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# SIMULATION OF GENERAL AVIATION CARGO PLATFORM RECONFIGURATION AT A REGIONAL AIRPORT

# SIMULACIÓN DE LA RECONFIGURACIÓN DE LA PLATAFORMA DE CARGA DE AVIACIÓN GENERAL EN UN AEROPUERTO REGIONAL

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***Resumen:*** La industria de la aviación ha experimentado cambios en los últimos años, específicamente en la última década se ha presentado un crecimiento en las operaciones de caga, este incremento conduce a la necesidad de realizar una investigación que permita visualizar los problemas operativos y de capacidad existentes en un aeropuerto regional. Se realizaron análisis técnicos y operacionales para identificar las necesidades del tráfico de carga y la infraestructura del aeropuerto en cuestión, se presentan propuestas de mejora para optimizar el flujo de operaciones de aeronaves de carga, con el objetivo de incrementar la eficiencia y funcionalidad del área destinada a dicho tráfico, estas propuestas son sustentadas en la base del marco regulatorio aplicado al diseño de aeródromos en México, logrando la simulación logística de dos propuestas de reconfiguración de la plataforma de carga. Como resultado de la simulación se identifican beneficios como el aumento de la calidad de los servicios ofrecidos por la plataforma de carga y la estación, posibilidades de crecimiento operacional y por ende un impacto positivo en la economía y la logística industrial de la región al facilitar el transporte aéreo de productos.

***Palabras Clave***: Infraestructura aeroportuaria, simulación logística, plataforma de carga, optimización.

***Abstract:*** The aviation industry has undergone significant transformations in recent years, particularly over the last decade, where a notable increase in cargo operations has been observed. This growth necessitates a comprehensive investigation to identify the existing operational and capacity-related challenges at regional airports. To address these concerns, technical and operational analyses were conducted to assess the requirements of cargo traffic and airport infrastructure. Consequently, several optimization proposals have been developed to enhance the flow of cargo aircraft operations, aiming to improve both the efficiency and functionality of the dedicated cargo area. These proposals are grounded in the regulatory framework governing aerodrome design in Mexico, enabling the logistical simulation of three potential reconfiguration strategies for the cargo platform. The simulation results indicate significant benefits, including an improvement in the quality of services provided by the cargo platform and terminal, expanded operational growth opportunities, and, ultimately, a positive impact on the regional economy and industrial logistics by facilitating air freight transportation.

***Keywords***: Airport infrastructure, logistics simulation, cargo platform, optimization.

## INTRODUCTION

From the mid-twentieth century to the present day, aviation has been crucial to humanity, significantly impacting logistics, engineering, medicine, and tourism. Its invaluable role has been in facilitating the rapid transportation of passengers, cargo, and supplies across long distances, outperforming other modes of travel in terms of time efficiency (Giménez, 2024). In a city where manufacturing is the primary activity, the daily handling of raw materials, finished goods, and semi-finished products for export and import occurs. Consequently, air cargo transportation plays a crucial role in these operations, driving the region's economic growth (Leñam, 2023).

In the sphere of international trade, air cargo transport plays a vital role for Mexico, serving as an essential hub for global connectivity and efficient commerce. Located strategically between North and Latin America, Mexico has witnessed air cargo emerge as a key engine of economic growth and competitiveness, with numerous cargo shipments passing through its airports each day. As a key regional logistics hub, this country capitalizes on the speed and adaptability of air transport to enhance supply chain efficiency, ensuring the prompt delivery of goods, particularly in sectors such as automotive, electronics, and manufacturing. This transport modality not only reduces delivery times but also enhances the export of fresh and perishable items, underscoring its significance in a globally connected, efficiency-driven economy (SafeLink Marine, 2024).

Although schedule recovery models have been analyzed in depth for passenger air transport, little work has yet been done on the recovery problem in the air cargo business. Disturbances in the passenger industry are different from those arising in the cargo market. They are due mainly to weather or the propagation of delays caused by late or cancelled flights, rather than demand fluctuations. Unexpected changes in demand are frequent, affecting the supply chain due to deviations in production, transportation, and storage costs, among others (Delgado & Mora, 2021). The purpose of this investigation is to conduct a technical and operational analysis to assess the requirements of cargo traffic and airport infrastructure. And with that information, develop optimization proposals to enhance the flow of cargo aircraft operations, all in compliance with the regulatory laws governing aerodrome design in Mexico.

According to the data provided by (*OMA*, 2025), the cargo platform at one of its eleven airports located in the northern region of the country, whose name will remain anonymous in compliance with confidentiality measures, was created in 2005 due to the growing need of the local manufacturing industry to transport its raw materials and assembled products in a more accessible and expeditious

manner. This cargo bay area is located on the north side of the airport hangars, next to the access to the General Aviation platform. A cargo terminal (OMA Carga) was built next to it, along with a fiscal precinct. The location of this platform was strategically selected after a series of studies carried out by the airport group. In this area, there is little passenger flow, in addition to having quick access to the hangars and the fiscal precinct. **Figure 1** shows an aerial view of the cargo platform and the surrounding area.

