Sapienza Università di Roma

Faculty of Civil and Industrial Engineering

Department of Civil, Constructional and Environmental Engineering

Master Degree in Transport Systems Engineering

PLANNING OF AIR CARGO TERMINAL

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Summary

1. Introduction

In the age of globalization, the transport of freights, from one country to another, has given great importance to airport cargo systems, such as to require continuous improvements and to ensure that the constant growth of the demand by the trade sector, must be supported by an adequate infrastructure.

The aim of this study is to try to emulate all the processes that are carried out in the air cargo terminal (from the arrival of the goods by trucks, to their positioning inside the airplanes hold, and vice versa) in order to create a valid tool to avoid situations that can compromise the stability of the airport handling operations.

The case study considered, has been conducted examining the handling processes that occur in the Cargo City of Milano Malpensa Airport, one of the largest cargo hub in Europe, particularly those related to Alha Group.

The reason why this study has been carried out in the airport warehouse of Alha Group, is based on the fact that, excluding the tons handled by traffic courier, it manages, up today, about 75% of the total freights in Milano Malpensa.

2. Cargo traffic: role of air cargo and flow distribution

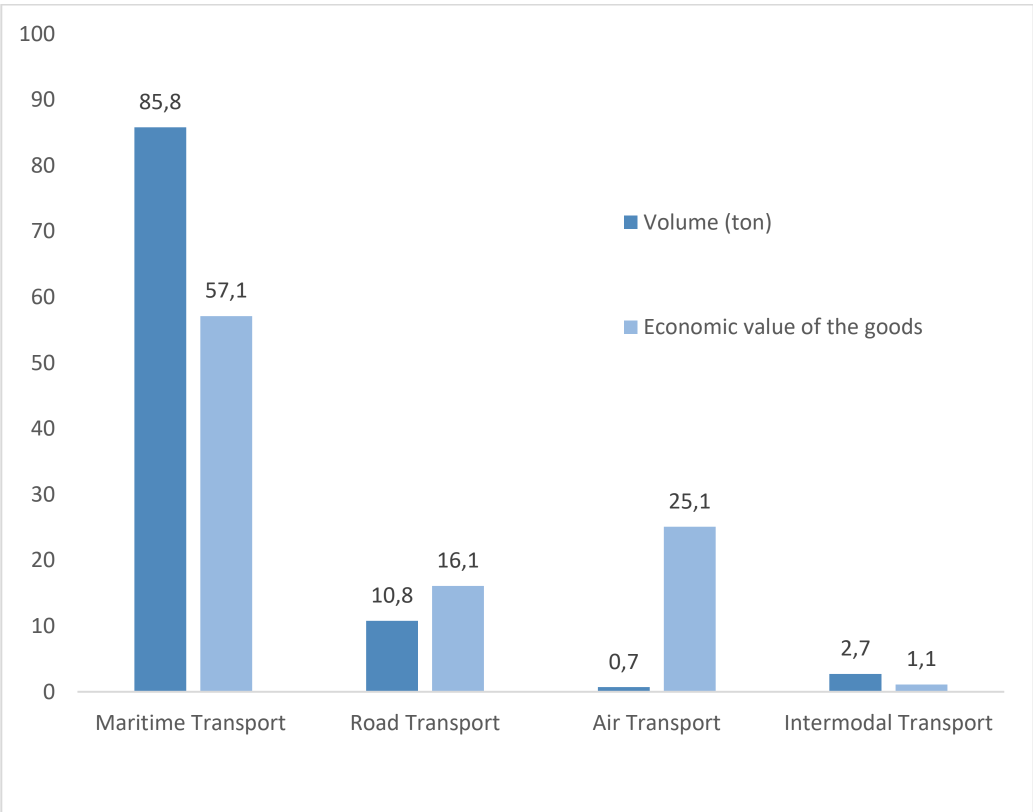
Over the last 20 years, the transport of goods by air is one of the transport modes in constantly evolution, with a certain progress, year by year, in terms of volume of goods. However, this transport cannot yet be compared to passenger transport, despite this growth, since the cost of air transport is significantly more expensive than other modes of transport, such as those relative to rail or truck. The conditions, under which air transport is used instead of other modes, are given by:

- the value of the goods transported;
- the possibility to reach long distances in short time;
- the easiness of using the air routes instead of the land ones.

Considering the volume handled by air cargo and sea transport, one of the most important aspect is that the ships move the 85% of the volume (tons) while the air transport move the 0,7%, this in relation to the value referred to the extra-EU export in 2016 [1]. But this 0,7% represents more than 25% of the value of global trade, and this clearly means that everything that comes by air travel is very important because it moves the truly decisive goods; it represents a key element in world trade.

Safety, speed and efficiency are other elements that clearly describe the reasons for choosing air transport. Goods carried by airplanes belong to the following three different categories: passenger baggage, mail, and proper goods.

In 2016, the Italian airports, cargo traffic reached a volume of one million tons, with a growth of 6%, compared to the previous year. The air cargo traffic represents roughly the 2% of the goods volume transported in all modes. Particularly, as far as exports to non-EU countries, air transport in 2016 represented 0,74% of the exported volumes and 25,18% of the economic value.



Graph 1 - Distribution of exports by mode of transport.

All modes of transport have different characteristics, and each one has strengths and criticalities [2].

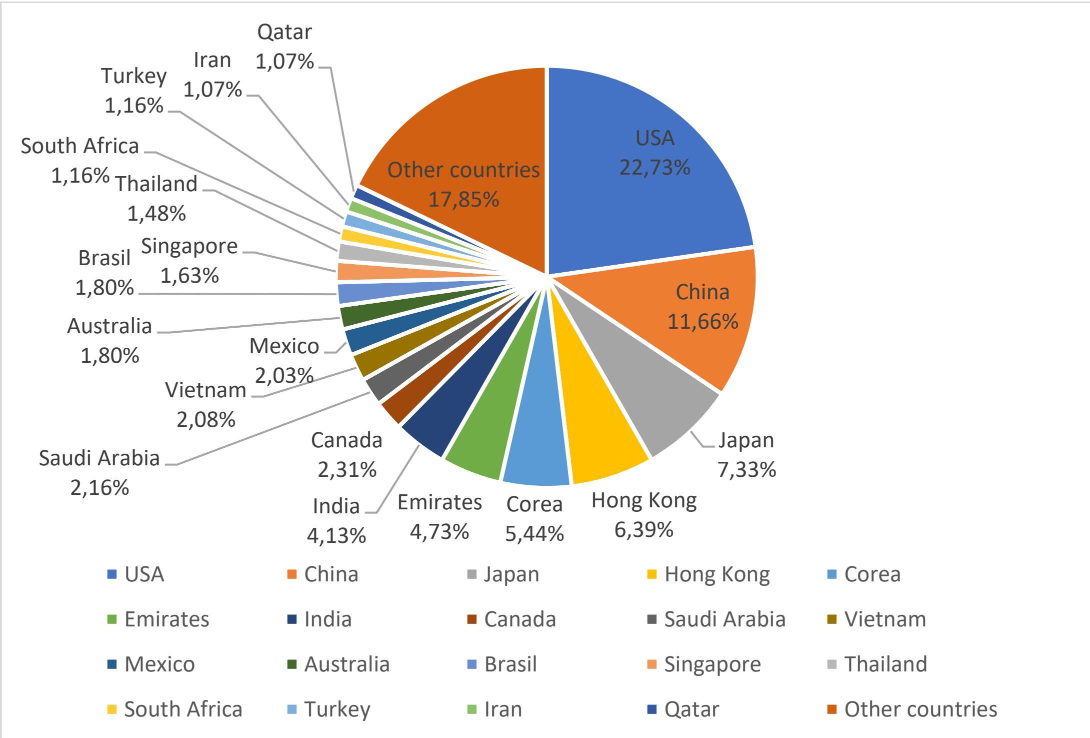
Modes of transport	**Advantages**	**Disadvantages**
See transport	Low costs of transport, variability of the departure and arrival date.	Slowness, high costs of packaging (except for containers), possibility of damages.
Road transport	Speed, possibility to delivery "door to door", wide availability of carriers.	Average risk of damages, high costs of transport.
Rail transport	Low costs.	Slowness, difficulties to find railway wagons, preparation and readiness of the railway wagons, uncertainty on departure and arrival time, reasonable possibilities of damages.
Air transport	Speed, very low risk of damages, particularly suitable for fragile, worth or urgent goods.	High costs.
Intermodal transport	Speed, single transport contract with a single carrier, less possibility of damages, certainty on departure and arrival time, is suitable for long distance itinerary.	Availability only on pre-planned itinerary.

Table 1 - Advantage and disadvantages between different modes of transport.

2.1. The trend of goods in the world

The relationship between Europe and the rest of the world

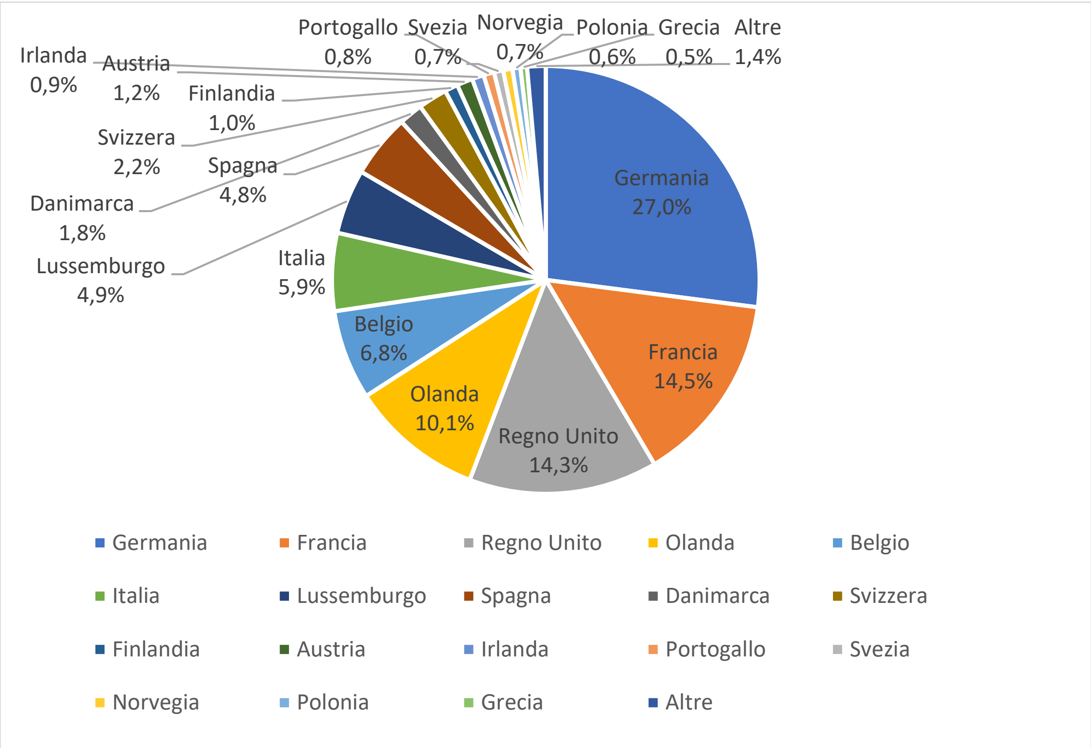
In 2016 the import/export volume of goods sent by air to non-European destinations amounted to 658 thousand tons; the United States of America have the first place in the ranking, with a market share (based on tonnage transported) of 22,7%, in second place China with 11,7%. Other three important Asian countries as Japan, Hong Kong and the Republic of Korea, are the recipients of Italian air exports and they represent 30,8% of exports. The graph 2 represents the partition of the export from the EU to the rest of the world.



Graph 2 - Distribution by destination country referred to 2016.

The trend of goods in Italy and the comparison with Europe

From the "ACI Europe" (Airports Council International) data referred to 2016, there is no doubt how Italy is the sixth country in terms of goods handled, without considering the mail sector. Still there is a remarkable discrepancy compared with other European countries flows, such as Germany and France. Indeed, the cities of Frankfurt and Paris individually move a considerable flow of goods, more or less 2 million tons yearly [1]. In the European airport ranking, with the highest number of moved goods, the first Italian airport reaches just the ninth places; while, the nineteenth place is occupied by another Italian airport (Roma Fiumicino).



Graph 3 - Freight transport by country in 2016.

During the economic crisis late 2007, cargo traffic in Italy has experienced a remarkable goods flow decrease and, more than any other European country, has suffered this situation. To find a similar situation as before crisis, is necessary to arrive in 2015, with values close to 500.000 tons per year. The difficulties to get out of an economic crisis and the time spent to succeed to do it, is in opposition with the positive trend in the last years, highlighting how Italy, unlike other European countries, has had a higher growth.

In the latest ten years volumes rose 18,2% comparison to 11,7% of the European average.

Countries	**Freight traffic [ton]** (without mail)	**Δ % 2015/2016**	**Δ % 2011/2016**	**Δ % 2006/2016**
Germany	4.456.000	3,2%	4,6%	31,9%
France	2.330.000	7,1%	-0,8%	10,0%
U.K.	2.272.000	1.8%	3,7%	2,0%
Netherlands	1.662.000	2,5%	9,1%	6,1%
Belgium	1.225.000	1,0%	2,9%	0,5%
Italy	971.000	8,2%	17,4%	18,2%
Luxembourg	802.000	8,7%	22,1%	26,5%
Spain	794.000	12,1%	18,3%	29,4%
Total	**16.285.000**	**4,8%**	**6,8%**	**11,7%**

Table 2 - Goods growth in the main European countries [1].

In the airport planning process, two different air traffic goods macro categories have to be taken into account, since they need different type of organizations, they are:

- **General Cargo**, where the traditional traffic provides a logistic chain in which IATA Agent, Airport handlers and an Air companies are part of the organization. Two different solutions are used for the goods transportation, the first one with "all cargo" airplane type and the second one within the "belly cargo" of the passenger aircraft, because General Cargo does not have their own airplanes.
- **Traffic Courier**, on the other hand, is managed by international express courier, which use their "all cargo" airplane type most of the time, in order to perform delivery of all dimension type of goods.

Both macro categories have different markets in relation with the surface of the commercial area in which they travel. Air traffic General Cargo has a majority profits market coming from the extra-EU exports, while the express traffic of the Traffic Courier receives its profits from the European inner flights. That is confirmed, referred to Italy, that extra-EU exports of the General Cargo services represent 84% of the goods moved by air.

More than 75% of the market is represented by north America and Europe. About 3 millions tons of goods are moved through the air transport system, and they can be listed in six macro categories:

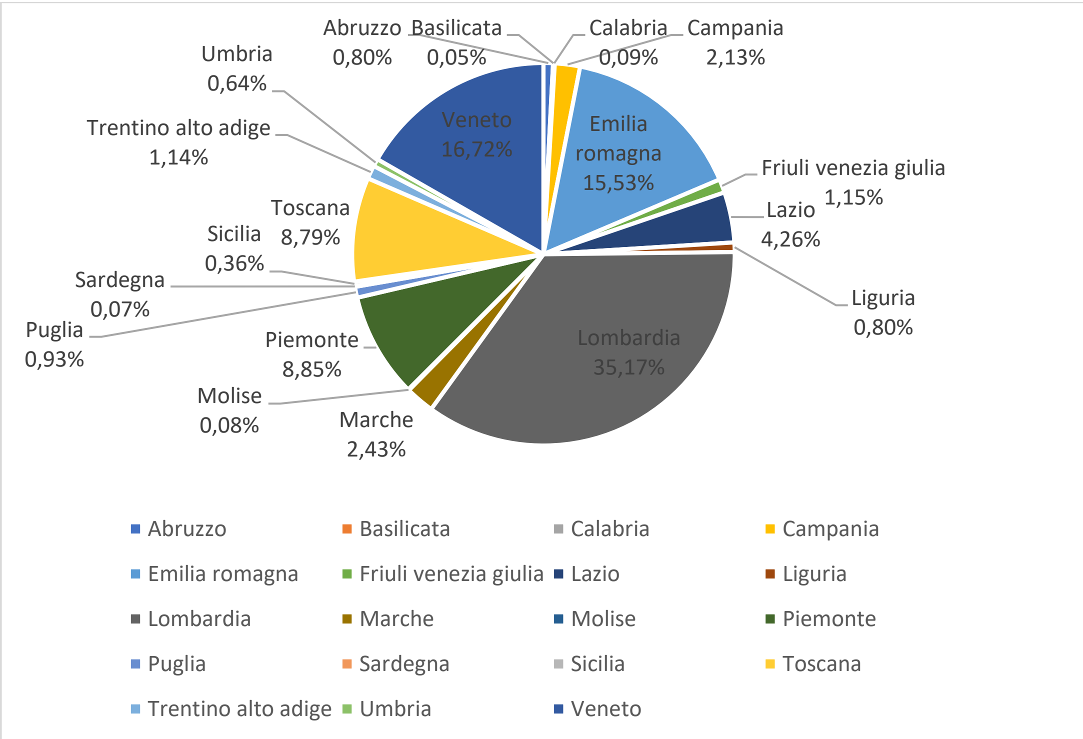
1. machines and electric devices;
2. small boxes;
3. chemical and pharmaceutical;
4. metallic products;
5. computers;
6. office devices.

