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SIMULATION OF BAGGAGE DELIVERY MANAGEMENT FOR AN INCREASE IN DEMAND IN A MEXICAN AIRPORT

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ABSTRACT

One of the airport operations that define customer satisfaction is baggage handling. This document analyzes baggage logistics once the plane lands. We used SIMIO® to construct a simulation model for the baggage delivery process in a Mexican airport, used to assess the associated degree of comfort and processing time.

In this preliminary study, IATA performance indicators were used to determine the service classification for the baggage claim unit and the overall baggage processing time for two scenarios. The first one considers the arrival of two A320 arriving a few minutes apart; the second one considers two A321 aircraft in the same conditions. Simulation results confirm that PBC's current operating conditions, aircraft types and flight frequencies allow the airport to have an acceptable service and comfort level in the baggage claim area. However, an increase in passenger demand can lower passenger comfort significantly, as the current baggage claim band violates IATA standards and is under-dimensioned.

Keywords: simulation model, baggage management, occupation level, IATA

1. Introduction

The saturation of Mexico City airport and its impossibility of growth have been identified since the 1990s. For over 15 years, the airport authorities and federal government have been proposing alternatives for the development of a new airport or the implementation of a Metropolitan Airports System (SMA: Sistema Metropolitano de Aeropuertos) to cover the current demand (ASA, 2006). The government of President Peña Nieto (2012-2018) agreed in 2014 on the construction of a new airport in Texcoco. However, at the start of the new federal government (2018-2024), this initiative was suspended in favor of the expansion of the military airport in Santa Lucía, which has required substantial changes in the original expansion proposals (La Jornada, 2019). A renewed interest arose in one of the earlier proposals to cover the demand with a network of metropolitan airports (Excelsior, 2016; Milenio, 2016; A21MX, 2019; América vuela, 2018), including those of Puebla, Querétaro, Toluca and Cuernavaca, which are close to Mexico City and already have the necessary infrastructure (Galindo López and Nava Figueroa, 2011; ASA, 2006). It should be mentioned that some of the secondary or regional airports could generate losses instead of being profitable (Doganis, 1995). In the case of the Metropolitan Airports System, only the Cuernavaca airport generates losses.

This type of airport system has been used in several big cities where the main airport has a very high occupation, however, operates efficiently supported by secondary airports. This is the case of for example London, where a set of six airports meet the demand of the entire city (Cantera, 2018), Paris, where four airports are used or New York that is integrated with three nearby airports (Neufville, 2013).

The Metropolitan Airports System includes Mexico City Airport, as well as the airports described in table 1. All four secondary airports are owned partially by the federal government, represented by ASA (Aeropuertos y Servicios Auxiliares), and the local government (Aeropuertos de México, 2013); in the case of TLC airport, also private participation exists. Figure 1 shows the Metropolitan Airports System.

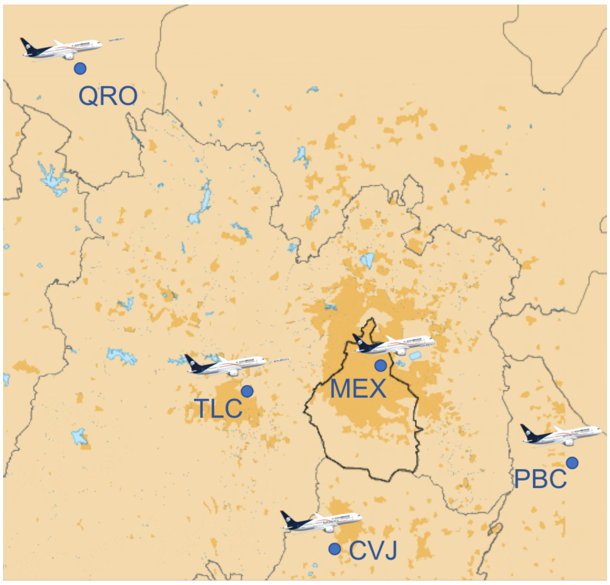

Figure 1. Central Mexico network of metropolitan airports

Not all airports in the Metropolitan Airports System have the right infrastructure for viable growth. CVJ started operations in 1988 and can handle an hourly rate of 1000 passenger; however, it currently does not handle commercial flights and no operator offers line services to this airport (low-cost carrier Volaris ceased operations in CVJ in 2017).

Table 1. Characteristics of metropolitan airports (Galindo López and Nava Figueroa, 2011; Excelsior, 2016).