**Figure 1**. *Aerial view of the cargo platform, cargo terminal (upper right), General Aviation (lower left), and hangars (lower center) of the Regional Airport under study*.
**Source**: (*Google Maps*, 2025) https://www.google.com.mx/maps/

In the last 10 years, due to several factors including the growing internet sales market and the insecurity crisis in various logistics corridors in the country (Soto, 2019), it can be observed that the number of tons of goods shipped by air to and from the Regional Airport under study has increased by approximately 60% compared to 2010 (Gob.mx, 2025) (**Figure 2**).


**Figure 2**. *Statistics of tons of cargo moved per year at the Regional Airport under study*.
**Source**: (Gob.mx, 2025)

The increase in growth is directly linked to the number of freighter operations recorded. It's evident from the statistics that this uncommon pattern arises because the freighter airlines at the station prefer deploying larger, more capacious aircraft like the B737 or MD83, rather than opting for more frequent flights or smaller aircraft such as the CRJ200 or the Fairchild Metroliner (**Figure 3**).


**Figure 3**. *Number of cargo operations per year at the Regional Airport under study*.
**Source:** (Gob.mx, 2025).

On the other hand, it is important to consider the use of logistics simulation software to propose solutions to problems related to aircraft operation and airport infrastructure, reducing the costs of projections, which allow a clear visualization of whether the benefits are truly substantial (Flores & Guimarans, 2015). This research aims to address the capacity challenge of the cargo platform at the regional airport in question, focusing on short- and medium-term projections. Initially, an on-site space analysis is conducted, followed by simulating the infrastructure with SIMIO logistics simulation software (*Simio*, 2025), in alignment with the national regulations governing airfield design.

The implementation of the solution obtained through simulation acts as a catalyst to leverage the potential of airports in supporting the maquiladora industry and the transportation of goods. In turn, it could enhance the competitiveness of air transport compared to other slower methods, creating labor and business opportunities in the air transportation sector (AMCA, 2025).

## A. Objectives

### General Objective

To develop an optimization proposal for the cargo platform of a Regional Airport by analyzing flows, activities, events, and times between cargo operations to more efficiently accommodate current operations and expand the capacity for operations and/or larger aircraft to safely meet the demand.

**Specific Objectives**

- Analysis and evaluation of the cargo platform of a regional airport in northern Mexico.
- Identify the national and international regulations and standards for the design of airfields.
- Identify the characteristics of the aircraft operating on the cargo platform of the airport under study.
- Study the times of air operations during peak hours.
- Create a logistics simulation of the cargo platform using SIMIO for Airports software.

## B. Problem statement

The current cargo platform at the Regional Airport was developed to meet the transportation needs of the manufacturing industry 20 years ago; however, there has been a significant increase in air demand, reflecting a growing and substantial movement of cargo tons transported to and from the airport under study in the past 10 years. This situation demands the use of larger aircraft to meet the emerging needs, all within the same infrastructure and physical resources of the airfield (*OMA*, 2025).

During the on-site evaluation and analysis, situations were identified that reflect saturation in the cargo bay areas and could trigger latent and unsafe conditions in aircraft operations. Category C aircraft were found parked on platforms designed for category D aircraft, along with reduced spaces that do not comply with the minimum separation between aircraft as established by the standard (Glazer, 2021).

Additionally, efforts have been made to utilize the existing infrastructure. Even the cargo platform has been used as parking for two category C aircraft simultaneously (from two different airlines). However, the space is insufficient to safely accommodate an additional aircraft, causing traffic diversions to other aprons, such as commercial or general aviation. This is the case with the B737-300F, which has repeatedly loaded and unloaded cargo on the commercial bay area due to the lack of space available on the cargo platform.

On the other hand, the cargo bay is equipped with guides and markings on the pavement, established for category D aircraft but not for category C aircraft, overlooking the regulations for the safe and expeditious operation of aircraft.

## DEVELOPMENT

### Methodology

The methodology was divided into three consecutive phases. The first phase consists of performing a visual analysis of the operations executed on the loading platform. The second phase involves analyzing the possible solutions to the detected problem, studying the normative and regulatory framework together with the operational statistics, proposing a solution to the problem, and describing the future projections. The third and final phase is related to the logistics simulation of the proposed solution, along with an evaluation of the results through the simulator, making it possible to determine if the proposed configuration is feasible.

**Phase I. Survey of cargo operations served at the airport platform.**

According to the data provided by (*OMA*, 2025). Three airlines provide services at the cargo bay area of the Regional Airport under study, **Aeronaves TSM** that directly serve the parcel delivery company Deutsche Post (DHL) with McDonnell Douglas (MD-82, MD-83, MD-88, DC-9), Fairchild (Metroliner), and Convair aircraft; **Estafeta Air Cargo** with Boeing (B737-300/400) and Bombardier (CRJ100/200) aircraft, and finally **TUM Aerocarga**, which operates for the parcel delivery company Federal Express (FedEx) with Bombardier (CRJ100/200) and Boeing (737-300/400) aircraft**.**

All the previously mentioned airlines together transported a total of 4,603 tons of cargo in 1,743 different operations during 2019, each with different schedules and aircraft with capacities according to the routes they handle. **Aeronaves TSM** has Saltillo as its origin and destination, with its aircraft arriving daily. **TUM Aerocarga** manages two destinations, the most frequent being the city of Chihuahua, followed by Monterrey, and finally, **Estafeta Air Cargo** with a destination to the city of Chihuahua. Most arrival operations occur in the early hours of the morning, while departure operations begin during the early hours of the night, unless there is some charter operation with another aircraft. The aircraft of the three airlines spend the entire weekend on the commercial and cargo platforms, arriving in the early hours of Friday and departing by Monday afternoon. These overnight stays usually vary according to the requirements of the airlines at their bases and operational centers.