Regarding Italian export extra-EU, data describe ten different types of goods representing the 44,4% of the moved tons and the 75,9% of the total exportation value. The ten different categories distinguished in "nuclear power reactors, machines, devices and mechanical appliances", that with the 13,4% represent the first category for exportation value, then other sectors follow as clothings and textiles, leather, pharmaceutical, eyewear and optical products, also antiques or pearls and precious stones sector, which have a high incidence for value and less in terms of weight as volume.

In the other hand, considering the extra-EU import market to Italy, the main sectors are antiques and collectors' items, pharmaceutical and mechanical.

2.2. The distribution of cargo traffic in the major Italian airports

Air cargo in Italy is focused on three airports that, more than the other, move the 80% of the Italian goods. With 550 tons Milano Malpensa Airport hub is considered the Italian leader airport for freight transport, with the fastest development year by year among the other European airports. The second Italian airport, according the number of tons handled, is Roma Fiumicino Airport with its annual 160.000 tons and, in third place, Bergamo Orio al Serio Airport with 117.000 tons. Milano Malpensa and Roma Fiumicino have suitable structures allow the airport handlers to work and, therefore, to increase the annual quantity of tons, using the General Cargo transport, as well as the Traffic Courier, while Bergamo Orio al Serio Airport has available only specific structures for Traffic Courier. In relation to the mail handling, Brescia Montichiari Airport reaches the 89% of the Italian handled amount. Among the Italian southern airports, Napoli Capodichino Airport and Catania Fontanarossa Airport have, respectively, more than 10.000 and 6.000 annual tons.



Graph 4 - Exports 2016 by air with Italy and EU exit for provinces of origin.

In terms of goods south Italy has a limited air traffic, compared to the north and the centre one, not even reaching the 2% of the total amount; while there is a situation almost similar between centre and south, regarding the mail handling, but, anyway, with a considerable positive gap for the north. The table 3 shows the differences between these three Italian geographic areas [1].

Geographic Area	Goods	Mail
North	79,60%	70,20%
Center	18,80%	13,30%
South - Island	1,70%	16,50%
Weight [tons]	998.127	45.295

Table 3 - The percentage of goods and mail between north, centre, and south Italy.

2.3. Differences between air cargo and passenger flight

The air cargo is a marginal traffic flow within Italian airports, the most important traffic flow is the passenger ones. Cargo is totally different from passenger business, there are six main crucial differences [3]:

1. Traffic flows

Passenger air traffic, flows normally in two directions (round trip): passengers have to come back home from a trip. Instead, goods handled by air traffic has a one-way trip. Therefore, it is important to find other goods to deliver the opposite direction, in order to avoid empty flights that give considerable loss for the companies, from an economic point of view. This situation has occurred recently with the air carriers that transported goods from China: many flights from this country to Europe or United States, were always full, even though there were not goods to be sent to China. The problem has been recently solved, because in the last years the demand of goods to China has increased, defining a similar traffic flow between these nations.

2. Ground processes

Another very important issue, is the basic process through which movements take place within the airport structure, as those movements done by travellers to reach their gates. So, the passengers are able to move by themselves, except when the movement is done through shuttle-buses to reach the airplanes. While, goods need forklift or dollies to be moved from one place to another of the warehouse, using different means of transport for different types of goods (e.g.: the dangerous or the controlled temperature ones) requires different processes.

3. Quantity optimization:

The third issue is quite simple. A specific seating position is available for one passenger. A completely different situation concern goods; the airplane has to be loaded with as many goods as possible, in order to avoid empty or half load flights, and the solution is not easy to find, because the volume of goods changes from one to another. Need to find an ideal situation for each type of good, for example with the belly cargo flights the radiogenic goods have to be positioned in the lower part of the airplane belly, in order to have a certain safe distance between such type of goods and the passengers.

4. Customer clusters:

The fourth issue is the business model: in the cargo fields there is a B2B (Business to Business) transaction, it means that the commercial exchange of services take place through companies. Instead, in the passenger air transport there is a B2C (Business to Consumer) transaction, it means that the commercial exchange of services take place between companies and consumers.

5. Booking behaviour:

The booking behaviour is completely difference between passenger and cargo. The passenger starts the booking 12 months before the flight, while the cargo business books only three days before the flight. The figure 1 shows this behaviour, for passenger and cargo traffic. Through the yellow line of the diagram, referred to passengers, shows how the curve has a constant increase starting 12 months before the flight departure. Through the blue line, referred to the cargo, has a fast increase just before the departure.

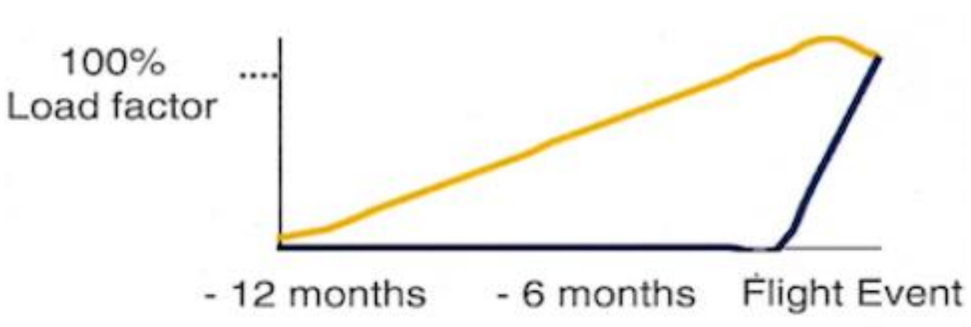


Figure 1 - The differences between passenger and cargo business in the booking behaviour.

6. Payment conditions:

The last point is about the payment conditions; the passengers pay their tickets before the flight, while the cargo business operates exactly in the opposite way, when the goods arrive at destination.

2.4. The relation between the air transport and the commerce

Air transport is the only possible option for certain type of goods; taking into considerations only the price, air cargo shouldn't have market. Indeed, for example, to carry out a trip from one of the most important European airport, such as Frakfurt, to one of the most important middle-east country, such as Shangai, the average price per kilogram is 1.84€/kg for the air cargo, in relation to the 0.04€/Kg for maritime transport [3]. But air transport mode is choosen because goods take less time to reach its destination: the travel from Frankfurt to Shangai takes 4 weeks by ship, and only 12 hours by flight (as shown in figure 2).

Figure 2 - Differences for time and money spent between air and see transport.

The time is a key variable for the commerce and, consequently, for the air cargo traffic flow. There are three different elements which well describe the reason to choose air transport instead of any other type of transport related to the time, such as:

- time to market;
- just-in-time logistics;
- perishability

The common aspect of these three elements is that specific type of goods travelling by sea transport, once the final destination is reached, its market value has changed. For example the *time to market* for an article of clothing, after four weeks travel is already out of fashion, or the *just-in-time logistics* for a mechanical part to be used to produce a car, after four weeks is at risk of making a longer time of delivery scheduled by a car company; also for perishability time is important to avoid to send bad food. Air transport has contibuted to speed-up the industrial process, changing from a “push” system, where the products inside the warehouse were ready to be sold, to a “pull” system, producing only what is necessary. In the air transport, security has a key role for items of a certain value, especially perishable goods such as meat and fish, who need to be trasported in short time inside cold storage container. Furthermore, another very important element for the air cargo is the security. For such element there are specific security procedures as for pharmaceutical products, which are subject to be stolen and then re-sold on the black market. Security has to be at a very high level within the airport warehouse.

Therefore, beyond the supply chain of pharmaceuticals, floral products, the fashion sector, technological and mechanical sector, the expansion of e-commerce that contributes to the demand for "express" products is becoming increasingly important [3].

3. Cargo City of Milano Malpensa

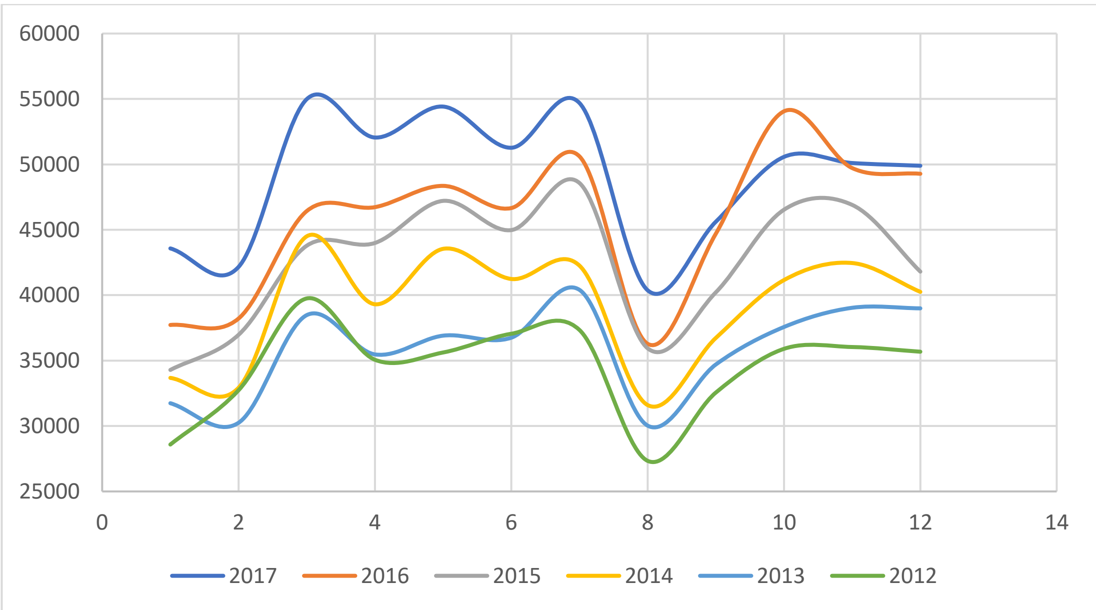
Milano Malpensa is an airport with a strong vocation for cargo and is absolutely the main freight junction for the Italian market, with two runways long 4000 m each. Milano Malpensa Cargo is located in the heart of the most industrialized area of Italy. Thanks to its highly technological structures and the innovative computerized systems, Milano Malpensa Cargo is the Italian leading airport and the sixth cargo airport in Europe. Milano Malpensa Airport, located in South Europe, has a strategic position, it is located in the fulcrum of Italian and European import-export flows, which involves regions of the peninsula such as Piemonte, Lombardia, Veneto, Emilia Romagna and Toscana and nations such as France and Switzerland. An effective road network linking the main Italian and European cities contributes to the growth of the Milano Malpensa Airport, not only for the goods arriving and then to direct them on the road in different zones but also for the goods that have to reach the airport in a simple way.

The exponential growth of Milano Malpensa Airport, in recent years, has been boosted also by the constant improvements in the quality of the operating processes and the simplification of the procedures, by the authorities control, such as customs or border inspection health services through computer tools.

To have an idea on how Milano Malpensa Airport had a significant growth, the table 4 and the graph 5, represent the monthly import-export tons handled by the Cargo City.

	2012	2013	2014	2015	2016	2017
January	28.586	31.743	33.681	34.287	37.725	43.577
February	32.733	30.247	32.921	36.971	38.214	42.159
March	39.752	38.477	44.500	43.781	46.430	54.983
April	35.067	35.474	39.308	43.991	46.730	52.053
May	35.620	36.907	43.544	47.211	48.357	54.418
June	37.052	36.751	41.239	44.976	46.661	51.271
July	37.344	40.409	42.263	48.577	50.614	54.694
August	27.338	30.031	31.602	35.942	36.284	40.378
September	32.554	34.701	36.730	40.215	44.696	45.613
October	35.900	37.571	41.156	46.535	54.058	50.573
November	36.039	39.037	42.459	46.903	49.718	50.105
December	35.680	38.995	40.254	41.802	49.280	49.895

Table 4 - Monthly tons handled in Milano Malpensa from 2012 to 2017.



Graph 5 - Monthly tons handled in Milano Malpensa from 2012 to 2017.

The management company of the Milano Malpensa Airport is SEA S.p.A. (Società per azioni Esercizi Aeroportuali), which has the task of designing and constructing new infrastructures and airport buildings. In the management phase of the air cargo of Milano Malpensa Airport, SEA has the function of granting to third parties the structures, built by them, to be used for services and commercial activities and handling. The activities of management and movement of goods inside the warehouses are performed by airport handlers in compliance with the rules and procedures contained in the call. The management Company SEA intervenes if handling of radioactive goods and admission of animals of medium and large size has to be performed. The services provided by the airport handler in SEA Airports, group several elements such as freight services by road, customs service, booking and sale of space on board aircraft [4].

Figure 3 - Immage of the Cargo City South of Milano Malpensa.

3.1. Cargo facilities and handler involved

The south-west area of Milano Malpensa Airport is dedicated to the cargo and covers an area of 500.000 m^2. During the last years, the annual capacity has reached more than 550.000 tons per year. Structures and infrastructures have been created to manage all types of goods and can handle traffic volumes up to 650.000 tons per year. The Cargo City of Milano Malpensa Airport is divided into two parts: Cargo City North and Cargo City South. As regards the first one, it develops over an area of 40.000 m^2 directly connected to the airside, which favors the loading and unloading of the goods to and from the aircraft. The facilities of the Cargo City North are also dedicated to the offices of various control Corps and to offices of cargo airlines, freight forwarders, freight agents, customs operators, road transport companies and airport handlers. In this area, the two largest airport handling companies of Milano Malpensa Airport work: Alha Group and B^3 MLE.

In the Cargo City South, with a warehouse of 15.000 m^2, one of the worldwide companies of the *traffic courier* namely FEDEX carries out its activities. During the 2018 an area of 15.000 m^2, will be released and it will be divided between two airport handlers namely WFS and Beta Trans. This last one has been temporarily placed in the Warehouse 136.

In the north-west part of Milano Malpensa Airport, another express courier DHL operates in addition to FedEx, located near Terminal 2.