	Cuernavaca	Toluca	Puebla	Querétaro
IATA	CVJ	TLC	PBC	QRO
Distance to MEX (km)	110	68	103	213
Main use	General services	Commercial	Commercial, industry and special services	Commercial and industry
Terminal building area (m^2)	1,200	28,300	6,800	5,241
Passengers in 2018	7,735	691,712	685,583	1,024,023
Capacity (pax/h)	240	1,850	450	400
Roadway capacity (ops/h)	14	36	20	45
Nr of operating airlines	-	2	6	8

The main competitive disadvantage of TLC is its altitude and meteorological conditions, which do not allow large passenger planes to leave with a full fuel tank (Expansión 2016; Alfadiario, 2019). For long journeys, this implies a departure with restricted weight and needing at least one stopover in the Caribbean, which considerably increases costs and makes the route less competitive. Although TLC has the capacity to serve eight million passengers a year, demand decreased from 4.3 million travelers in 2008 to less than 700,000 in 2018 (Milenio, 2016).

For both PBC and QRO, approximately half of the flights correspond to cargo and business flights. The large proportion of cargo flights are due to the presence of important industrial parks, including aeronautical and automotive industry in QRO and automotive industry in PBC. Despite its proximity to the Popocatepetl volcano, PBC has grown in recent years.

The increase in the occupation of secondary airports that were not originally designed to serve a high flow of passengers brings challenges in terms of service logistics to maintain the level of customer satisfaction, including baggage and its handling, very valuable for the passenger.

This article describes the evaluation, for PBC airport, of the degree to which the currently installed baggage reception capacity is sufficient to cover possible future increases in demand, if the airport absorbs part of the demand from Mexico City.

1.1. PBC Airport

The Puebla International Airport (IATA Code: PBC, ICAO code: MMPB) or Huejotzingo Airport, officially named Hermanos Serdán International Airport, is located in the municipality of Huejotzingo, 25 km from downtown Puebla; operated by ASA, it serves flights from Puebla to major cities in Mexico and abroad (figure 2).

PBC airport has a 16,400 m^2 platform with 6 loading positions and a terminal building with capacity for approximately 450 passengers per hour (Red ASA, 2019). PBC's platform is classified to be 4D according to the ICAO Aerodrome Reference Code (wingspans between 36 and 52 m and outer main gear wheel span between 9 and 14 m). However, the characteristics of the airport runway support the arrival of B747 (up to 412 passengers), A380 (up to 550 passengers) or AN124 (up to 150 tons of cargo) aircraft; the latter has been used for cargo transport in PBC.

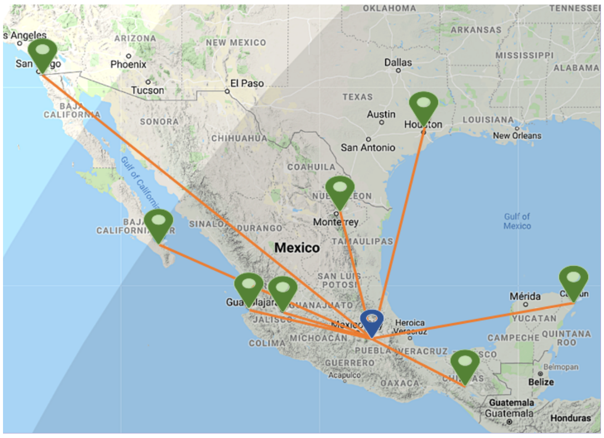

Figure 2. Commercial flights from PBC airport

The majority of commercial flights arriving at PBC are operated by low-cost carriers (Volaris 32%, VivaAerobus 15%, Aeromar 15%). Aeromexico, the only Mexican full-service carrier, is responsible for another 15% of the PBC demand. The remaining 23% is divided into four other low-cost airlines, of which two are from the USA.

Average annual growth has been approximately 10% since 2014, due to an increased airline participation and renewed terminal infrastructure. Puebla has become a reference airport and the presence of automotive assembly plants in the surroundings still offers opportunities for growth. Passenger demand is presented in figure 3.

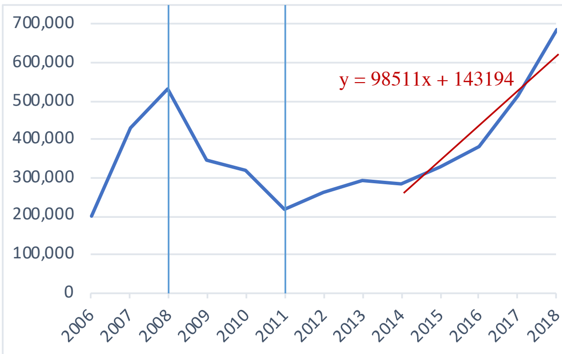

Figure 3. Yearly number of passengers served in PBC

Before 2008, PBC showed significant growth, mainly due to demand from the automotive sector. However, due to the poor physical conditions of the runway, some airlines withdrew their flights and demand dropped significantly. After a change of administration and a major remodeling of the facilities in 2011, demand started to grow again. As of 2014, the growth rate becomes very similar to that between 2006 and 2008; that rate was used to estimate future demand by linear regression, as shown in Table 2.