The airfield in question is classified as an international airport and is considered a “fifth-generation” airfield (AMCA, 2025). It is in the interest of this project to evaluate the infrastructure for cargo operations, which lead to a proposal for space optimization (**Figure 4**).

**Figure 4.** *Image of the Regional Airport under study.*
**Source**: (*Google Maps*, 2025) https://www.google.com.mx/maps/

The cargo bay has only one Category D parking position according to (*ICAO*, 2025) for an aircraft with a wingspan of up to 52 meters, in which, at times, two Category C aircraft can be accommodated. The cargo terminal and the fiscal precinct are located nearby. The hangar area is also very close, making it very accessible for aircraft service companies to get close to the aircraft.

Interviews were conducted with personnel directly involved in cargo operations to learn about aspects of interest that would allow for a solid space optimization proposal. It is important to know the average amount of cargo transported by each operation, as well as the routes and frequencies of greatest occupancy. The names of the interviewees are kept anonymous, and the results of the interviews have given rise to various approaches that have allowed the development of the research.

**Phase II: Proposed solution to the problem.**

The analysis of the current cargo bay area determined that it has a total area of 3,899 square meters, a width of 61.25 meters, and a length of 63.92 meters. It has a docking guide for use by a category D aircraft and is located 26 meters from the left runway strip and 34 meters from the right strip. This same guide is 46 meters long from the base of the platform and 18 meters away from the service road at the top. There are two strips on the left margin, and these, together with the berthing guideway, are painted yellow with the separation indicated by the ICAO Aerodrome Design Manual (*ICAO*, 2025), Sections 2 and 4, taxiways and platforms, as well as visual navigation aids, respectively.

The service roads at the edge of the platform are 9.5 meters wide, divided into two lanes, one in each direction. Each of these directions has arrows indicating turns or curves, along with other arrows indicating the direction. There is a central axis with white dashed lines and striped crossings for pedestrians in certain strategic areas. There are two poles with white light lamps used to maintain visibility

during night operations. There are two yellow information signs with night lighting on the lower right side, one indicating the location of the cargo area and the other for general aviation. Specific measurements of the loading platform were taken, identifying spaces between taxiways, lighting, information signs, and signage (**Figure 5**).

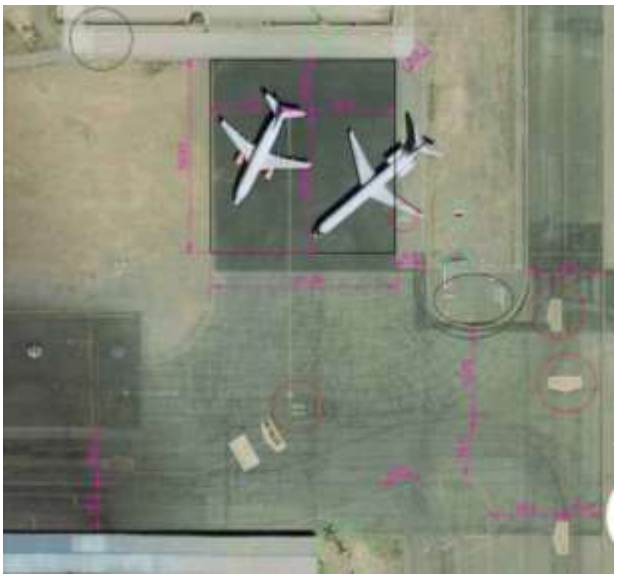

**Figure 5**. *Aerial view with emphasis on the loading platform infrastructure*.
**Source**: (*Google Maps*, 2025) (https://www.google.com.mx/maps/).

Based on the data provided, a solution aimed at optimizing space and available resources is being sought, leading to two improvement proposals. **Table 1** presents a plan centered on modifying the signage and repositioning the current taxiway, whereas **Table 2** suggests extending two category C spots and introducing a hybrid remote position.

| Proposal | Change in signage and relocation of taxiway. |
|---|---|
| Pros | Cons |
| Only requires investment in paint for signage | Does not present a medium and long term solution, only short term |
| Does not require soil resistance studies, since there is no expansion | In case of prolonged stay of the aircraft in the taxiway, it may cause delays to other aircraft |
| Better use of the space where it is currently located | It is not certain that the clearances between aircraft will be respected |
| Relocating the service road requires less investment and less construction time | Could lead to latent practices that violate safety standards. |

**Table 1**. *Proposal 1. Change of signage and relocation of taxiways*.
**Source**: Self-made.

| Proposal | Expansion and configuration of 2 category C positions and one hybrid C/D. |
|---|---|
| Pros | Cons |
| Allows a better flow of aircraft with adequate signaling | Requires technical studies for its construction, as well as an investment in labor |
| Each of the positions would be independent, so delays in one would not affect the others | Its execution could take time, during which the apron would be disabled |
| By having capacity for one more aircraft than the current configuration, it would avoid the invasion of the commercial platform | Disabling the platform to carry out this proposal would aggravate, albeit temporarily, the problem that is occurring |
| It allows fluid and independent access, clearance and movement for both aircraft and service vehicles | Temporary closure of the cargo apron would represent a drop in the apron's competitiveness and capacity |
| There is sufficient space in the surrounding area to consider an even larger expansion in the medium term. | It would mean eliminating 3 positions on the aviation platform that are currently annexed to the work area. |

**Table 2**. *Proposal 2. Extension and configuration of two category C positions and one hybrid C/D position*.
**Source**: Self-made.