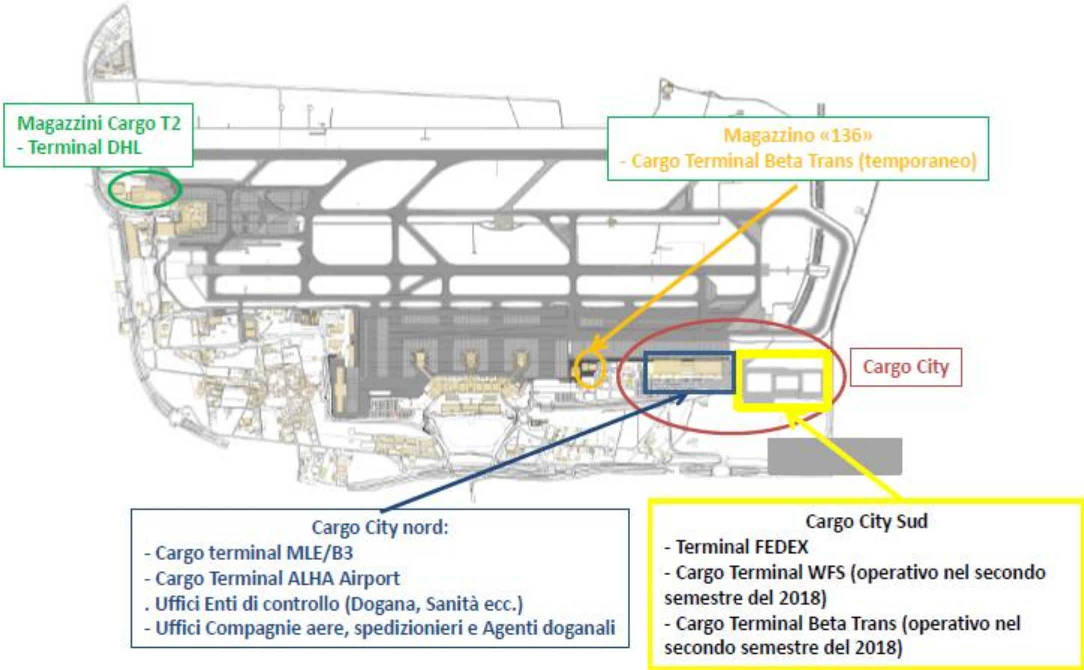


Figure 4 - The position of Cargo City and the warehouse of traffic courier inside Milano Malpensa Airport.

Beta Trans now placed in a small warehouse, will move during the 2018 in the new warehouses of the Cargo City South of Milano Malpensa Airport, near another handler (WFS). Alha Group handles 400.000 of the 550.000 tons of annual managed within the Cargo City of Milano Malpensa. The remaining tones are divided between B^3 MLE, that holds a considerable portion of the 100.000 remaining tons, and the different express couriers, as FedEx and DHL with an annual handling that is around 50.000 tons [5].

Alha Group

Alha Group represents a fundamental resource to improve the potential development of Milano Malpensa Airport, at European and global level. Alha Group is operating in the airport of Milano since 1997, is located in the Cargo

City North, where the main Cargo Terminal, which cover an area of 25.000 m^2, are the buildings E and F, which have a direct access to the ramp services of the aircrafts, to reduce the loading and unloading process times. The potential capacity of the warehouse, depending on the annual movements, is 400.000 tones; cooperates with 32 airlines, making an average of 34 all-cargo flights every week.

Inside the warehouse there are innovative structures in the air cargo field, such as a system of management, alignment and storage of loading units that manages to move simultaneously 550 ULDs. The terminal works 24 hours a day and 365 days a year, with 18 doors for the truck interface to the warehouse for loading and unloading the goods [6].

B cube MLE

In addition to Alha Group, another airport handler that contributes to increase the flow of goods within Milano Malpensa Airport is Bcube MLE, which operates in Malpensa since 2009, and, from 2008, is the only handler of Rome Fiumicino Airport. Unlike Alha Group, Bcube MLE has a less flow of goods, this is defined by the fact that this airport handler operates since less years and also because one of the target of Bcube is to increase the synergy with Roma Fiumicino Airport [7].

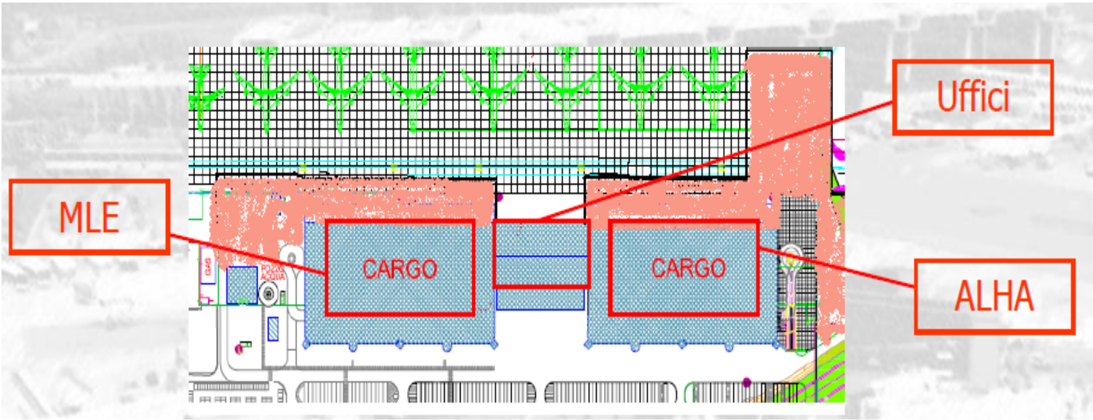


Figure 5 - MLE and Alha Group inside Cargo City North.

3.2. Airport elements

SEA S.p.A. makes available to the airport handlers some important elements, such as infrastructures, services, facilities and equipment. One of the most important equipment is the device for radiogenic control of goods located in the warehouses of the airport handlers and also for the express couriers, for a total of 29 equipment, 11 of which with a capacity of 5.000 kg and 180 cm of maximum height and width, 8 smaller sizes for small goods and mail packages and, finally, 10 ETDs equipment (i.e. dispositive for detecting traces of explosives). Additional services provided are security and supervisory systems, to ensure that no one approaches the sterile area, that is part of air side where controls are applied to ensure that no person or vehicle is allowed to get access into it, since the two main handlers Alha and MLE are close to that area. On the contrary the inside of the warehouse is controlled by video surveillance systems made by the same airport handlers. In carrying out the loading and unloading operations of the bulk goods from the truck, several mechanized systems are made available for heavy goods.

Figure 6 - Radiogenic control device inside the warehouse of Alha Group.

In the handler warehouses are installed 40 doors with electromechanical tilting platform, 12 for the airbone (Aviocamionato) warehouses. The platforms are useful to allow the truck to carry out the loading and unloading operations in an easy way, because not all tracks have the same height, so the elettromechanical platform goes up and down according to the suitable height. For the warehouse couriers are installed 6 doors with electromechanical tilting platform and 6 for the Airbone warehouses. Very important are the systems for preparation and storage of the ULDs. Regarding the ULD preparation, there is a total of 36 working stations with lifting platforms, 18 of which are equipped with weight scales; while for the storage and handling there is a completely automatic system directly connected to the work stations with related casterdeck.

In the world of the air cargo, of vital importance is the presence of infrastructures for special goods, of which:

- 2 temperature-controlled structures for **Perishable** goods of animal origin (intended for human consumption and not), for vegetable products, consisting of cold rooms at differentiated temperature between -20 to +15 Celsius degrees, located inside the warehouses and having a total surface area of more than 4.500 m^2, with annexes two border inspection centers for imported goods, manned by the health authorities;
- 2 temperature-controlled structures dedicated to **Pharmaceuticals** and specifically realized for the purpose (total about 2.000 m^2);
- Areas equipped for the stationing and control of live animals of small and medium/large size;
- 2 areas for **Desirable goods** with infrared systems;
- 4 Armored rooms for **Values;**
- 1 Underground caveau (about 250 m^2);
- 1 storage for death bodies;
- 2 Deposits for radioactive goods;
- A warehouse area dedicated exclusively to the **Postal Traffic** [5].

Figure 7 - Temperature-controlled room.

For the airport movement the elements frequently used are the ULD - Unit Load Device. These units identify some typology of containers or pallets are positioned inside the airplane cargo holds, whose dimensions are codified by IATA rules. The figures 8 and 9 shown the most common Unit Load Devices used inside the Malpensa Airport.

Figure 8 - Aeronautical container, on the left the AKH and on the right the AAP ULDs.

Figure 9 - Aeronautical pallets.

There are different ULDs for different type of aircraft, in order to have the best solution to storage these units inside the proper location. Indeed, for the Airbus A319 – A320 – A321 the ULD always used is the type AKH, that belongs to the LD3 series. Instead, for the Boing B747 – B767 – B777 and for the Airbus A300 – A310 – A340 the ULD used is the type AAP – AA2, that belongs to the LD) series, furthermore other types of ULDs are PAG – PAD – PAA – PAJ – PAP – P1A – P1C – P1D – P1G – P1P – P1X – PAX [9].

To move the ULDs from the storage rooms of the warehouse to the airplanes, different carts are used as the "ballerina" or the "dolly"; the first one is used to move containers of different dimension, while the other one is commonly used to move pallets and large containers.

Figure 10 - Ballerina cart.

Figure 11 - Dollies cart.

To move bulk goods there are other type of carts, as those for luggage (small size cart), those for goods and the last typology are those for radioactive goods, which must be always used to move RRY and RRW goods.

Figure 12 - Respectively carts for bulk goods, luggage and radioactive goods.

To move the ULDs and the bulk goods inside the airplanes two different vehicles are used:

- the Transporter;
- the Cargo loader.

Figure 13 - On the left the transporter and on the right the cargo loader vehicles.

3.3. Cargo handling processes

The operating handler process, related to the goods movement, is composed by several steps. The first process starts with the *decision* made by the business owner that sells its products to a customer, who previously has completed the order. The business owner or someone else for him, get in touch with the freight forwarder and give him all the details concerning the volume and the weight of the goods is going to send, this second part is the *preparation of the shipment*. Once the package is done and the label is filled-in and attached on it, in the third step the freight forwarder provides to *pick-up* the goods through suitable vehicle and then leaves it at the warehouse waiting to be transported to the airport. In the meantime, the freight forwarder calls the Italian air carrier service to know the availability (fourth step).

The choice of the air carrier is directly connected with the type of the flight; in the air cargo there are two different type of flight:

- The direct flight, composed by the all-cargo or mixed (with passengers), that reach the destination without stopover, because the air carrier has his own warehouse at the destination airport;
- The indirect flight, reach the destination with one or more stopovers, that means waste of time.

As well as a passenger need a ticket to fly, each package need to have one, the AWB (Air Waybill) that represent the transport contract, it contains all the details about the goods (fifth step).

The sixth step is the consolidation of the goods, where the freight forwarder brings together different packages with the same final destination, in order to have an advantageous situation between him and the air carrier and so comes a new shipment, named “Master Shipment”. Afterwards the freight forwarder takes the package to the airport in time to take the booked flight. Now it’s time to deliver the goods to the air carrier or the handling agent (seventh step).

Now everything needs to be controlled, since each missed warning of anomaly in the state of the goods involves the assumption of responsibility for the airport handler, with particular attention to the labels, the security and the dangerous goods. Regarding goods they must have labels which represent their ID card, in order to identify correctly all the details about the goods and the delivery.

Figure 14 - Label of the package.

Furthermore, at the arrival of the goods inside the warehouse needs to be checked and evaluate different situation:

- the state of the package, in the case of it shows anomaly, by the way the handler cannot open the packaging (figure 15);
- leak of fluid, no sign of fluid must be outside the package and check if the fluid comes really from the inside (figure 16);
- sign of probable burglary, the integrity of the packaging means that nothing has been stolen from it or, in the opposite way, put something inside (figure 17).

Figure 15 - Demaged packages.

Figure 16 - Leak of fluid from the packages.

Figure 17 - Burglary packages.

Vital importance for the air transport, and not only in this field but in all transport modes, is the security of the flight with dangerous goods. The definition of dangerous goods, gives by IATA, is:

*"**Dangerous Goods** are items that may endanger the safety of an aircraft or persons and animal on board the aircraft. **Dangerous Goods** are also known as restricted articles, **hazardous** materials and **dangerous cargo**. Many common items found in your household can be considered **dangerous goods** for the purpose of air transport" [10].*

Not all the goods are dangerous in the same way, there are goods with:

- low dangerousness, that can be moved by air all cargo or by air with passenger;
- high dangerousness, that can be moved only by air all cargo;
- highest dangerousness, goods that cannot be moved by air transport.

There is a list of dangerous type of goods, according the regulations in force, adopted by the United Nations; each class indicates a group of dangerous items (eighth step).

The palletization is the ninth step, where all the grouped packages, named "terrestrial pallet" will be packed in the same ULD (Unit Load Device), which are the air pallet type.

There are different approaches to build up the ULD, for example by using metal containers, often used by airbone, but the most used one is with one or more polyethene covers to keep the goods out of the rain, leaned over a light alloy floor board with hooks for the knitted net. In this step the warehouse worker need to adapt different solutions to fit the ULD to the shape of the airplane and at this point the load operation take place.

Once the export operations are completed with the goods loaded inside the airplane, the take-off can be done to reach the destination airport. When the landing is completed, import operations can start unloading the goods (tenth step).

The ramp handlers, once the goods are on the air side ground, *move* and *receive* them inside the warehouse with the following documentation *check* (eleventh, twelfth and thirteenth steps).

In the fourteenth step, after the depalletization is completed, all goods are positioned in a specific position inside of the warehouse (e.g.: perishable goods, armoured vehicle items and dangerous goods).

Afterwards, the freight forwarder or the local one receives information about the arrival of its goods at the airport, it takes care of the Custom Clearance operations and dispatches a truck to the airport to be ready to pick up the goods (fifteenth, sixteenth and seventieth steps).

Once the freight forwarder arrives with the truck at the airport, goes to the field office with the relative documents where are specified all the goods data. Only then the freight forwarder moves to the indicated stall to pick up the goods (eighteenth step).

The last two steps are the sorting and the delivery, through which the freight forwarder leaves the goods inside its warehouse, and then carries out the delivery to the customer [9].

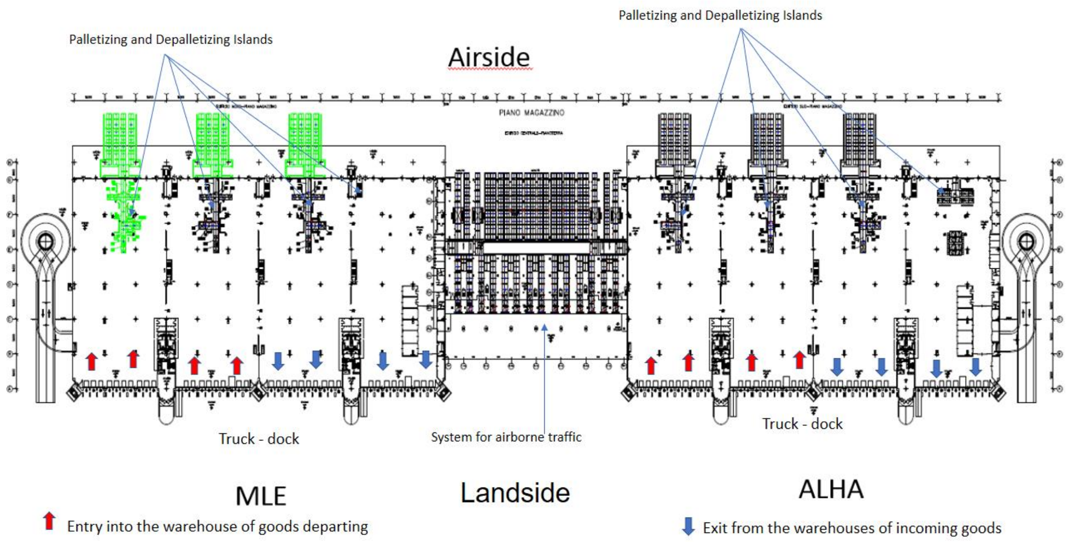


Figure 18 - Flows movements inside the warehouse of Cargo city (Milano Malpensa).

The above-mentioned processes, done in several steps, take into account a generical point of view regulated by international relationship between sellers and customers; while the internal air cargo process is regulated by handling process. The air cargo warehouse, for a single airport handler, is divided into two different parts. One of these is for the export flow and the other for the import flow, and each of them are divided into sub-flows, in relation to the typology of the goods, as:

- bulk goods, which can be transported by air without specific controls, inside ULDs or aeronautical pallets, regulated by IATA standards;
- big size goods, also this type can be transported without specific controls, and cannot be moved by ULDs and aeronautical pallets (for example cars, motorcycles, spare parts, mainmast and ship parts).
- special goods, such as perishable, dangerous, radioactive, precious and refrigerated goods, to be transported they must pass specific controls.