Table 2. Passenger number forecasts for PBC

Year	Future periods (x)	Forecast (y)	Growth (%)
2019	7	832,771	
2020	8	931,282	11.83
2021	9	1,029,793	10.58
2022	10	1,128,304	9.57
		Average	10.18

Demand is expected to stabilize in a few years. In case of using BPC as a secondary airport to MEX within the Metropolitan Airports System, the forecast might need to be adjusted. At the moment, mainly small aircraft (A319 and A320) arrive to PBC, although the runway also supports B757 and B767 aircraft.

Although the airline is the responsible entity, the baggage handling of the PBC airport is outsourced to an independent company, while the physical facilities are owned by the airport. Baggage handling international regulations consider that it should be done exclusively by trained and supervised personnel, and that the delivery of the baggage to the passenger must occur in maximum 30 minutes.

2. LITERATURE REVIEW

Passenger baggage travels along a logistic path at the airport until it is loaded on or removed from the airplane. Baggage problems constitute one of the main causes of passenger's complaints and baggage handling is an important indicator of customer satisfaction (Frey, 2014; Cavada et al., 2017). Due to the increase in congestion, baggage handling is becoming increasingly complex at international airports and one of the biggest management problems of airports worldwide (ABC viajar, 2015), ranging from late delivery to loss and damage to suitcases.

The concept of "service level" was introduced by the US Highway Capacity Manual in 1965. Given a certain demand and maximum process capacity, the service level of an infrastructure can be determined, indicating some degree of user satisfaction. Lemer (1992) mentions different performance factors for passenger satisfaction in airport terminals, emphasizing, however, the overall performance. Based on Lemer's formulation, Correira and Wirashinge (2010) propose operational indicators that should be considered when measuring the level of passenger satisfaction regarding the airport baggage claim service (see table 3). Ronzani and Correia (2015) use an index of service based on the IATA performance indicators used in this paper, specifically for the baggage claim unit.

As baggage handling performance depends on the volume and flow rate of baggage from incoming and departing flights, busy flight schedules can overload the system, extending bag in-system time (Le et al., 2012).

Table 3. Airport baggage claim operational indicators (from Correira and Wirashinge, 2010)

Factor	Description
Equipment configuration and claim area	Type, layout, feed mechanism, and rate of baggage display: space available for waiting passenger; relation of wait area to display frontage; access to and amount of feed belt available
Staffing practices	Availability of porters (sometimes called "sky caps") and inspection of baggage at exit; rate of baggage loading/unloading from cart to feed belt
Baggage load	Number of bags per passengers, fraction of passengers with baggage, time of baggage arrival from aircraft
Passenger characteristics	Rate of arrival from gate, ability to handle luggage, use of carts, number of visitors

As baggage handling performance depends on the volume and flow rate of baggage from incoming and departing flights, busy flight schedules can overload the system, extending bag in-system time (Le et al., 2012).

Several tools can be used for airport analysis, depending on the required level of detail and observed process complexity. For example, Ghobrial (1982) presents an interesting paper describing an empirical model that, for different demand and device conditions, can predict the performance of a claim device. However, when stochasticity plays an important role, mathematical models may not be applicable and simulation tools can help to identify the critical points of the system and the viability of the improvement proposals.

Different authors have applied simulation tools to analyze the baggage handling process. One of the first authors to simulate baggage handling systems was Robinson (1969). He focused on delays suffered by passengers and assessed the problem with a computer code written in GPSS III. More recently, modeling systems such as ARENA have been used to analyze the need for a baggage carousel to serve demand created by a large aircraft (Eller et al., 2002) or to predict human behavior and its influence on the check-in system (Appelt et al., 2007). Automated baggage handling systems have been simulated in ExtendSim for Riga airport (Savrasovs et al., 2009), adapting the traffic software package Quadstone Paramics to simulate the baggage handling system of Santiago de Chile airport (Cavada et al. 2017), using Delmia Quest to analyze two merging conveyor lines in a conveyer-based baggage handling system (Johnstone et al., 2015) or using ProModel to assess passenger congestion in an Indonesian airport (Novrisal et al., 2013).