Based on the statistics of the number of tons of cargo moved to and from the airport in question over the last 10 years, the data was processed, and those showing unusual or out-of-trend behavior were ignored. **Table 3** shows a relationship between the tons of cargo moved to and from that airport and the number of operations performed each year, thus giving the average annual cargo moved per aircraft.

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|
| TONS | 2823 | 2682 | 3140 | 2910 | 2772 | 3171 | 3436 | 3794 | 4101 | 4603 |
| OPS | 1226 | 1264 | 1809 | 1377 | 1176 | 1204 | 1655 | 1580 | 1532 | 1743 |
| TOTAL | 2.30 | 2.12 | 1.74 | 2.11 | 2.36 | 2.63 | 2.08 | 2.40 | 2.68 | 2.64 |

**Table 3.** *Relationship between cargo operations and the number of tons moved.*
**Source:** (Gob.mx, 2025)

**Figure 6** shows a trend graph indicating projected market growth through 2024.

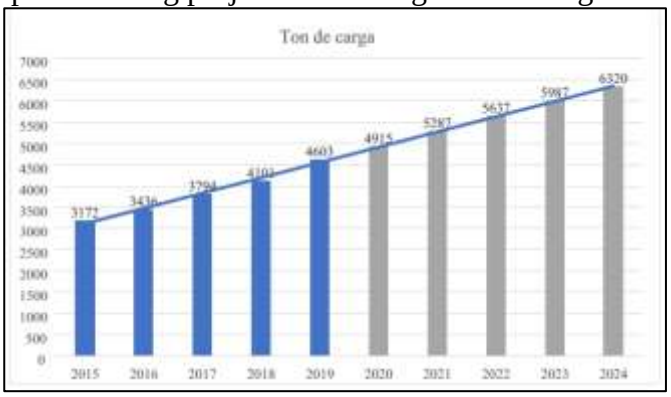


**Figure 6.** *Growth trend for freight tonnage*.
**Source:** (Gob.mx, 2025).

**Table 4** shows the average tons handled in the 3 most frequent aircraft types (year 2020) for each of the 2 operations (arrival and departure), allowing us to obtain the total tons transported during the year. This tabulation corresponds to the cargo bay in its current configuration. In the following table, we added the average tons per operation by CRJ 200 and with the current conditions in which the commercial platform is shared with cargo aircraft, transporting 4,942 tons during the year 2020.

| CONFIGURATION ACTUAL MIX | | | | |
|---|---|---|---|---|
| ACFTS | MD82/83/88 | B737-300 | CRJ100/200 | TOTAL |
| TONS/OP | 2.85 | 2.67 | 1.25 | |
| OPS | 2 | 2 | 2 | |
| TOTAL | 2080.5 | 1949.1 | 912.5 | 4942.1 |

**Table 4**. *Total tons per operation during the year 2020*.
**Source:** (*OMA*, 2025)**.**

**Phase III: Logistics simulation**

Based on the analysis of the current conditions of the loading platform and the identification of technical data such as dimensions, pavement resistance, types of aircraft, signage, among others, plans are developed using AutoCAD software (Deingenierias.com, 2019) (**Figure 7**).

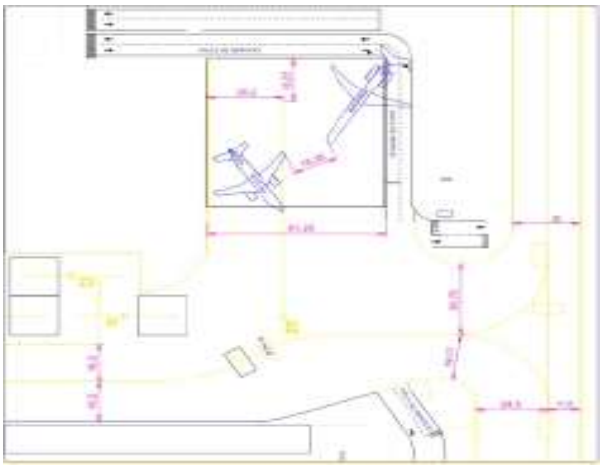

**Figure 7.** *Plan showing the current conditions of the loading platform*.
**Source**: AutoCAD software (*AutoCAD Web App*, 2025) (Self-made).

**Drawing of plans with the recommended proposals**

Considering the technical data and using the original plan with the current conditions of the apron as a basis, the plan is developed with the first proposal. This proposal aims to maximize the existing space on the apron, accommodating the aircraft efficiently while adhering to the regulations and standards

associated with airfield design, without significantly modifying the existing surface, as shown in **Figure 8.** The MD82/83/88 is taken as a reference since it is the aircraft with the largest dimensions currently operated by local cargo airlines.