The export flows, divided into sub-flows, when arrive at the airport need to be sent to different areas with different procedures, these flows are:

- Airbone, where the goods are already pre-packaged into ULDs or the aeronautical pallets. First step for the truck is to move inside a proper system, dedicated to the airbone traffic, to carry out the ULDs unload operations on the track-dock. Later the ULDs are moved, through an automatic system, towards the air side where are positioned on the dollies, for then, few hours before the flight departure, be moved near the airplane by the airport handler, using the transporter or cargo loader vehicles.
- Bulk, big size and special goods, need to be unloaded from the truck through the tilting platform; once the goods are outside the truck, they are subjected to a Custom control. The goods arrived before the

scheduled time, are stocked inside the warehouse. Once all the goods planned to stay inside the same ULDs or aeronautical pallets, the palletization operation starts through the UHS (ULD Handling System figure 19). Some aeronautical containers, palletized time in advance, are placed in the stacker area (figure 20), the other are moved in the staging area (figure 21). Then, as per the airbone flow, the ULDs or aeronautical pallets are moved, few hours before the flight departure, from the staging area near the airplane by the airport handler, using the transporter or cargo loader vehicles.

As for the export flows, for the import one same operations must carried out, such as:

- Airbone, the procedures and the areas used are the same as the export flows, but in in the opposite way, the goods are unloaded from the airplane and moved to the land side, ready to be loaded inside the truck.
- Bulk, big size and special goods, are unloaded from the airplane through the transporter or the cargo unloader, positioned on the dollies and moved inside the warehouse, giving priority to perishable goods. The goods arrived before the scheduled time, are stocked inside the stacker area. First goods to be processed are the special goods (perishable, dangerous, radioactive, precious and refrigerated). Afterwards, the bulk goods are depalletized and placed in the proper shelf waiting to be cleared through the custom and then loaded inside the track [8].

Figure 19 - UHS (ULD Handling System).

Figure 20 - Stacker Area.

Figure 21 - Staging Area.

4. Methodological approach

To carry out a study on a system, to improve it, optimise it, making a data comparison or to predict future behaviour, the models are used.

A model is an abstract representation of a system. The models are useful to plan the construction of systems and to study the renovation of an existing structure or system. There are several types of models:

- Mathematical or analytical models, which consist of mathematical law that regulate the system;
- Simulation models, that give a representation of reality, reproduce the dynamic behaviour of the system within the time;
- Hybrid models, that are something between analytics and simulation models.

4.1. Mathematical or analytical models

Mathematical or analytical models are a set of concepts expressed in the form of mathematical equations able to reproduce, with a certain degree of approximation, a natural phenomenon. A model large used to reproduce this type of phenomenon is the Continuous-Variable Dynamic Systems (CVDS), which includes the most common physical quantities such as position, speed, acceleration, temperature, pressure and flow. The domain X of the Continuous-Variable Dynamic Systems is the set to the real number **R** and $x(t)$

can assume any value from this set, where $x(t)$ is the solution of the differential equation $x'(t) = f(x(t), u(t), t)$, with $u(t)$ the input of the equation and t the time [12].

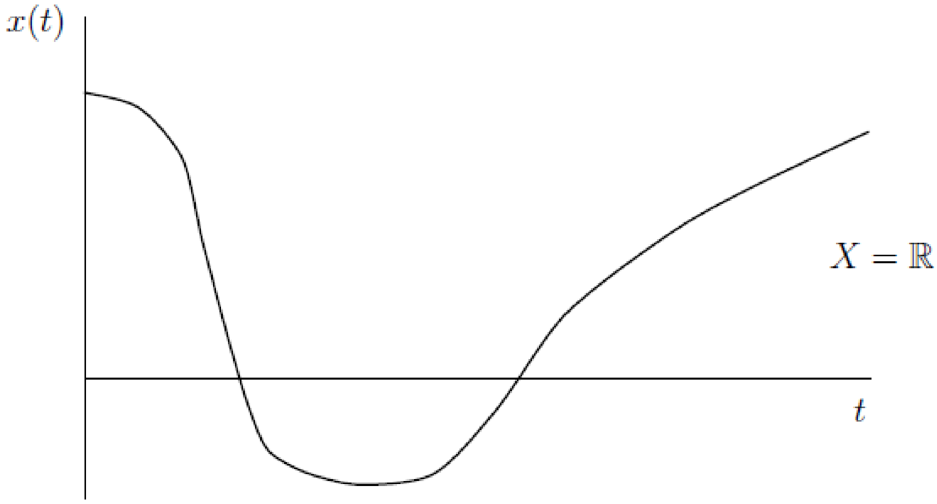


Figure 22 - Continuous-Variable Dynamic Systems (CVDS).

4.2. Simulation Models

Simulation is a numerical technique for conducting experiments on a digital computer, which involves logical and mathematical relationships that interact to describe the behaviour and structure of a complex real-world system over extended periods of time [11].

Replication of a specific operation system can be done through simulators, using specific software in order to obtain same system results. Simulation can be done either for concrete and abstract models.

Concrete models are those size-scaled that allow to take measurements and carry out simulation tests in order to estimate the performances of the system, as for the seismic insulators inside a building, or the performance of a dam in absorbing the energy of waves.

Figure 23 - Example of a concrete model, seismic insulators.

Simulation for abstract models is carried out to replicate the working process of a system. It is based on the concept of reproducing operations through a stochastic system, using probability distributions, to generate random events that make sure to give a certain randomness to the phenomenon that is being studied, and to obtain statistics observations for performance of the system.

The use of simulators to represent a system and the reasons why today this tool is widely used, lies in the fact that simulators can reproduce the real system, even when it is necessary to represent very complex systems, taking into consideration of the uncertain sources. Another reason is to reproduce behavior of a system in relations to situation that are not directly experimental. Allows to make "what – if" evaluations, without effects on the system. It represents an economic saving.

There are several classifications in order to describe better the different simulation models:

A first classification differentiating:

- continues model: state variables that change continuously during the time;
- discrete models, state variables that change during a certain instant of time.

A second classification of the simulation models is defined by:

- Static models: that represent the system in a particular instant of time;
- Dynamic models: when the system changes continuously during the time.

A last distinction is between:

- Deterministic models: do not include probabilistic events;
- Stochastic models: include random components.

Obviously, it is necessary to take into consideration that simulation gives system behavior indications and it does not develop exact answers.

Application fields to simulate real systems using simulators are different as:

- Design and analysis of manufacturing systems;

- Determination of procurement policies of a warehouse;
- Design and implementation of transport systems such as motorways, airports, subways, ports, etc.;
- Analysis of economic and financial systems;
- Determine the critical points (bottlenecks);
- Project of communication systems and related protocols.

To build a simulation model, several aspects have to be taken into consideration, such as:

- Formulation of the problem and goal setting;
- Collect data and model setting;
- Validation model:
    - discussion with expert on the credibility of the model,
    - discussion with expert on data randomness,
- Implementation and realization,
- Pilot run execution and validation:
    - comparison with existing data,
- Experiment design:
    - initial condition (warm-up period),
    - arrest criterion,
    - number of replication,
- Experiment execution,
- Output analysis,
- Any model correction.

4.2.1. Elements of simulation model

As said before, a simulation model needs several elements to be represented. Elements as:

- State variables

The *state variables* are essential elements in the simulation model, because the system is represented by a group of variables in every moment of time. Time is a fundamental component, it can be represented in discrete systems, when the change of the variables takes place according to certain moments of time, and also in continuous systems, when the variables change with continuity of time. So, for example, the number of users within a queued system represents a status variable.

- Events

Event means any instant situation that allows the change of at least one of the state variables. There are different *exogenous events*, i.e. the external to the system, as the arrival of a user to the system, or *endogenous events*, internal to the system, as the beginning of the service to a user already present within the system.

- Entities and attributes

Entity is defined as tangible elements within a real world, system elements, as the user himself, or a server of a queued system. The first one is defined dynamic entity of the system, while the second one is a static entity.

Attributes means intrinsic characteristics of the entities, i.e. specific characteristics assigned to different entities. For example, at a highway tollbooth a car with a smart-pass (e.g.: tele pass) has priority to go through, differently from other queued vehicles, or within a mono-server queued system, where the arrival time of a user is established by a specific instant of time. Therefore, attribute can be considered as the priority of a user to be served before other users, in relation of the arrival time into the system or during an emergency situation.

- Resources

The elements that ensure to provide service to the entities are called *resources*. An entity going inside of a system requires to be served, therefore if resources or the resource (in the case of mono-server) is busy, the entity must go into a queue and wait until the resource is free, according a pre-organized order or defined rules. Examples of resources can be the unload operations of a truck within a warehouse, in this case the user (i.e. the truck) must wait until the unload operations are completed and, subsequently, free up the next resource (i.e. the stall), to the queued user.

- Activity and delay

An *activity* is defined by operations that are known a priori.

Such as the duration of a server operation (i.e. the resource) that can be a constant or an uncertain value defined by a distribution of probability.

Delay means the time spent by the user within the system when it waits in queued system for long time [14].

4.2.2. Simulation to discrete events

The simulation model examined in this studio is based on discrete, dynamic and stochastic simulation models, commonly known as simulation models with discrete events DES (Discrete Event System). DES is based on the evolution of the state that is fully influenced on the occurrence of asynchronous discrete events over time. This type of system satisfies two different properties:

- The state space is a discrete set;
- The state transition mechanism is event-driven.

The domain *X*, for the Discrete Event System (DES), is given by some discrete set as $X = \{s_1, s_2, s_3, s_4, s_5, s_6\}$ and *x(t)* is a constant function, because the sample path can only jump from one discrete value to another, whenever an event occurs. Not always when an event occurs there is a state transition indeed how is shown in figure 24, in the instant t_3 when the event e_3 occur, it does not change the situation.

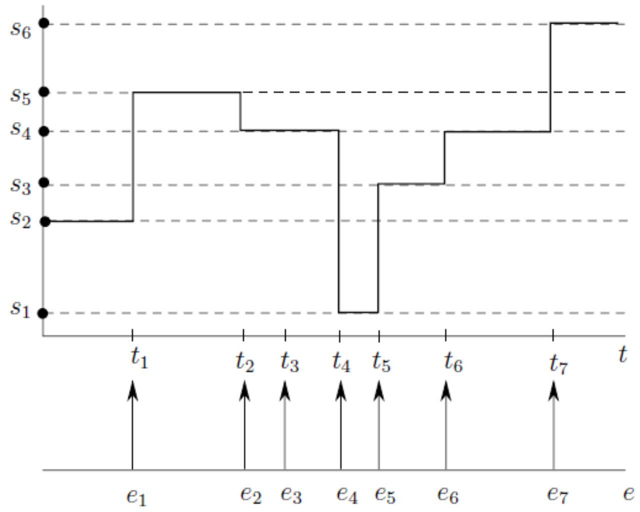


Figure 24 - Discrete Event System (DES).

As the figure 24 show, each event occurs at a specific time, so event e_1 occur at time t_1, event e_2 at time t_2 and so on. This particular situation is a "deterministic" system, because the next state, after the occurrence of an event, is unique. Consider a sequence of time and event as *(e_1, t_1), (e_2, t_2), (e_3, t_3), (e_4, t_4), (e_5, t_5), (e_6, t_6)* this set is the *timed language* model of the system.

Inside this set of time and the relative event, statistical information can be included such as some kind of probability distribution function, to give a stochastic elapsed time between successive occurrences of each event. In this case, the timed language model of the system, with associated probability distribution functions for the events, is call *stochastic timed language*. The stochastic timed language, lists all possible sample paths together with relevant statistical information about them.

Stochastic timed language modelling is the most detailed model of system, because it contains different information, such as:

- information in the form of event occurrences and their orderings;
- information about the exact times at which the events occur;
- statistical information about successive occurrences of events.

In relation to the timed language the *untimed (or logical) language* or, in a simply way, *language* is obtained only if the timing information is neglected. That is the set of all possible orderings of events that could happen in the given system, without considering the time and, consequently, without considering the ordering of each occurrence, for example $(e_1, e_2, e_3, e_4, e_5, e_6)$.
Language, *timed language* and *stochastic timed language* represent the three level of abstraction at which Discrete Events System is modelled and studied.

Obviously, in the thesis work we are interested in the "logical behaviour" of the system, so, the precise sequences of *ordering of events* that occurs (e.g., first-come first-served in a job processing system). Indeed, large researches have been done for the Discrete Events System as for modelling, analysis, control, optimization and simulation at all three levels of abstraction [12].

4.2.3. Queuing Theory

The Queuing Theory gives the opportunity to study and develop models based on the waiting phenomena given by the demand and the service.

Application fields of this theory are various and belong to transport, communication or elaboration system, such as:

- the bank customers;
- the vehicles at a junction;
- the vehicles at a mechanic;
- the airplanes waiting to take off or land;
- the goods handled inside a warehouse.

This theory is based on the probability concepts of the random variable, that can be **discrete** when the entity X can assume a discrete finite or infinite number of values and each value of x_i has the probability to occur $P(X = x_i) = p_i$, where $\sum_i p_i = 1$.

On the other hand, the random variable can be **continuous** when the entity Y can assume a y value of a subset S of the real line, composed by one or more intervals. The amplitude of each infinite interval dy has the probability $P(y < Y \leq y + dy) = p(y)\, dy$, that Y can assume a value of this interval. The function $p(y)$ is the density function that has $\int p(y)\, dy = 1$.

These random variables, whose values and probabilities are time-function, are a stochastic process. The temporal trend of a stochastic process take place in a discrete or a continuous way, for example, the number of people in the queue changes at discrete instant during some events, while the time between the inter-arrival of customers changes with continuity.

The queue system, from a physical point of view, is composed by the resources that give a service to entity (e.g.: the customers) and by the waiting area able to hold the entity.

When the entity finds the resources busy, it has to proceed in a queue and wait according to the service rules.

The stochastic processes that regulate the queue, from a dynamic point of view, are given by:

- the arrival process;
- the service process.

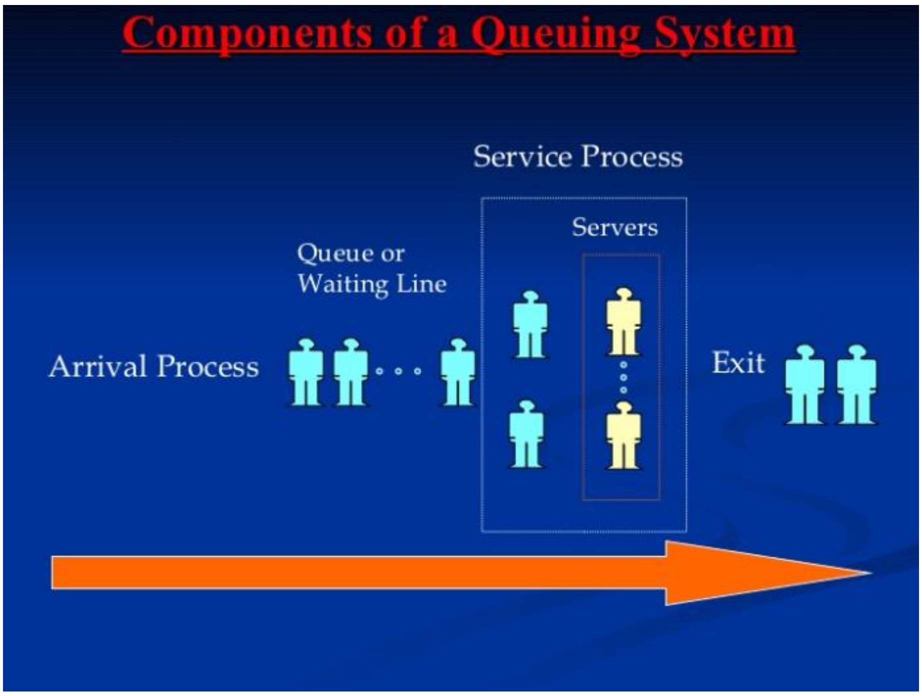


Figure 25 - Example of queuing system.

Inside the queue there are different type of elements that define the waiting phenomena. Element as:

- Population

The population is represented by the entity and it can be finite or infinite.

