapid technological advancements and developments in the approach to use alternative fuel for handling equipment and vehicles are presumed to provide considerable opportunities for industry growth.

6.4.4 Threats

The internal weaknesses of the installation of the system and the human responsibility in such task, lead to the alteration of the normal operating functions of the airport. Congestions and delays appear along with the increasing costs for the airlines and the airport.

It is also important to notice that there could be structural problems of incompatibility of the pull car with the aircraft nose wheel, which will constitute a possible safety threat.

Other possible threat, as in the previous cases, is the existence of other innovations, which require less installation investments and workload, therefore less costs for their performance.

Finally, weather conditions go beyond the control of humans and technology and always constitute a dangerous hazard to take into account when performing this delicate service.

SWOT analysis diagram 4: Aircraft Towing System

6.5 Electric push-back vehicle

6.5.1 Strengths

The electrical push-back vehicle reduces costs regarding maintenance and personnel. On the one hand, it has very low maintenance costs because all its components are located in the same compartment. On the other hand, unlike the traditional procedure where two operators are needed, by using this vehicle only one operator is required. The operator will receive a small training for controlling remotely the vehicle so no driving license is demanded.

The fact that it is fully electric entails less emissions to the atmosphere as no fuel is consumed by the vehicle. Moreover, once the vehicle is charged, it becomes completely available for servicing many aircrafts immediately.

6.5.2 Weaknesses

Human factors are one of the main sources of error. The push-back vehicle is remotely controlled by an operator, which is the main responsible for the procedure so the possibility of error is implied. Sensors are the other source of responsibility for the correct push-back of the aircraft, which also involves failure.

In addition, the availability is limited by the recharging times. From time to time, the vehicle needs to be recharged so it can continue working which means that it cannot be fully available.

6.5.3 Opportunities

Similar to the previous system, electric propulsion vehicles are thought to provide considerable opportunities for the market´s growth as aviation field is evolving through environmentally friendly measures.

6.5.4 Threats

Structural problems and adverse weather conditions are a source of external issues that may harm the process. Other factor is the need for training the personnel in order to control remotely the vehicle. This may lead to error due to the lack of experience.

SWOT analysis diagram 5: Electric push-back vehicle

6.6 Underground system

6.6.1 Strengths

One of the outstanding achievements of the underground system is the reduction of the risk of accidents by freeing the apron from ground support equipment. Once the system has successfully supplied the aircraft, it is lowered down to the ground so no disturbance can be made. The fact of being underground makes the equipment to last longer than the traditional vehicles, therefore reducing the costs of maintenance.

Due to the simplicity of the procedure using this system, which basically consists in easily raising and closing the pits, a smaller number of operators are required. Furthermore, for being a fixed installation, it is always ready to be used once the aircraft has parked in the stand, so waiting times for the ground support vehicles are eliminated.

Regarding the pollution, none of the equipment installed underground uses diesel engines, unlike vehicles in the apron, which emit high amount of emissions that have a great impact on the environment.

Finally, it is very important to highlight that this system can service any type of aircraft regardless its dimensions.

6.6.2 Weaknesses

The main setbacks of this system are related to the installation of the underground infrastructure. As in some of the previous cases, a high initial investment is required and more operators are needed for the installation of the infrastructure. There is an increase in the workload and a deterioration of the working conditions of the operators which lead to a bad performance.

6.6.3 Opportunities

The aviation sector is highly competitive and is constantly searching innovative ways for creating bigger and more efficient planes. This is how, in the past few years, aircrafts like the A-380 or B-787 Dreamliner have entered the market. For being able to supply these aircrafts, the traditional ground support equipment is not enough due to the dimensions of the aircraft. This system has a clear opportunity for handling the aircrafts that are to come in the future.

6.6.4 Threats

The installation of the underground system requires a new design of parts of the airport, which needs to be deeply studied. Furthermore, this system is also susceptible to maintenance procedures performed by the operators, leading to human error.

SWOT analysis diagram 6: Underground system

7. Conclusion

Air transport is constantly challenging itself to improve existing aircraft and airport performance following the specified requirements around safety and security. As it has been mentioned throughout the thesis, the main goal of the airlines is to maximize the use of the aircraft in the air while minimizing the time spent on ground for cost savings and customer satisfaction. In order to achieve this, ground handling must be as efficient as possible, always prioritizing safety procedures.

The efficiency comes with the introduction of new approaches to overcome the weaknesses and limitations of the current practices. Along this thesis, several innovations have been introduced and evaluated. Firstly, a comparison with the traditional procedures have been made in order to state the differences and achievements. However, every new implementation brings new limitations, which are to be studied as well. After identifying the weaknesses of the new procedures, a safety assessment has been made in order to identify and correct the potential hazards and their root causes.

When wondering about the implementation of such new technology in practice, a SWOT analysis is required to evaluate the possible strengths, weaknesses, opportunities and threats. It is a decision making tool used to generate a realistic strategy and state the main objectives for implementing the systems. The implementation of the systems should be based on their strengths and opportunities, being able to stop and correct their weaknesses and protecting themselves from the possible external threats.

After evaluating all of the innovative solutions, it is possible to see that most of them have more strengths than weaknesses, which are mostly based on the failure of the sensors and the human factor. On the one hand, failure of the sensors is not likely to happen as there are many companies dedicated to make them as reliable as possible. On the other hand, regarding the human factor, most of the systems only rely on the operators in case technology fails, so the situation where the operator takes control of the process will not be often performed.

There has also been stated that all of the systems have opportunities as ground handling is a growing market and many concerns have arisen in the introduction of new systems that accelerates the process of servicing the aircraft in an efficient way. Furthermore, many of the solutions are oriented towards the reduction of the emissions to the atmosphere and this is starting to be a major concern for aviation authorities.

All systems except the ASD and ATS systems have already been implemented in some airports and they are providing the services to the aircraft successfully. As for the other two, studies are being made for implementing them in a near future as they are seen to be viable for the current installation.

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