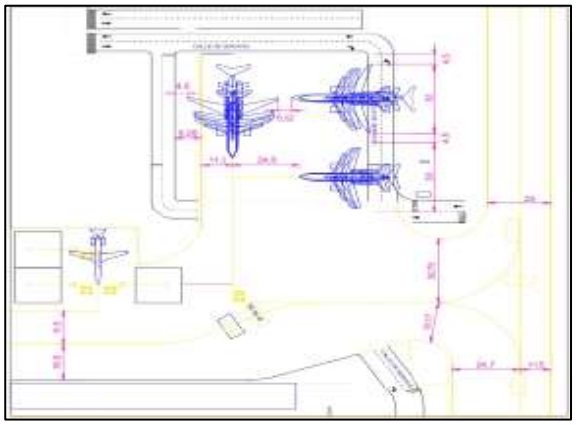

**Figure 8**. *Plan to draw of the configuration for the initial proposal of the loading platform*.
**Source**: AutoCAD software (*AutoCAD Web App*, 2025) (Self-made).

Applying this configuration would imply disabling the service lane on the right side of the apron, at least if there are aircraft occupying positions 1 and 2. This would require building and enabling a new section of service lane at the other end of the apron with the same characteristics as the area to be disabled. It should be noted that this proposal was made based on the current schedules used by cargo airlines.

The second proposal is independent of the first; however, it could be considered the next stage in the medium term. This proposal offers a solution to the problem by adding approximately 5,500 square meters of surface area, allowing for safer operations since aircraft could enter by taxiing and exit by towing. At the same time, it includes a third position for overnight and maintenance use, as well as for aircraft in transit, which would eliminate the existing dependence in the first proposal between positions 1 and 3 (*ICAO*, 2025).

In this case, given the configuration of the platform, there are no exit lines, so the trailer operator will be guided by the entry lines during the exit maneuver (Santibanez, 2025) (**Figure 9**).

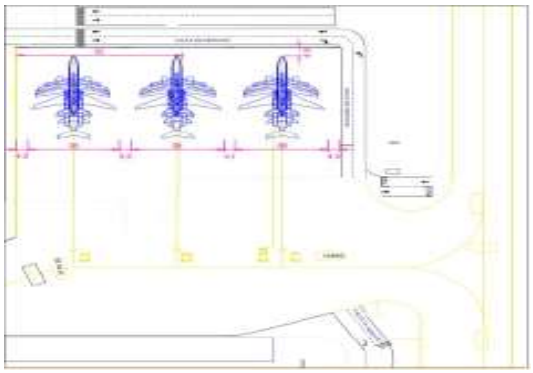

**Figure 9**. *Plan drawing of configuration 1 of the second proposal for the loading platform*.
**Source**: AutoCAD software (*AutoCAD Web App*, 2025) (Self-made).

Although in the Aerodrome Design Manual («flycaribes.com», 2005) as well as in Annex 14, it is mentioned that in the linear configuration, aircraft enter taxiing by their momentum and exit by towing, in this case, both maneuvers would be performed with towing and engines off. This is due to the proximity of the general aviation apron, the hangar area, and the potential damage that could occur due to the flow of exhaust gases from the engines of the operating aircraft.

In the C2 position, it is planned to receive a category B aircraft, which must have a maximum wingspan of 21 meters. Since it is between a category C aircraft and the critical aircraft, the clearance distance of the highest-ranking aircraft, which is the Boeing 757-200PF, must be respected (**Figure 10**).

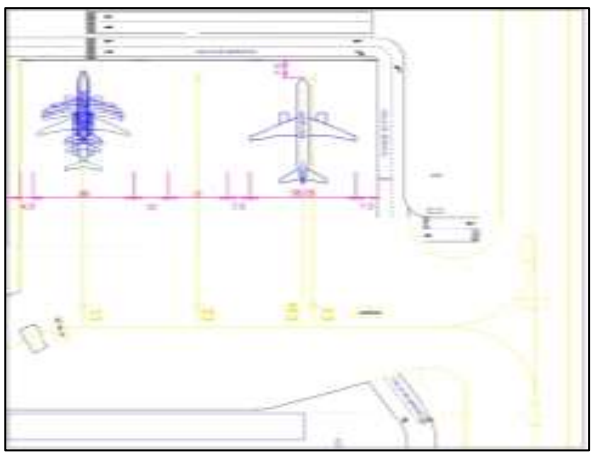

**Figure 10**. *Plan showing configuration 2 of the second proposal*.
**Source**: AutoCAD software (*AutoCAD Web App*, 2025) (Self-made).

To graphically illustrate the difference between the current platform and proposal number 2, **Figure 11** shows the plan with the proposal superimposed on an aerial photograph of the loading platform.

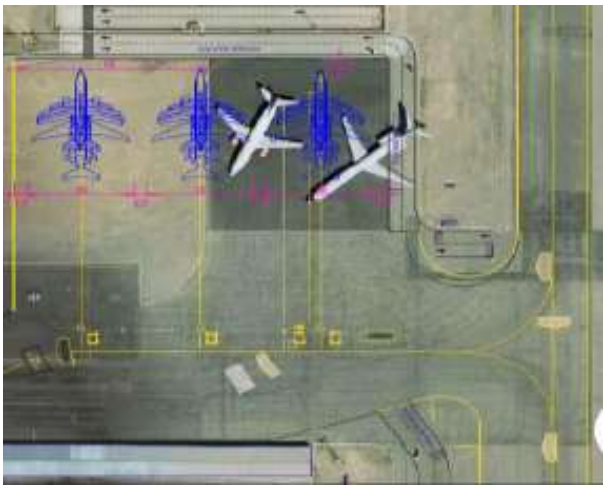

**Figure 11**. *Plan to draw of the proposal vs. recent aerial photography*.
**Source**: (*Google Maps*, 2025) (Self-made).