- Arrival process

As previously described, it is a stochastic process that provides the inter-arrival time between two consecutive entity inside a system. This process can be deterministic or stochastic.

- The queue

It is defined by the entities or users inside the system and it is known as buffer, that includes also the number of servers. The capacity of the buffer can be finite or infinite.

- $K \epsilon N^{+}$
- $K = \infty$

In the case the queue has a finite capacity, if the user arrives when the buffer is saturated, they are rejected. As, for example, when the maximum number of parking places is reached.

- The server

Their number is known a priori, and it is fixed at project level. They usually have the same characteristics and work in parallel. If there are different servers, a common buffer for all the entity is used, even though can be used different buffers when there are more servers, and each user inside different buffer has to do different operations.

- The service process

In this process is described the way through which the server gives the service, it defines the duration of the process and it can also be deterministic or stochastic. So, it describes the service time of each server. The service process is conditioned by the arrival process; indeed, a user can be served only if it has arrived inside the system.

- The service rules

They define which entity will be served between those waiting when a server will be free. The service rules, very common in the reality and easily usable in mathematics, are:

- FCFS or FIFO (first-come first-served or first-in first-out);
- LIFO (last-in last-out);
- SIRO (service in random order);
- PR or PRI (service based on class of priority);

In 1953, David George Kendall introduced a useful notation for the immediate description of the queue system, called *Kendall notation,* defined as A/B/c/K/m/Z, where each letter indicates:

- A inter-arrival distribution;
- B service time distribution;
- c number of service;
- K system capacity (default: infinite);
- m dimension of the population (default: infinite);

- Z service rules (default: FCFS).

Particularly, the notations A and B can replace by the following letters:

- M exponential distribution (Markovian);
- D constant distribution;
- E_k Erlang distribution;
- G generic distribution;
- GI generic distribution of independent event for the arrival.

For example, M/M/1 stands for M/M/1/∞/∞/FCFS, queue with Markovian process for the service and arrival, one server, infinite system capacity and arrival process and first-come first-served for the service rules.

The queue theory identifies some performance indicator, such as:

- L_s average numbers of entity inside the system (both the waiting one and those receiving);
- L_q average numbers of entity waiting to be served;
- W_s average waiting time of entity inside the system (both the waiting one and those receiving);
- W_q average numbers of entity waiting before to be served;
- p_n the probability that *n* users are inside the system;
- ρ utilization factor of the servers (relationship between the time spent for the and the total time available).

The value assumed by the indicators are parametrically dependent from the queue structure and the arrival rate of the entities. Therefore, the planners should be able to determine the characteristics of the queue, such as the number of servers and the speed to do it. Once the performance indicators are known, the aim of the planners is to minimize the cost to realized it [13].

4.2.4. Arena Simulation

There are many interactive software packages for high-level simulation such as ARENA, WITNESS, EXTEND, MICRO SAINT, PROMODEL, AUTOMOD, FLEXSIM, MODSIM etc., those are packages for application-oriented simulation. Through these simulators the analysts are free from the times spent in the programming phase, in this case they use graphical menus. Some of these simulators are generic with the possibility of using the same for different fields of application, while others are specific to the same field as that of the nuclear centers simulators or the cardiovascular physiology simulators. They are easy to learn but, having standard features, there is a limitation in the modelling phase and, therefore, the absence of customization [14].

Arena is a simulation software package produced by Rockwell Automation, Inc. The Arena modelling system is a flexible and powerful tool that allows analysts to create animated simulation models that accurately represent virtually any system. To create simulation models that represent accurately and virtually a real system, the Arena modelling system is an important tool for the analysts. This system is based on a the SIMAN simulation language.

The Arena system provides specific modules based on different fields, such as manufacturing and material handling; these specific models are in addition to other core features for resources, queueing, inspection, system logic, and external file interface.

In relation to the manufacturing, Arena contains this type of modules referred to machine downtime and maintenance schedules. While for material handling, the modules are referred to representing conveyors (synchronous and asynchronous) and various types of transportation devices.
To allow these features Arena is composed by three different panels, such as:

- the Common panel, containing modules for the fundamental simulation process (arrivals, services and departures);
- the Support panel, containing modules for specific actions and the decision logic;
- the Transfer panel, containing transfer (or flow) modules for the entities through the system.

A useful tool of Arena, the input analyzer, is used to determine an appropriate distribution function for the input of the model. So, the input analyzer allows the user to take raw data and fit it to a statistical distribution to be included directly inside the model.
Once the model is created through Arena, and after the simulation run process has been performed, the output analyzer provides analysis features, such as the confidence interval or the variance, used by the analyst [15].

4.3. Forecast

In different fields the use of data from a series of events, implies the knowledge of the evolution of a certain system, such as the airport, the warehouse, the use of vehicle in the city, etc., these data are at the base of the time series. They are a sequence of numbers $x_1, x_2, \ldots, x_n$ it must have a temporal trend of a certain value (e.g.: economic, financial, physical, etc.). The numbers *1, 2, …, n* of the sequence are discrete values over time, such as, for example, the air cargo forecast, these values are referred to the annual tons handled in a certain airport related to the *n* years or, in the same way, what normally happens in a financial environment [16].

The aims of the time series are two:

- **analysis**, find the series characteristics (e.g.: trend or repetitive events);
- **forecast**, allow to calculate, at least approximately, the future values of the time series.

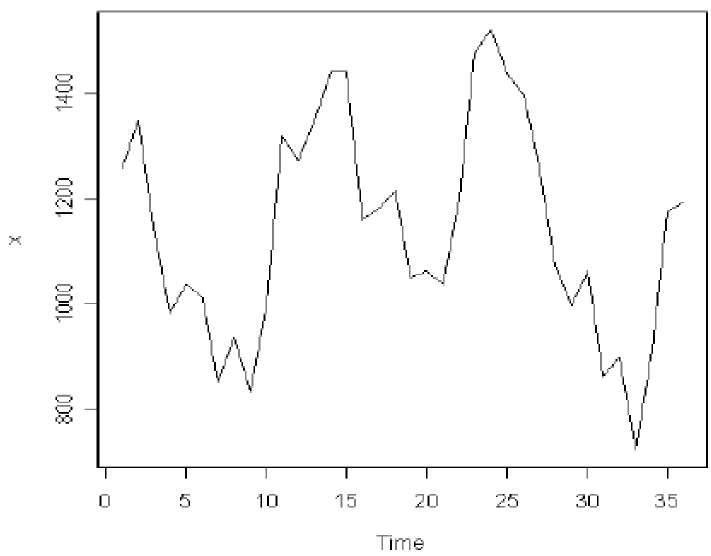


Figure 26 - Example of time-series.

4.3.1. Regression Analysis

Regression Analysis is a statistical technique for estimating relationships between a dependent variable and one or more independent variables. Considering that a cartesian coordinate system has the independent variable on the abscissa axis and a dependent variable on the ordinate axis, the regression analysis explains how the typical value of the dependent variable changes when any one of the independent variables is varied, while the other independent variables are held fixed. The dispersion diagram is used to find the relationship between the two variables, and it can be express through mathematical function with a regression model. The choice of the correct mathematical model is given by the distribution of the values inside the dispersion diagram, such as the linear distribution, the inverse linear distribution, the polynomial distribution, the inverse polynomial distribution, the curvilinear one or without relation between the two variables X and Y. If we are looking for a linear regression, the least squares method, allow us to determine the equation of this line, known as the regression line or the least squares [17].

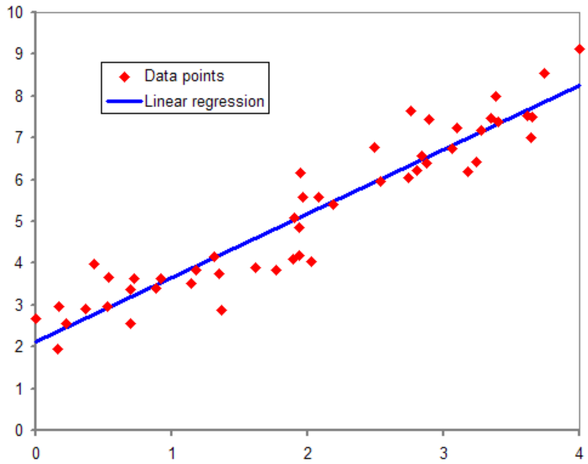


Figure 27 - Example of linear regression.

$$\boldsymbol{Y}_i = \beta_0 + \beta_1 \boldsymbol{X}_i + u_i$$

- i change between observation $i = 1, 2, \ldots, n$;
- $\boldsymbol{Y}_i$ is the variable dependent;
- $\boldsymbol{X}_i$ is the variable independent;
- $\beta_0 + \beta_1 \boldsymbol{X}_i$ is the regression line or the population regression function;
- β_0 is the intercept of the population regression line;
- β_1 is the angular coefficient of the population regression line;
- u_i is the statistical error.

Regression analysis is widely used for the forecasting, to understand which independent variables are related to the dependent variable and to explore the forms of these relationships.

As well as time-series, regression analysis is a useful tool to evaluate historical trend of the variables over time.

5. Application to the case study of Milano Malpensa - Cargo City

The methodology mentioned in the previous paragraph, has been applied to the specific case of study of Milano Malpensa Cargo City. In particular, the simulation of all logistic processes, has been carried out within the warehouse of Alha Group, considering three different scenarios, the current one and other two different scenarios based on the future projection up to 2030.

5.1. Input data

The input data collection used for this study, have been provided by different resources, such as Assaeroporti, Service Charter of Milano Malpensa Cargo and experts in the air cargo field, as the Cargo Manager of the SEA Milano Malpensa Airport.

The study has been conducted dividing it into two different parts, analysing in detail:

- freight forecast;
- data for the simulation model.

5.1.1. Freight forecast

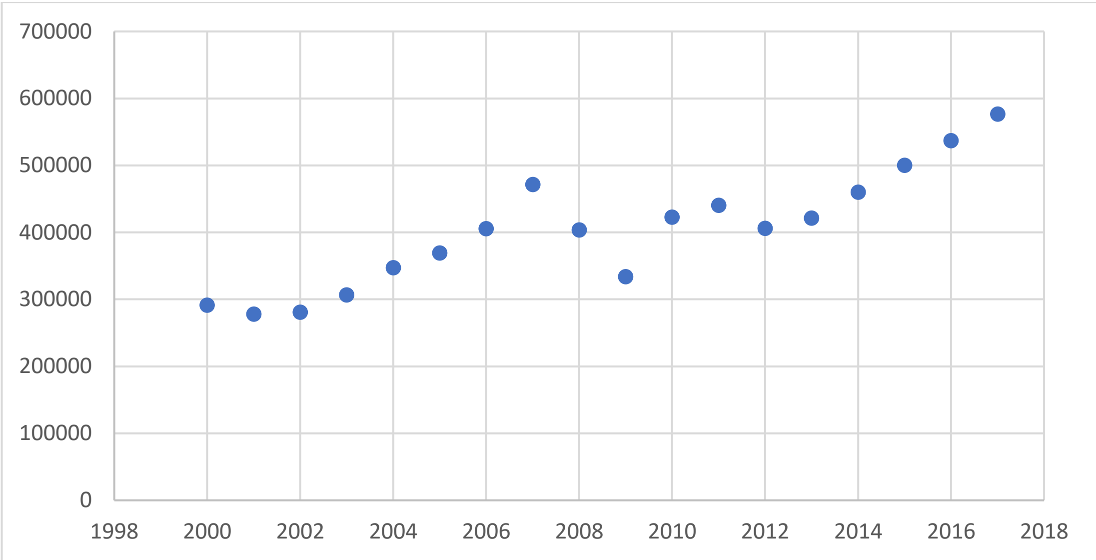
Air cargo forecasts allow to estimate possible future results and give more information to the planners, in order to provide improvements that cargo facilities might need. For this reason, cargo forecast is one of the most important part of an airport's master planning activity [17]. The freight forecasts are referred to the traffic data provided by ENAC (Ente Nazionale Aviazione Civile) and Assaeroporti annual/monthly statistical report. ENAC is the Italian authority for technical regulation, certification and supervision in the field of civil aviation under the control of the Ministry of Infrastructures and Transport, while Assaeroporti is the association of Italian airports, representing 33 airport management companies for 42 airports at Italian and European institutions.

The preliminary phase of this study has been conducted by analyzing the trend of the freight in the last seventeen years, so since 2000, when the first significative results of Milano Malpensa have been recorded, in terms of tons handled, as reported in the table 5.

Years	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Tons	290.980	277.591	280.420	306.623	347.065	368.976	405.452	471.147
Years	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Tons	403.585	333.721	422.429	440.258	405.858	421.277	459.696	500.054
Years	**2016**	**2017**						
Tons	536.862	576.539						

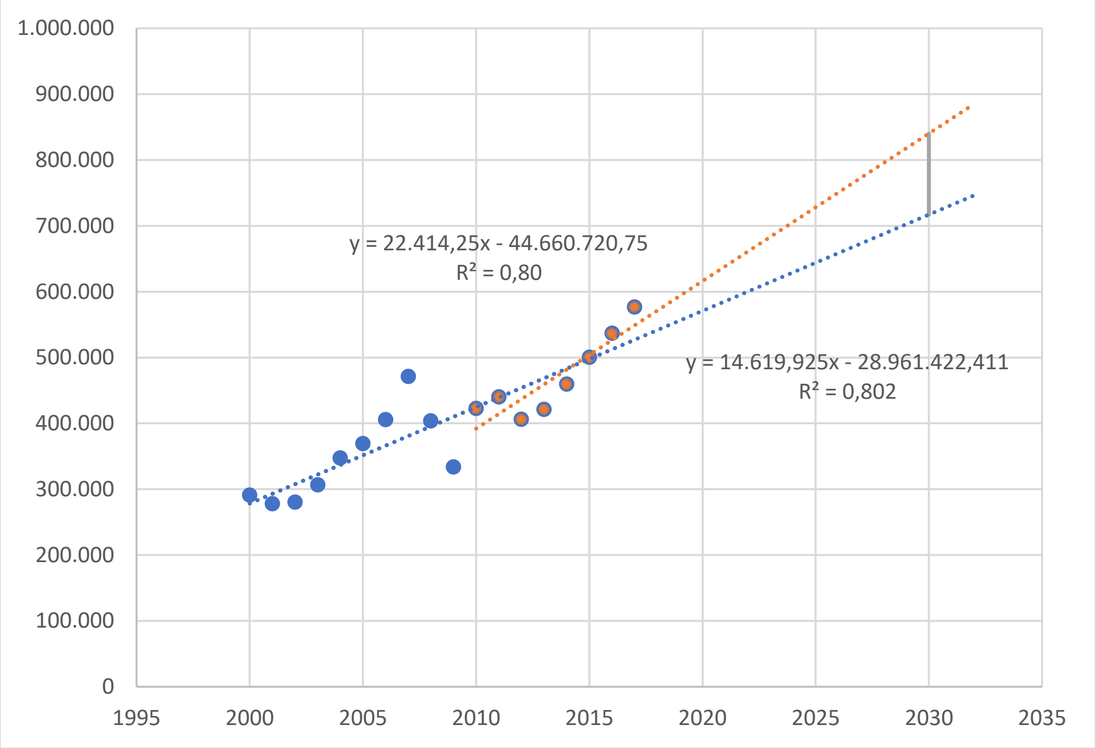
Table 5 - Annual tons handled in Milano Malpensa from 2000 to 2017.

These data have been used to outline the sequence of events which, as shown in the graph 6, represents how Milano Malpensa Cargo City has grown over the years in terms of tons.



Graph 6 - Time series of Milano Malpensa between 2000 and 2017.

These time series have been analyzed by the linear regression method, considering two different projections; the first one is based on the whole period of time (2000-2017), while the second one on the trend of the last eight years (2010-2017) [19], that is the period after the crisis. These two projections are shown in the figure 7 and is possible to define a minimum and a maximum future estimate value. The blue line shows the minimum future projection, with a strong correlation indicator greater than 0,7 (R^2 = 0,802). Also, the red one showing the maximum future projection, have a strong correlation indicator greater than 0,7 (R^2 = 0,80). The table 6 shows the tons handled in 2017, in 2030 (considering the minimum future projection) and in 2030 (considering the maximum future projection), call respectively current scenario, scenario 1 and scenario 2. Table 7 shows the increment in percentage from the current scenario to the two future scenarios.



Graph 7 - Maximum and minimum values for 2030, using linear regression.

Year	Tons	Scenario
2017	576.539	Current scenario
2030	717.025	Scenario 1 (minimum future projection)
2030	840.206	Scenario 2 (maximum future projection)

Table 6 - Maximum and minimum trend lines.

Scenario	Percentage variation %
Scenario 1	24,37%
Scenario 2	45,73%

Table 7 - Tons percentage increment from current scenario to scenario 1 and 2.

5.1.2. Data for simulation model

The inputs to be provided to the Arena simulator are relative to the number of trucks that daily carry out the loading/unloading operations inside the Alha Group warehouse, located inside the Cargo City, and the number of airplanes that weekly unloads the goods inside the Milano Malpensa Airport. First an average capacity for the truck and for the airplanes has been assessed.

Airplanes

Various air companies, working with Alha Group, use different kind of airplanes, with the capacity listed in table 8.

Airplane type (C = All Cargo) (P = Passengers)	**Maximum capacity [tons]**
Boing 747-8 (C)	120
Boing 777-F (C)	90
Airbus 300-F (C)	45
Boing 777 (P)	14
Boing 757 (P)	5
Boing 737 (P)	2 – 6
Airbus 319 (P)	1
Airbus 320 (P)	2

Table 8 - Maximum capacity of airplanes.

The number of flights per week, for all-cargo aircraft, has an average of 34, while for passenger airplanes there is an average of 33 flights/weeks. Between the two types of aircraft, the number of tons moved is distinctly different, even having the same number of flights. As described with the formula below, the weight (W) that can be load inside the aircraft, in relation to their maximum capacity, is 45 tons, which must be respected in order to avoid economic loss [3].

$$W = \frac{n^\circ\ cargo\ flight \cdot avg\ of\ max\ cargo\ capacity + n^\circ\ pax\ flight \cdot avg\ of\ max\ pax\ capacity}{n^\circ\ cargo\ flight +\ n^\circ\ pax\ flight}$$

The goods are composed in ULDs to be loaded inside the airplanes; there are different type and dimension of ULDs, with an average size of 3.112 kg ≅ 3 tons. Table 9 lists the different types of ULDs, the suitable airplanes and their relative gross weight.

ULD type	Airplanes	Max gross weight [kg]
LD3-AKE	Boing 777, 757	1.588
LD9-AAP	Boing 777-F, 747-8	6.033
LD11-ALP/PLA	Boing 777, 747-8	3.175
PAP/P1P/PAG	Boing 757	4.264
AKH	Airbus 319, 320, 300-F	1.134
PMC	Boing 747-8	5.034
LD2-APE	Boing 737	1.225
AQF	Boing 737	2.449

Table 9 - ULDs types.

Through the data reported in tables 8 and 9, has been calculated the input values for the simulation model, which precisely corresponds to the average interval of time between the consecutive arrival of two airplanes.

Scenarios	Weekly flight	Daily flight	Max airplanes capacity [tons] (n° ULD)	Tons per ULD	Average of inter-arrival time between airplanes [h]
Current Scenario	67	9,52	45 (15)	3	2,52
Scenario 1	83	11,84	45 (15)	3	2,03
Scenario 2	97	13,88	45 (15)	3	1,73

Table 10 - Inter-arrival time of the airplanes for Alha Group.

Table 11 shows the values of the weekly/monthly/annual imported tons, handled by Alha Group, according to the different scenarios.

Scenarios	Weekly tons	Monthly tons	Annual tons
Current Scenario	3.000	12.000	144.000
Scenario 1	3.731	14.924	179.089
Scenario 2	4.372	17.488	209.855

Table 11 - Weekly / Monthly / Annual imported tons.

Truck

Once the import values are known, is possible to determine the export data for the Alha Group Airport handler, in relation to the total tons moved within the Milano Malpensa Airport (divided into those moved by Traffic Currier and those by airport handlers). Indeed, is possible to calculate the annual export tons handled by Alha Group, knowing that, them manage the 75% of the total tons in Malpensa without considering those handled by the Traffic Currier, and then subtract this value with the annual import of Alha Group, as shown in table 12.

Scenarios	**Annual tons handled**			**Annual tons handled by Alha Group**		
	in Milano Malpensa Airport	**by truffic couriers**	**by handlers**	**import**	**export**	**total**
Current Scenario	576.539	43.000	533.539	144.000	256.154	400.154
Scenario 1	717.025	53.478	663.547	179.089	318.572	497.660
Scenario 2	840.206	62.665	777.541	209.855	373.301	583.156

Table 12 - Subdivision of the freight handled in Milano Malpensa Airport.

Through this export data is possible to evaluate the average number of tons, to be provided to the simulation model, that each truck transports inside the warehouse of Alha Group. This data, shown in table 13, is given by the ratio between the daily export tons handled by Alha Group and the average number of daily trucks. The table 13 provides an additional input data, related to the number of inter-arrival time of the trucks in the warehouse.

Scenarios	Export tons handled by Alha Group		Average n° of daily truck	Tons per truck	Average n° of truck per hour	Inter-arrival time between truck
	Monthly	Daily				
Current Scenario	21.346	712	420	1.69	18	3.42
Scenario 1	26.548	885	522	1.69	22	2.75
Scenario 2	31.108	1.037	612	1.69	26	2.35

Table 13 - Inter-arrival time of the trucks for Alha Group.

Other input data

In order to describe all the operations carried out within the cargo area (landside and airside), the simulation model needs the following information:

- the unloading operations of the goods from the truck (40 minutes);
- the loading operations of the goods on the truck (40 minutes);
- the unloading operations of the goods from the airplane (90 minutes);
- the loading operations of the goods on the airplane (90 minutes);
- the radiogenic control operations for one ton of goods (4 minutes);
- the palletization operations (30 minutes);
- the depalletization operations (30 minutes).

All the data refer to the average time.

5.2. Formulation of the simulation model

In the development of the simulation model, created through the application software "Rockwell Arena Automation", has been considered a certain randomness in different operating processes, to generate various scenarios that represent the operation of the system; so, it is essential that a simulation generates random observations from probability distributions.

In the specific case, several processes have been analyzed, such as:

- inter-arrival time;
- service time;
- logical processes.

5.2.1. Inter-arrival time

The processes related to the arrival time, have been considered according to the average values concerning the arrivals of the trucks and the airplanes, calculated in the previous paragraph. In both cases, the same basic assumptions have been considered for the choice of probability distribution.

In the present case, there was a difficulty to carry on surveys on site, to evaluate the real trend of the inter-arrivals time between a truck or an airplane, in order to find the correct probability distribution of such intervals. The only available data was the average interval between two subsequent arrivals. Therefore, as the literature suggests, we can assume that customers (trucks or airplanes) arrive one at a time to a service system and the number of customers arrive at separate and independent intervals. Then there are theoretical reasons (memoryless property) to assume that the times of inter-arrival are independent random variables and identically distributed according to a Poisson process, with an exponential distribution for the inter-arrival time.

In the practical cases there are queues with inter-arrival times having exponential distribution, which is the one that has a greater application and that has a better tractability from a mathematical point of view.

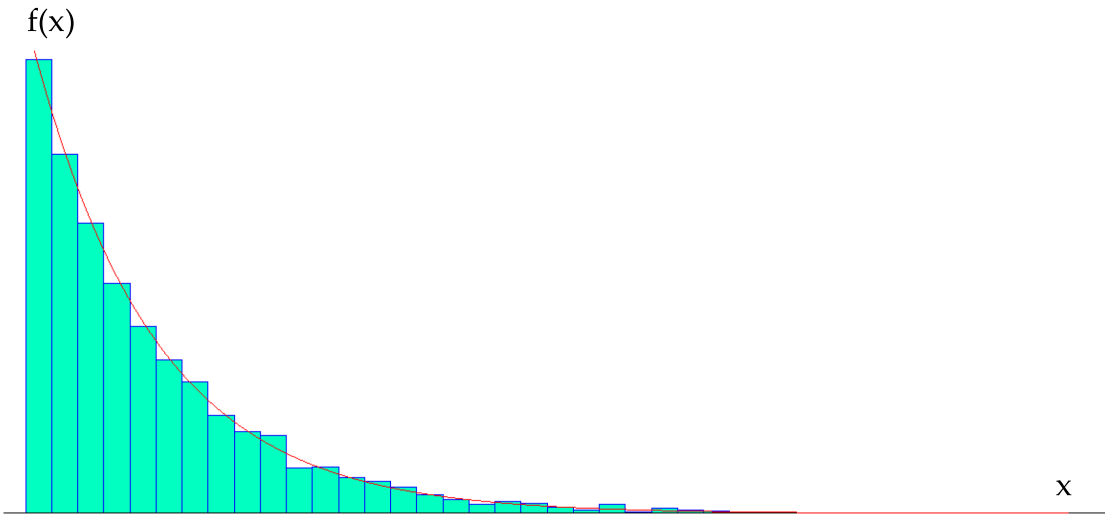
A random variable X has exponential distribution, with parameter $\lambda > 0$, when its PDF (Probability Distribution Function) $f(x)$ and the CDF (Cumulative Distribution Function) $F(x)$ are respectively:

$$f(x) = \begin{cases} \lambda e^{-\lambda x} & for\ x > 0 \\ 0 & for\ x \leq 0 \end{cases} \qquad F(x) = \begin{cases} 1 - e^{-\lambda x} & for\ x > 0 \\ 0 & for\ x \leq 0 \end{cases}$$

The inter-time between two subsequent events, related to the same process, can be modeled with an exponential random variable, if the following conditions are satisfied:

- The probability that an event occurs within an infinitesimal interval time dx, is proportional to dx;
- The probability to have more than one event in an infinitesimal interval time dx, is equal to zero;
- The probability that the next event will lag beyond a given limit, does not depend on how long the previous event occurred (Markov property refers to the memoryless property of a stocastic process).

The graph of random variables, shown below, is relative to the inter-arrival time of trucks, which follow an exponential distribution, generated random by a uniform distribution $U = UNIF(0,1)$, then have been set $U = F(X)$, with $F(X)$ the CDF of exponential distribution, and solved for $X = F^{-1}(U)$. This procedure has been carried out also for the airplanes, and the future scenarios.



Graph 8 - The goodness-of-fit for the sample data.

Through "Input Analyzer" (tool of the Rockwell Arena Automation software), the **goodness-of-fit** of the random data generated has been analyzed, and the exponential distribution resulted the best curve as deducted from the tests carried out by the tool (Chi Square test and Kolmogorov-Smirnov test). The relative values of the tests are reported in figure 28.

```
        Distribution Summary

Distribution:   Exponential
Expression:     EXPO(3.43)
Square Error:   0.000084

Chi Square Test
  Number of intervals   = 24
  Degrees of freedom    = 22
  Test Statistic        = 15.1
  Corresponding p-value > 0.75

Kolmogorov-Smirnov Test
  Test Statistic        = 0.00674
  Corresponding p-value > 0.15

        Data Summary

Number of Data Points   = 4028
Min Data Value          = 0.000104
Max Data Value          = 28.9
Sample Mean             = 3.43
Sample Std Dev          = 3.38

        Histogram Summary

Histogram Range         = 0 to 29
Number of Intervals     = 40
```

Figure 28 - The report of "Chi Square" test and "Kolmogorov-Smirnov" test.

Figure 29 represents the command *Module Create* inside the Arena Simulation Software for truck, that are referred to the current scenario. Also in the forecast scenarios the same procedure has been carried out, in order to know the correct distribution fuction to be considered for the simulation model, as shown in table 14.

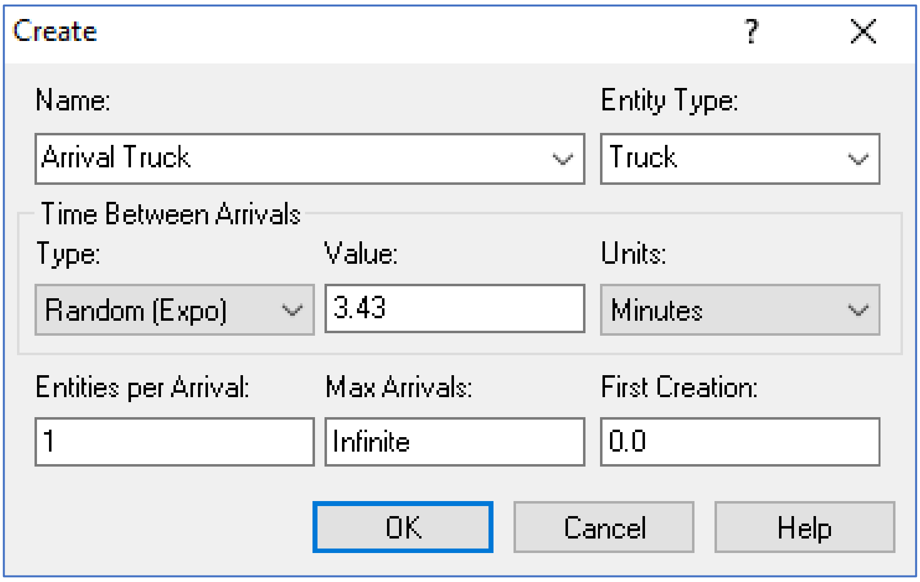


Figure 29 – "Module Create" of Rockwell Arena Automation.

Scenarios	**Inter-arrival time ditribution**	
	Truck	**Airplane**
Current Scenario	EXPO (3.43)	EXPO (2.52)
Scenario 1	EXPO (2.75)	EXPO (2.03)
Scenario 2	EXPO (2.34)	EXPO (1.70)

Table 14 - Input for the inter-arrival time distribution to be insert on Rockwell Arena Automation.

5.2.2. Service time

In the case of study, this entity refers to the truck or airplane. As far as the truck is concerned, each pallet of goods to be unloaded has been assumed equal one ton. The unloading operations take place in the appropriate truck-dock, where it is considered a triangular distribution for the number of pallets inside the truck, depending on the average value of tons per truck, calculated in the previous paragraph. Then the command *Separate Module* has been used, as shown in figure 30. The service time refers to the average number of pallets unloaded from the truck in one hour through the forklift. This value is equal to 4 pallets/h. To carry on the unloading operation, have been used 18 forklifts, one for each truck-dock, the same for the loading operations.

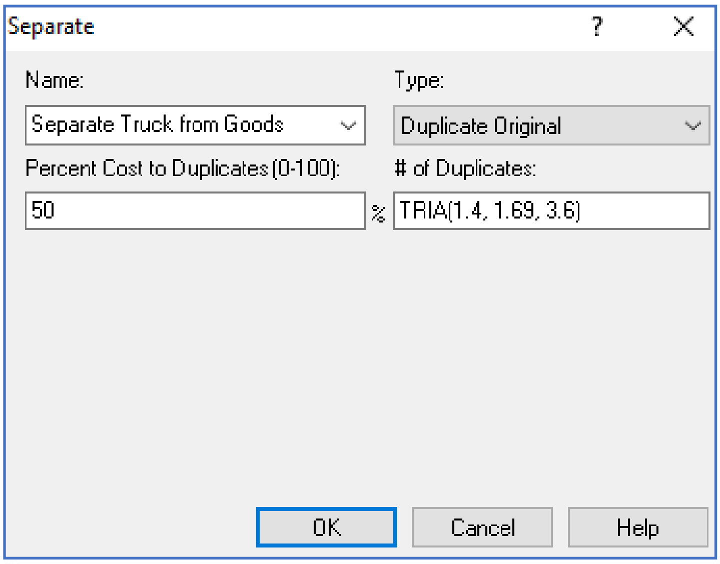


Figure 30 – "Module Separate" of Rockwell Arena Automation.