## Logistics simulation of the cargo bay spaces

Based on the current configuration of the platform, a scheme was drawn up with the routes taken by the aircraft, including their transfer times, using the following symbology (**Table 5**).

| OP/ACFT | MD82/83/88 | B737-300F | VRJ-100/200 |
|---|---|---|---|
| ETA (GMT) | 13:15 | 14:15 | |
| TAXI (TWY A TO SD) | 00:55 | 01:03 | |
| PUSHBACK | 01:38 | 01:36 | |
| SERVICE TIME | | | |
| OVER NIGHT | 690 | 660 | |
| TOWING | 2:35 | 3:00 | |
| NUMBER ACFT SERVED | 1 | 1 | |

**Table 5**. *Average time in minutes for each aircraft operation on the cargo bar area*.
**Source**: (*Jeppesen NavData*, 2019) (Self-made).

This scheme aims to capture the platform's present state within the software, allowing results to be compared with those from the two improvement proposals (**Figure 12**).

**Figure 12**. *The current scheme of the loading platform is plotted in SIMIO*.
**Source**: (*Google Maps*, 2025) (Self-made).

**B737**: Represents the entry into the system of a Boeing 737.

**MD80**: Represents the entry of an MD82/83/88 into the system.

**C01**: Represents the current Cargo position 01.

**C02**: Represents the current Cargo position 02.

**SD**: Point where engines are shut down on arrival, before tow to position.

**TWY_B**: Departure to taxiway B.

**Simulation of proposal 1**

The schematic is drawn up based on the plans generated for Proposal 1, taking into consideration the established times and the characteristics of the aircraft included in the proposal. After entering the data and programming the sources that represent the input of the aircraft, the result is a three-dimensional view of the schematic model created, providing a clearer perspective shown in **Figure 13**.

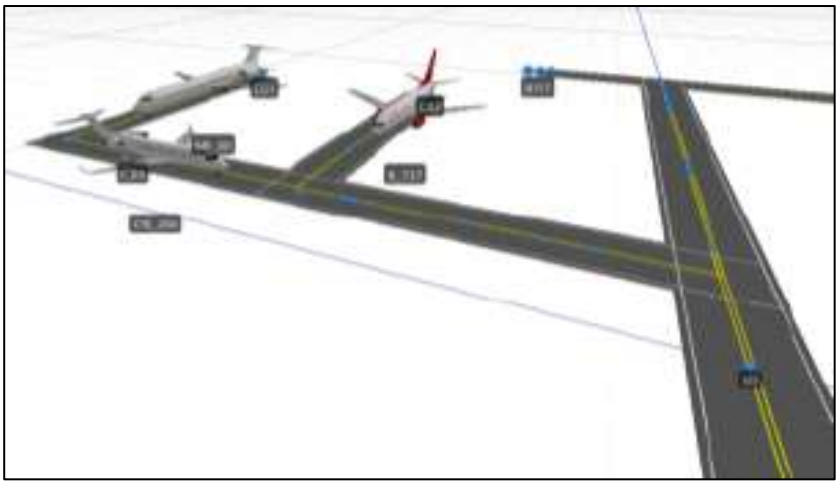

**Figure 13**. *3D view of the simulation scheme for proposal 1 in the SIMIO program*.
**Source**: (*Simio*, 2025) (Self-made).

### Simulation of proposal 2

The simulation scheme for proposal 2 is created, including a symbology very similar to the one used in proposal 1, considering each parameter as an independent command, from which **Figure 14** shows a three-dimensional view.

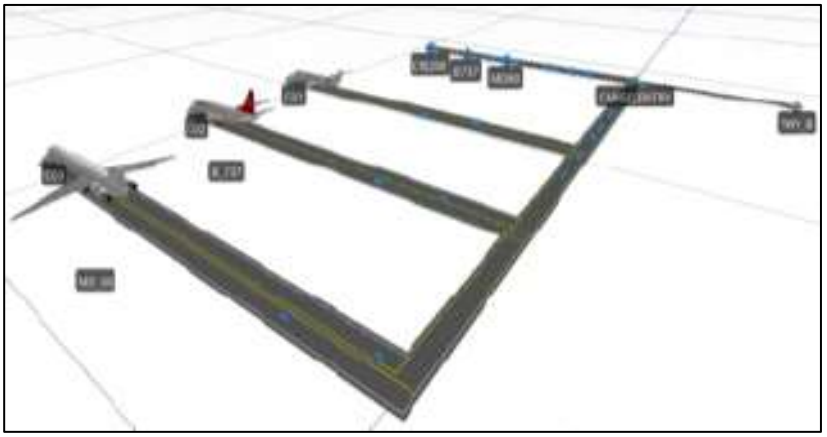

**Figure 14**. *3D view of the simulation scheme for Proposal 2 in the SIMIO program*.
**Source**: (*Simio*, 2025) (Self-made).