As regards the loading and unloading operations of the airplane, have been considered a constant distributions with values calculated in the previous paragraph, equal to 45 tons per airplane. This value refers to 15 ULDs, taking into account an average of 3 tons for each ULD. The service time is related to the average number of ULDs loaded and unloaded from/to the airplane in one hour through 7 transporters, one for each apron. This value is equal to 10 ULD/h.

Other service times, within the system, are related to the Radiogenic control and palletization/depalletization, where for the first one has been considered a value of 15 pallets/h. While, for the palletization and depalletization processes, have been defined a service time through a triangular distribution with the command *TRIA (Min, Mode, Max)*, as shown in figure 31.

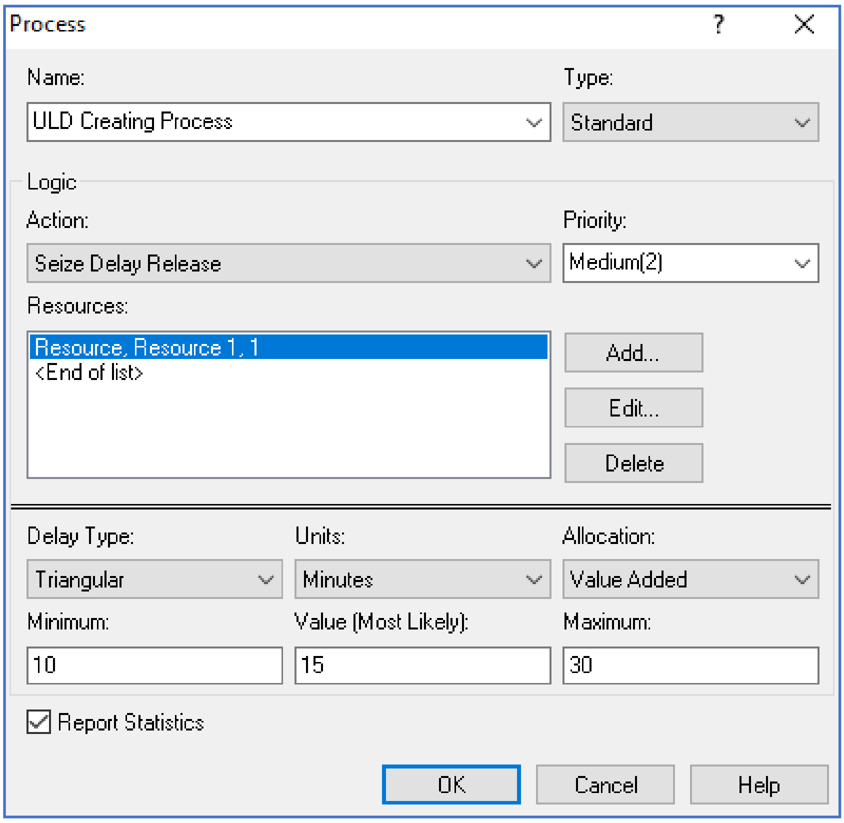


Figure 31 – "Module Process" of Rockwell Arena Automation.

In relation to the handling time of the goods inside the warehouse and the airside, have been considered the average values in time unit for the pallets (moved by forklift, from the export warehouse to the ULD Handling System and from this last one to the import warehouse) and for the ULDs (moved by the dollies, 15 at a time, from the export stacker/staging area to the airplane and from here to the import stacker/staging area). So, for the first operation, the value assumed is equal to 6 pallets/h, while, for the second one, the value assumed is equal to 75 ULD/h. To carry on the palletization operation, 12 forklifts have been used, one for each UHS, the same for the depalletization. While, have been used 7 dollies for the operation from the export stacker/staging area to the airplane, and other 7 from the airplane to the import stacker/staging area, one dolly for each apron for both operations.

5.2.3. Logical processes

To reproduce the real situation in the simulation model, different variations have been made from the real processes, in order to simplify the model and to better analyze some specific situation, concerning different processes, that, with more details, it would have been more complicated in relation to a greater amount of data to be processed and they would have carried a greater distortion of the output data.

Once specified the inter-arrival distribution time and the service time, already discussed in the previous paragraphs, the simulation model is created.

The fundamental logical processes used into the simulator, refer to decisions taken by different entities. The first decision is submitted to the truck entity, which has to decide whether to go to the truck-dock available to carry out the unloading operations, or, if all the truck-docks in the warehouse are busy, proceed to the queue and await one's turn. Once the truck has carried out the unloading operations, 64% of the truck exit the system, the remaining percentage (36%) take place in the truck-dock for the loading operations in the import area of Alha Group warehouse; percentages referred to the difference between the tons moved in import and export. The logical processes that describe these situations are shown in the next two flowcharts in figures 32 - 33.

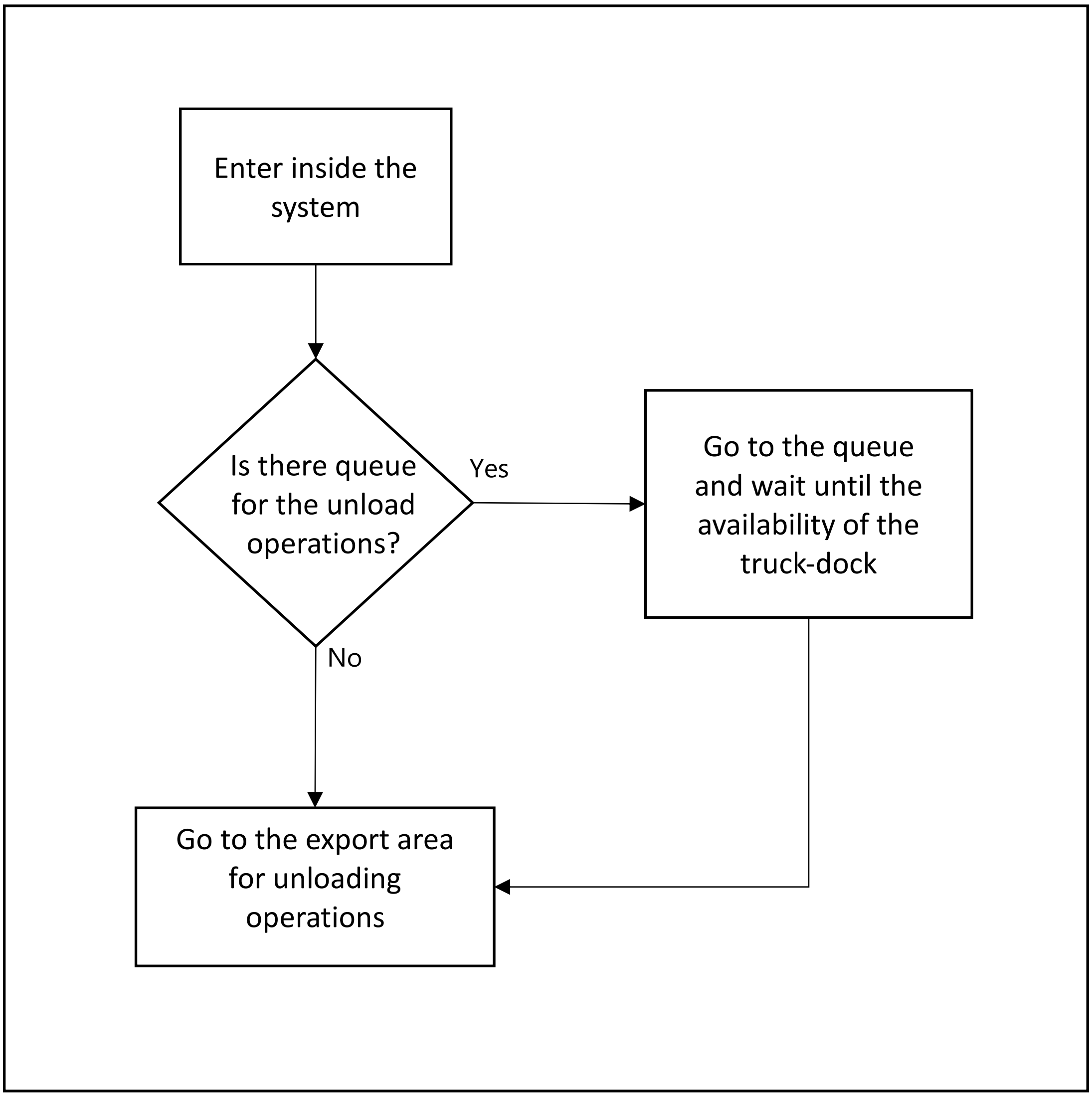


Figure 32 - Logical process for the truck when arrive into the system.

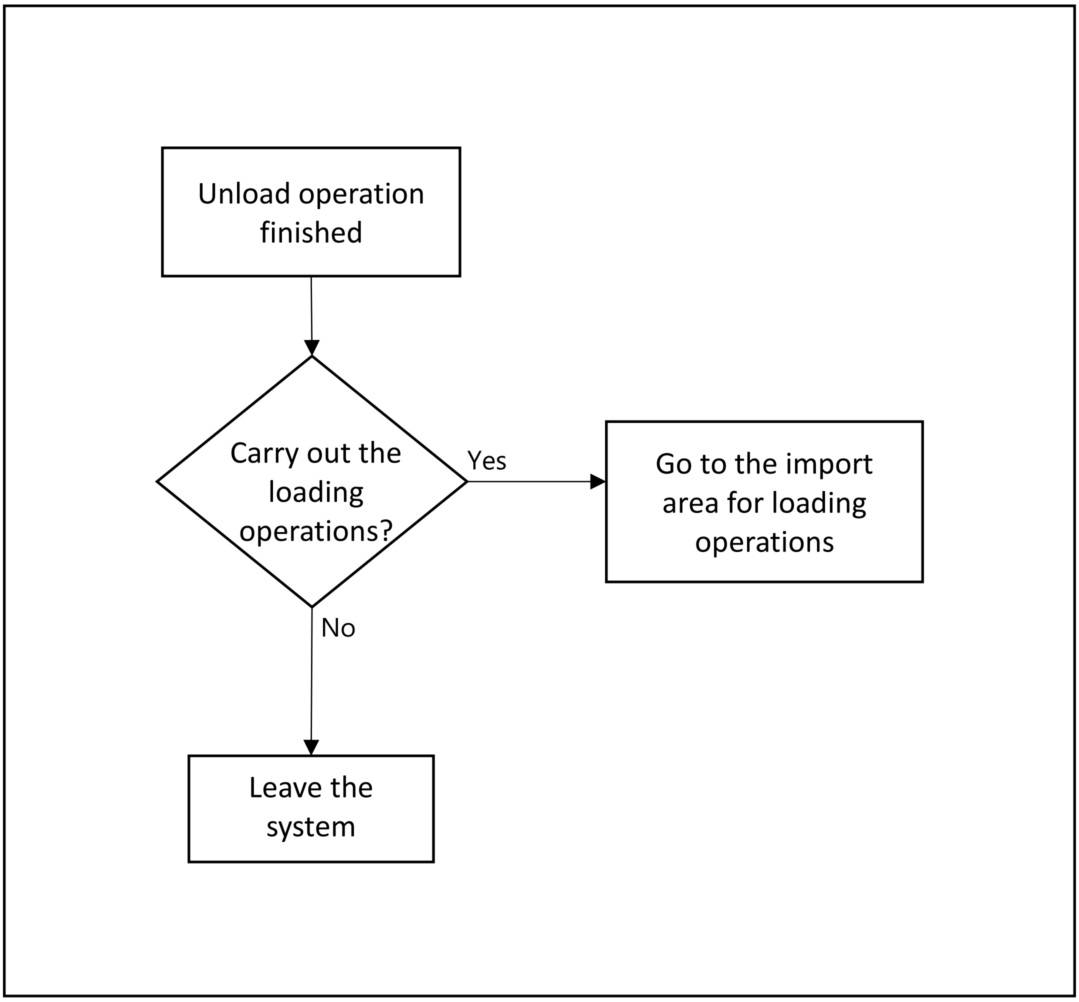


Figure 33 - Logical process for the truck when finish the unloading operation the system.

Further fundamental elements, which have been reproduced in the model, are related to the queues that occur at certain critical points of the Alha Group warehouse in Milano Malpensa. Completed the unloading operations of pallets from the truck, the following operations occur:

- the handling operations of the goods within the system, moving them through the radiogenic control;
- the export area of the warehouse, the palletizing operations;
- the stacker/staging area;
- the load on the airplane.

These operations have the same logical processes, based on sequential behavior, without considering decisions by the entities, such as pallets or ULDs. The entities will be processed, one after the other, following a fixed path; the same considerations also apply to the opposite process (from the airplane to the truck).

5.3. Simulation scenarios

Once analyzed the input data and the different probability distributions useful for the simulation, the system has been modelled through “Rockwell Arena Automation”, taking into account all the processes that Alha Group carries out inside its cargo area, already discussed in the third chapter.

The aim of this study is to determine the average waiting time in the queue system of the different entities, such as trucks, airplanes, pallets and ULDs, in relation to the different scenarios considered, and comparing those values with a certain level of service define by the Milano Malpensa Airport.

Different areas have been identified where these queues occur, such as:

- the truck parking area;
- the radiogenic control area;
- the export warehouse area;
- the stacker and staging area;
- the import warehouse area.

The figure 34 shows the different areas.

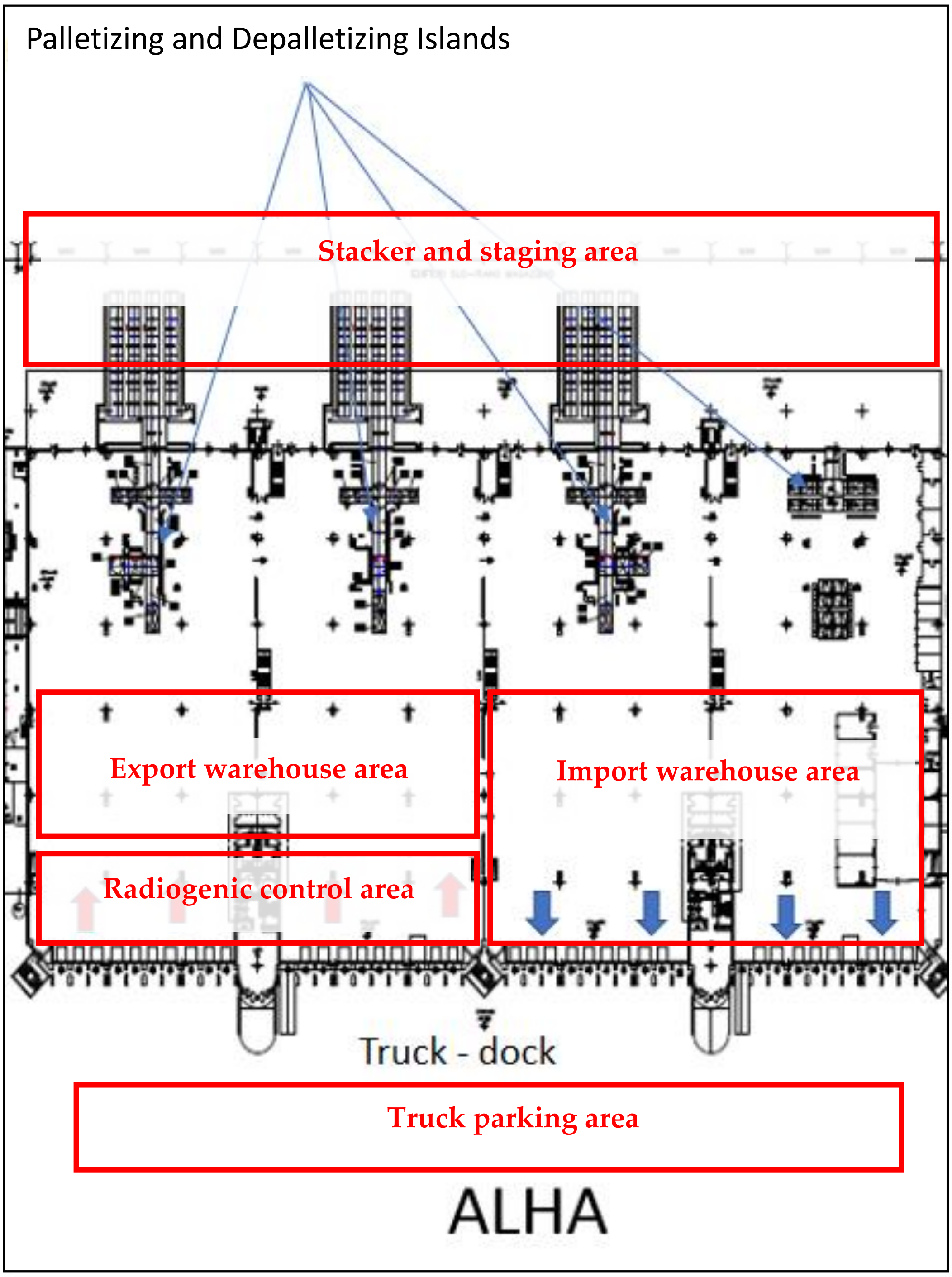


Figure 34 - Subdivision of the Alha Group terminal areas.