## RESULTS AND DISCUSSION

Table 6 shows the average elapsed times for each aircraft and for each phase of the arrival and departure operation at the cargo apron under the current configuration. Since this configuration is where the problem arises, the capacity to service two aircraft per day is managed. The Service Times section is omitted from this first table, as the overnight time section is used instead.

| OP/ACFT | MD82/83/88 | B737-300F | VRJ-100/200 |
|---|---|---|---|
| ETA (GMT) | 13:15 | 14:15 | |
| TAXI (TWY A TO SD) | 00:55 | 01:03 | |
| PUSHBACK | 01:38 | 01:36 | |
| SERVICE TIME | | | |
| OVER NIGHT | 690 | 660 | |
| TOWING | 2:35 | 3:00 | |
| NUMBER ACFT SERVED | 1 | 1 | |

**Table 6**. *Average times in minutes for each action within the operation of The aircraft on the cargo platform*.
**Source**: (*Jeppesen NavData*, 2019)(Self-made)

Once proposal 1 is implemented, the following tables (Table 7 and Table 8) illustrate how the platform increases its capacity to serve three aircraft almost simultaneously, allowing the CRJ100/200 aircraft to be served without delay. Departure times were reduced by approximately 40 seconds and entry times by 30 seconds for the Boeing 737-300F, whereas for the MD82/83/88, they increased by 20 seconds on

average. This was due to the greater length and complexity of accommodating the MD82/83/88 aircraft in position C01, which was chosen for the MD82/83/88 due to its extended overnight and apron stay times. Additionally, the times for each phase of the operation are shown; only one aircraft per category is counted as the number of aircraft served.

| OP/ACFT | MD82/83/88 | B737-300F | VRJ-100/200 |
|---|---|---|---|
| ETA (GMT) | 13:15:00 | 14:15:00 | 18:30:00 |
| TAXI (TWY A TO SD) | 00:55 | 01:03 | 0:00:50 |
| PUSHBACK | 01:38 | 01:36 | 0:01:00 |
| SERVICE TIME | | | |
| OVER NIGHT | 690 | 660 | 7:00:00 |
| TOWING | 2:35 | 3:00 | 0:02:18 |
| NUMBER ACFT SERVED | 1 | 1 | 1 |

**Table 7**. *Average times in minutes for each aircraft operation over the cargo bay area under proposal 1*.
**Source**: (*Jeppesen NavData*, 2019) (Self-made).

**Table 8** considers two aircraft that, according to the overnight schedule and the operating hours of the airport in question (07-21hrs) (*Jeppesen NavData*, 2019), can use the cargo platform. This situation arises because, by the time of the arrival of the following two aircraft arrive, the first two that were in the cargo bay area would have already taken off from the station, thus leaving two positions free. With the data mentioned for the simulation, the results show a service capacity of 5 aircraft in total.

| OP/ACFT | MD82/83/88 | B737-300F | VRJ-100/200 |
|---|---|---|---|
| ETA (GMT) | 13:15:00 | 3:15:00 | 1:30:00 |
| TAXI (TWY A TO SD) | 0:00:55 | 0:01:03 | 0:00:50 |
| PUSHBACK | 0:01:45 | 0:01:03 | 0:01:00 |
| SERVICE TIME | | 0:40:00 | 0:20:00 |
| OVER NIGHT | 11:30:00 | | |
| TOWING | 0:02:54 | 0:02:23 | 0:02:18 |
| NUMBER ACFT SERVED | 1 | 2 | 2 |

**Table 8**. *Average times in minutes for each action during the operation of the aircraft on the cargo platform under the proposal*.
**Source**: (*Jeppesen NavData*, 2019) (Self-made).

Returning to the statistical prediction data mentioned above and considering the increase in service capacity at the cargo platform under Proposal 1, a maximum of 7,803.4 tons can be transported each year, as shown in the following table. This data indicate that the new platform capacity under Proposal 1 significantly exceeds the amount expected to be transported over the next 5 and 10 years (**Table 9**).

| CONFIGURACIÓN ACTUAL MIX | | | | |
|---|---|---|---|---|
| ACFTS | MD82/83/88 | B737-300 | CRJ100/200 | TOTAL |
| TONS/OP | 2.85 | 2.67 | 1.25 | |
| OPS | 2 | 4 | 4 | |
| TOTAL | 2080.5 | 3898.2 | 1825 | 7803.7 |

**Table 9**. *Total tons transported per year due to the implementation of proposal 1*.
**Source**: Self-made.

The results of implementing the second proposal are shown in **Table 10**. In this proposal, aircraft arrival conditions are handled differently, as there is no longer a codependency between positions C01 and C03. Additionally, the aerodrome's operating hours were discarded, and a 24-hour simulation was performed. The arrival intervals shown in the first row are per the schedule provided in the previous section. In terms of time, for each phase of the aircraft's ground operation, an increase can be observed for both the arrival and departure tows. This is because the taxi and pushback operations are considered a single operation, as reverse towing to the parking position is not required. Considering the average service times for each aircraft on the ground, their arrival intervals, overnight conditions, and a 24-hour operating time for the airport, it is observed that the maximum number of aircraft that can be served on the loading platform increases to 7.

| OP/ACFT | MD82/83/88 | B737-300F | VRJ-100/200 |
|---|---|---|---|
| ETA (GMT) | 23:50:00 | 5:15:00 | 12:00:00 |
| TAXI (Cargo in to pos) | 00:04:10 | 0:03:14 | 0:02:45 |
| SERVICE TIME | 0:25:00 | 0:35:00 | 0:20:00 |
| OVER NIGHT | 13:00:00 | 11:30:00 | 8:00:00 |
| TOWING | 0:03:49 | 0:03:16 | 0:02:15 |
| NUMBER ACFT SERVED | 1 | 4 | 2 |

**Table 10**. *Average times in minutes for each action within the operation of the aircraft on the cargo platform under proposal 2*.
**Source**: (*Jeppesen NavData*, 2019) (Self-made).

## Advantages and disadvantages of the proposals

**Table 11** presents the advantages and disadvantages of proposal 1, and **Table 12** allows us to visualize the advantages and disadvantages of proposal 2.

| Advantages | Disadvantages |
|---|---|
| Increases aircraft handling capacity by 150% | Provides short-term solutions, as the number of cargo operations is expected to increase |
| Improves safety during operations carried out on the apron due to adequate signage | There is codependency between positions C01 and C03, which can cause delays and ground aircraft in the event of unscheduled overnight stays |
| Maximizes the use of available space without the need to increase or modify it | The dependency between positions limits the operational capacity of the cargo apron |
| Requires minimal adjustments in its implementation | Access maneuvers to positions require adequate personnel training to avoid accidents and/or damage to aircraft and adjacent areas |

**Table 11**. *Advantages and disadvantages of implementing the implementing the proposed solution 1.*
**Source**: Self-made.

| Advantages | Disadvantages |
|---|---|
| It eliminates the dependency between positions C02 and C03 | It requires modifying the current space to add approximately 5,500 square meters |
| It increases the space available to carry out operations safely and with adequate signage | Its implementation involves the elimination of three positions currently part of the General Aviation platform |
| By eliminating the dependency between positions, its aircraft handling capacity increases by 250% compared to the current configuration | Its execution requires considerable time, during which some sections of the apron would be disabled, exacerbating the current problem |
| The increase in capacity solves the current problem in the short, but also in the medium term | It requires studies, bidding, and quotations for the work, which may not be included in the PMD in the short term |
| The capacity to receive a category D aircraft is reopened without limiting the use of the apron to the current level. | The reception of the critical aircraft would represent a decrease in the platform's capacity, since it is reduced from three Cs to one C, one B and one D. |

**Table 12.** *Advantages and disadvantages of proposed solution 2.*
**Source**: Self-made.

The findings provided here contribute to a more visual and practical comprehension of the initial problem and its potential solutions. When comparing the methodology applied in this project to that employed by (Delgado & Mora, 2021) in their article published in the *Journal of Air Transport Management*, titled "A matheuristic approach to the air-cargo recovery problem under demand disruption," it is clear that their approach relied on a mathematical formulation model to evaluate the interplay among various parameters and variables. By contrast, this project utilized real-world data incorporated into simulation software for its analysis. The foundation of the methodology applied in this investigation was taken from the book by (Flores & Guimarans, 2015), *Applied Simulation and Optimization in Logistics, Industrial and Aeronautical Practice. *

## CONCLUSIONS

Based on the criteria outlined in the diagram for Proposal 1, this proposal is deemed feasible. A key factor contributing to its viability is the 150% increase in platform capacity it offers, coupled with only minor modifications, such as repainting access and docking guides, without altering the existing surface. While the two positions rely on each other, which might cause postponements and brief aircraft grounding, such problems can be circumvented by sticking to the schedules and ensuring smooth aircraft arrivals and departures at position C03. Likewise, deactivating the existing service lane on the apron's

right side poses no issue, as the left side provides ample space for establishing a new service lane to facilitate secure and organized aircraft access.

Concerning Proposal 2, following the logical flow, its construction is deemed feasible for the medium term, contingent upon the expenditure timeline outlined in the Master Development Plan for the assessed airport. The primary limitation lies in the initiation requirements, which encompass bidding, obtaining quotations, conducting several studies, and acquiring specialized labor. These conditions have positioned Proposal 2 as the subsequent stage following the first optimization. Although both proposals show slight increases in arrival and departure times, the viability of the proposals prevails, as the benefit is not focused on reducing operating times, but rather on eliminating the dependency between positions that existed in the first proposal. This elimination of dependencies means increasing capacity by 250% compared to the original, thereby reducing the saturation of the commercial platform, which is exacerbated by the problems at the cargo platform.

The proposals allow for digital visualization of aircraft operations and analysis of aircraft performance, enhancing space distribution and optimizing existing resources. The proposals aim to accommodate a greater number of aircraft and enable their movements to be conducted in a safe, orderly, and efficient manner. The proposals primarily seek to establish a flexible cargo apron configuration that can adapt to future operational demands. The use of logistics simulation software allows for projecting the proposal's performance and assessing whether the changes are suitable to meet the airport's growing demand. Finally, optimizing the cargo platform provides the airport with greater opportunities for air connectivity for the market and export of products, as well as job creation in the northern region of the country.

## RECOMMENDATIONS FOR FUTURE RESEARCH

For upcoming research, it is advisable to investigate the application of metaheuristic models and digital twins in simulating and optimizing airport cargo platforms. This approach has the potential to deliver more dynamic solutions that incorporate a broader spectrum of process variables.

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