In the current system of the Milano Malpensa Cargo City, are defined the correct level of service for the average waiting time in queue, for the different operations.

Waiting time for the trucks in the parking area

These values are according to the maximum time, equal to two hours, that the driver of the truck can wait before being indemnified, *"according to art. 6-bis, paragraph 2, Legislative Decree of 6 July 2010, No. 103, converted by law 127/2010"*. **The decree defines the cost per hour concerning the work and the waiting time of the vehicle, for the purpose of determining the value of the compensation due to the carrier for each hour or fraction of hour exceeding the deductible period, related to the waiting time in order to carry out the loading and unloading operations of the goods.**

Therefore, the waiting time of the truck driver has been considered an average time equal to an hour. The case of waiting time exceeding two hours would be sporadic.

Waiting time for the goods in the radiogenic control area

In this area the goods unloaded from the truck do not have to wait for long time, indeed they must proceed directly to the radiogenic control process. So, the average waiting time for the pallets must be as minimum as possible, because this area cannot contain a large volume of goods.

Waiting time for the goods in the export warehouse

The maximum average waiting time of the goods before being palletized, has been assumed equal to 12 hours, according to the time limit for the delivery at the airport of the goods to be sent, considering the current situation of Milano Malpensa Airport.

Waiting time for the ULDs in the stacker/staging area

The maximum average waiting time of the goods before being moved near the airplane, has been assumed equal to 5 hours, according to the time limit for the delivery at the airport of the goods to be sent, considering the current situation of Milano Malpensa Airport.

Waiting time for the goods in the import warehouse

The average waiting time of the goods before the loading operations, once the truck arrives, has been assumed equal to a value between 32 and 36 hours, according to the current situation of Milano Malpensa Airport.

In relation to the export operations, the *waiting time for the trucks in the parking area, the waiting time for the goods in the export warehouse* and the *waiting time for the ULDs in the stacker/staging area*, are referred to the time limit for the goods delivery at the airport, equal to 18 hours before the flight, according to the Service Charter of Milano Malpensa Cargo. The acceptance time limit of the goods starts from the arrival of the truck at the airport.

In the simulation the following assumpions have been considered: a timeline of one week, from Monday to Sunday, all the facilities of the airport handler are operative, 24 hours a day and 7 days a week.

In the 168 hours that identify the whole-time period of the week, there are additional 30 hours that are relative to the warm-up period, which is the time necessary for the model to reach steady state and, therefore, mimic the actual system, as shown in figure 35.

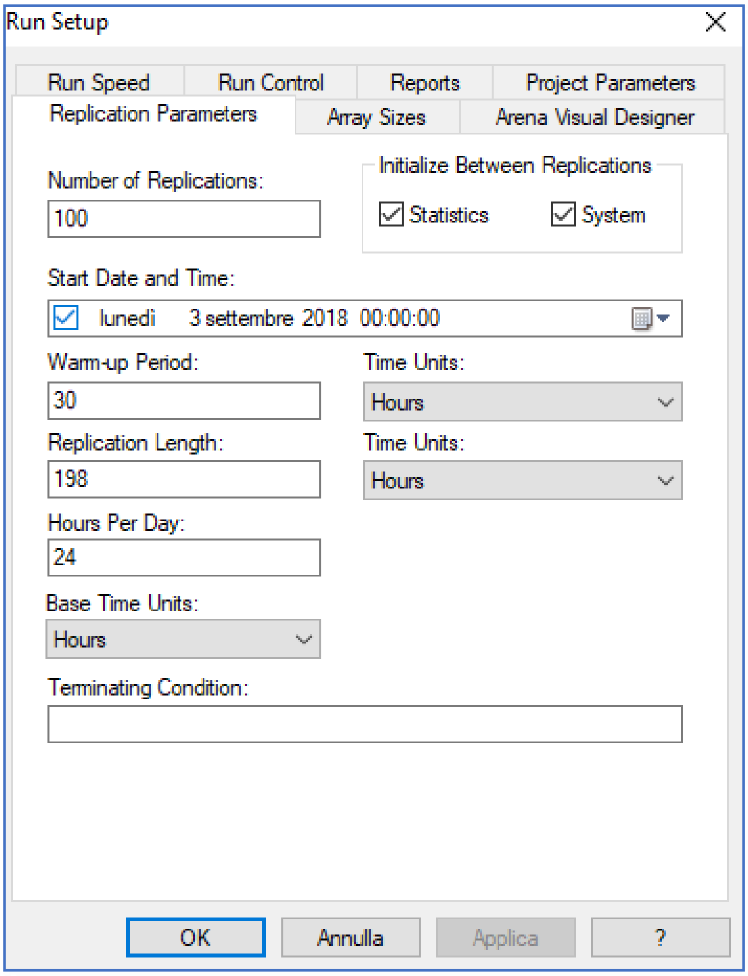


Figure 35 - Run Setup settings of Rockwell Arena Automation.

5.3.1. Current Scenario

Completed the run operations of the simulation model, the output data, related to the queued times of the various entities, including trucks, pallets and ULDs, have been analyzed, comparing them with the average time of waiting in queue in the real situation.

Current Scenario	
Area	**Average queue waiting time [h]**
Parking area	0,02
Radiogenic control area	0,31
Export warehouse	2,85
Stacker/Staging area	5,11
Import warehouse	35,02

Table 15 - Average time spent from different entity inside the terminal in the Current Scenario.

This output data shows how the average waiting times of the real situation of Alha Group warehouse, have been respected for all the considered areas.

5.3.2. Scenario 1

In this scenario, the forecast values for 2030 have been assumed considering the future minimum projection. The results of the simulation are shown in table 16.

Scenario 1	
Area	**Average queue waiting time [h]**
Parking area	4,94
Radiogenic control area	6,13
Export warehouse	6,92
Stacker/Staging area	4,53
Import warehouse	35,41

Table 16 - Average time spent from different entity inside the terminal in the Scenario 1.

In this scenario bottleneck situations have been observed in two different areas, such as the parking area and the radiogenic control area, exceeding the average waiting value in those areas.

To avoid these bottlenecks, the number of the truck-docks available have been increased from 18 to 19, increasing also the number of radiogenic controls for the goods from 2 to 3 controls. Then, the data about this new scenario have been analyzed.

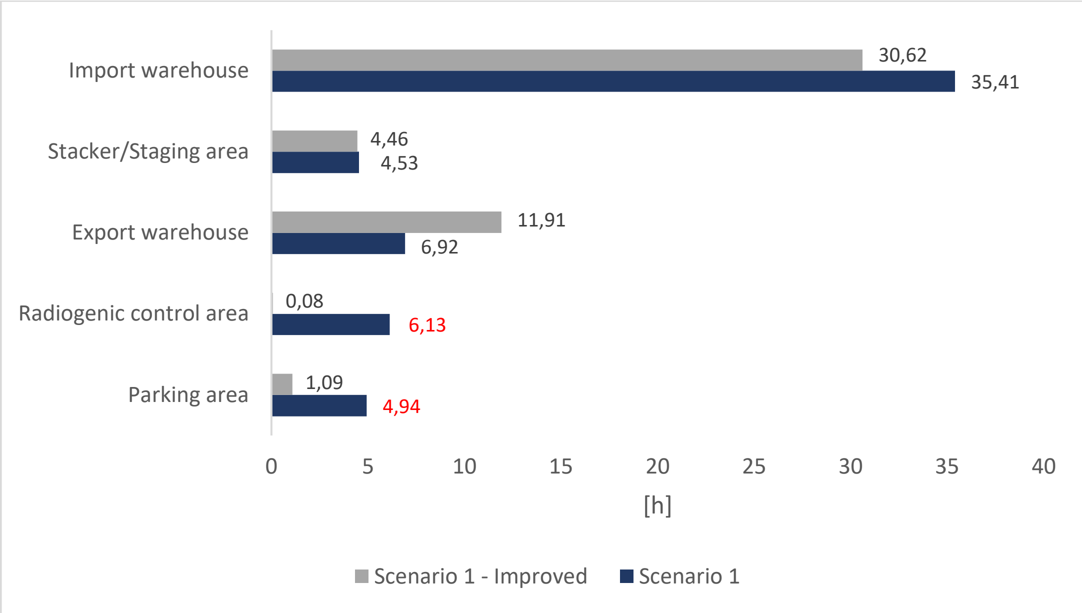
Scenario 1 - Improved	
Area	**Average queue waiting time [h]**
Parking area	1,09
Radiogenic control area	0,08
Export warehouse	11,91
Stacker/Staging area	4,46
Import warehouse	30,62

Table 17 - Average time spent from different entity inside the terminal in the Scenario 1 (improved).

This new scenario (scenario 1-improved) has changed from the previous one (scenario 1), decreasing the average waiting time and removing the bottlenecks, carrying out more fluid operations inside the Alha Group warehouse.

Area	Average queue waiting time [h]	
	Scenario 1	Scenario 1 - improved
Parking area	4,94	1,09
Radiogenic control area	6,13	0,08
Export warehouse	6,92	11,91
Stacker/Staging area	4,53	4,46
Import warehouse	35,41	30,62

Table 18 - Differences between Scenario 1 and Scenario 1 (improved) for the average time spent from different entity inside the terminal.



Graph 9 - Differences between Scenario 1 and Scenario 1 (improved) for the average time spent from different entity inside the terminal.

5.3.3. Scenario 2

In this last scenario, the forecast values for 2030 have been assumed considering the future maximum projection. The results obtained are shown in the following table.

Scenario 2	
Area	**Average queue waiting time [h]**
Parking area	21,45
Radiogenic control area	6,47
Export warehouse	6,98
Stacker/Staging area	2,31
Import warehouse	47,52

Table 19 - Average time spent from different entity inside the terminal in the Scenario 2.

The above data shows situations of bottlenecks in different areas, so improvements have been introduced to have a more fluid flow of the freight. These variations concern the number of truck-dock in the warehouse for the unloading operations, from 18 to 22 truck-docks and an additional system of a radiogenic control.

Scenario 2 - Improved (temporary)	
Area	**Average queue waiting time [h]**
Parking area	1,11
Radiogenic control area	0,15
Export warehouse	20,19
Stacker/Staging area	1,60
Import warehouse	37,52

Table 20 - Average time spent from different entity inside the terminal in the Scenario 2 (improved-temporary).

The above average time values are within the optimum range for the execution of the airport handling operations. Only one area, the one relating to the export warehouse, has disregarded these expectations by using a greater amount of time, not to be neglected. Therefore, a further improvement of the system has been introduced, adding two ULD Handling Systems to the fourth palletizing island, reaching 16 UHS from an initial situation with 12 UHS.

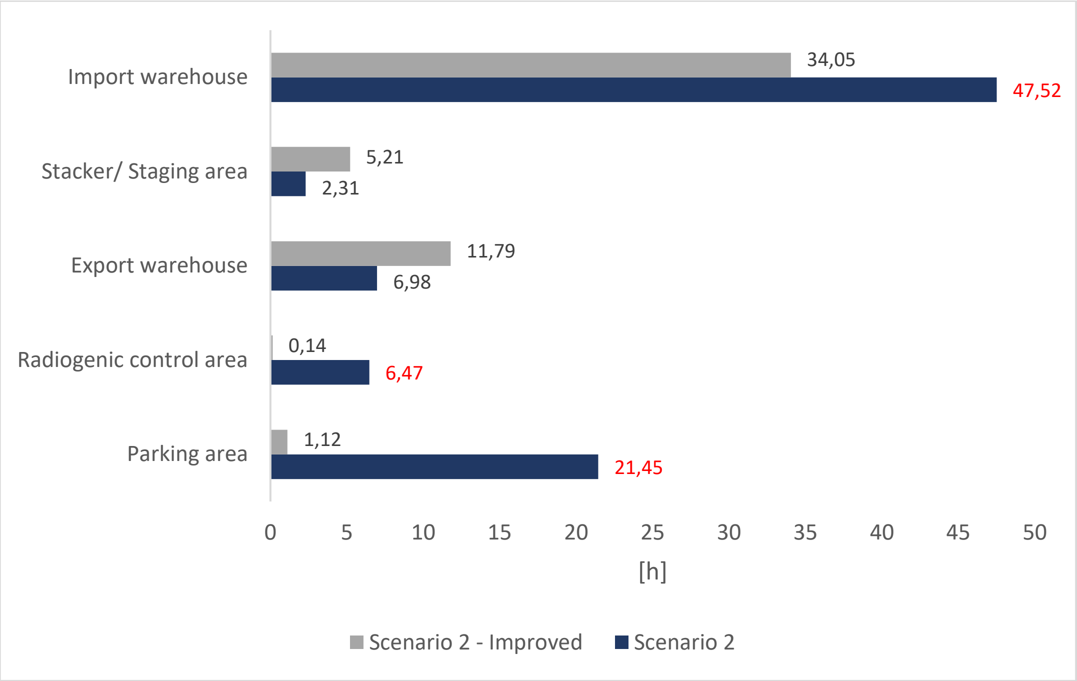
Scenario 2 - Improved	
Area	Average queue waiting time [h]
Parking area	1,12
Radiogenic control area	0,14
Export warehouse	11,19
Stacker/Staging area	5,21
Import warehouse	34,05

Table 21 - Average time spent from different entity inside the terminal in the Scenario 2 (improved).

Adding these two UHS operations, has been reached the optimization of the system. The table 22 shows the changes from scenario 2 to the same one with the improvements obtained.

Area	Average queue waiting time [h]	
	Scenario 2	Scenario 2 - improved
Parking area	21,45	1,12
Radiogenic control area	6,47	0,14
Export warehouse	6,98	11,79
Stacker/Staging area	2,31	5,21
Import warehouse	47,52	34,05

Table 22 - Differences between Scenario 2 and Scenario 2 (improved) for the average time spent from different entity inside the terminal.



Graph 10 - Differences between Scenario 2 and Scenario 2 (improved) for the average time spent from different entity inside the terminal.

6. Conclusion

Thanks to the "Rockwell Arena Automation" software, has been carried out the study about the warehouse of Alha Group in Milano Malpensa Airport. Allowing to create a model to identify, with a good approximation, the actual performance of the activities inside the warehouse of the airport cargo structures, and then adapting this model to future scenarios.

The results obtained have given a variation of the structure, increasing the number of truck-docks available for unloading operations from the trucks, the radiogenic controls and the ULD Handling System, in order to remove the problems connected with bottlenecks, regarding the two analyzed scenarios.

Scenario 1 - minimum future projection:

- adding a truck-dock for the unloading operations from trucks;
- adding a radiogenic control of the goods.

Scenario 2 – maximum future projection:

- adding 4 truck-dock for the unloading operations from trucks;
- adding a radiogenic control of the goods;
- adding 2 ULD Handling Systems for palletizing and depalletizing operations.

In conclusion, the model simulated in this specific case study for the cargo terminal of Milano Malpensa Airport, can be considered as a strategic planning tool. Furthermore, through the study conducted with this simulator, is possible to extend the simulation to modelling other cargo terminal airports.

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