SIMIO® is a discrete event modelling system that has supported several airport-related investigations, such as the simulation of Mexico City airport's air traffic and the associated congestion problems (Mendoza et al., 2015), or the development of a model to increase the productivity of Amsterdam airport (Mota et al., 2017).

This document analyzes baggage logistics once the plane lands. We used SIMIO® to construct a simulation model for the baggage delivery process in a Mexican airport, used to assess the associated degree of comfort and processing time by means of different simulation scenarios.

3. METHODOLOGICAL APPROACH

In this section, we describe the methodology of this paper, including the simulation approach and corresponding determination of input data.

The simulation was carried out using Discrete Event Systems (DES), which is a modelling approach where the state of the system variables changes only at discrete instants of time; the term "event" is used to represent the occurrence of discontinuous changes at possibly unknown intervals (Flores de la Mota et al. 2017). Figure 4 describes the methodology that was used.

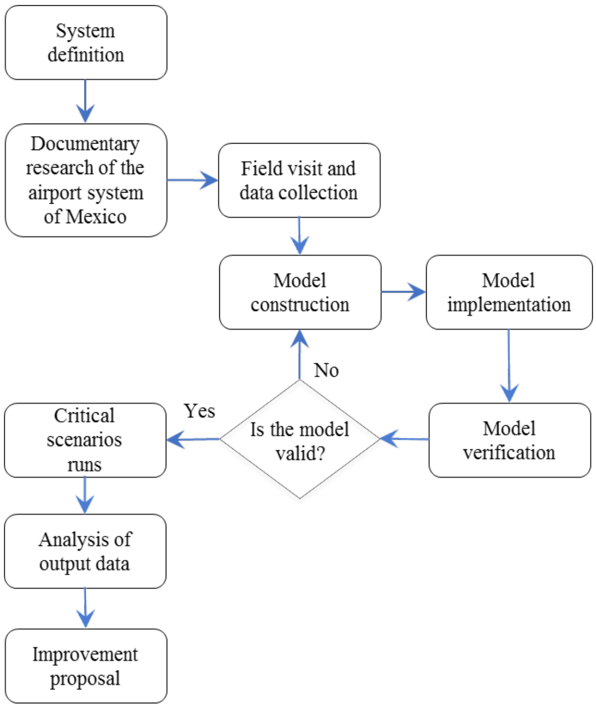

Figure 4. Methodology

Simulation requires modeling, model validation, selection of probability distributions, design and analysis of simulation experiments, as well as the analysis and discussion of results. The simulation consists of the different runs or replicas of the system to analyze different scenarios (Flores de la Mota et al. 2017), considering uncertainty in several model variables. In our case, uncertainty mainly affects the number of passengers and documented bags, as well as the bag processing time and time when passengers arrive to the baggage claim area; however, the structure of operations is fixed. SIMIO® was used, which is a flexible software that uses intelligent objects and requires little or no programming (Simio LLC, 2019). It has an attractive graphic environment and good computation times, making it efficient for simulating different industrial environments (Mujica, 2013).

PBC airport's baggage delivery service is analyzed to identify the characteristics of its operation and the processes that involve customer satisfaction in baggage management. A field visit was made to the PBC airport, where information was obtained on the baggage delivery process, including the unloading of the baggage from the plane, the transfer by cart to the delivery band and a timely collection of the baggage by the passenger. The data taken was analyzed to characterize the required probability distributions and average process times. In addition, the current conditions of the baggage claim room were evaluated, in accordance with the international IATA regulations.

The starting time of the corresponding simulation process depends on the arrival time of the flight (Frey, 2014). The arrival data to PBC was obtained from the *flightradar24.com* platform; the resulting database was cleaned and analyzed with the R software.

The evaluation of the results of two scenarios allowed us to analyze whether the configuration of the band supports an increase in the flight frequency, the arrival of larger aircraft and the decrease in arrival interval time. Possible problems of delayed baggage delivery, bottlenecks and system response to changes in flight frequency were observed.

Based on the simulation results, required changes in the baggage claim area configuration are proposed to improve the delivery process.

3.1. Comfort standards

The International Air Transport Association (IATA, 1995) uses the following international comfort indicators:

1. *Required baggage claim area*

$$A\,[\text{m}^2] = 0.9\,\boldsymbol{e}\ (+10\%) \qquad (1)$$

where $\boldsymbol{e}$ is the maximum hourly number of passengers in the terminal

2. *Number of baggage claim devices for narrow-body aircraft*

$$n = \frac{er}{300} \qquad (2)$$

where $\boldsymbol{e}$ is the maximum hourly number of passengers in the terminal (m^2) and $\boldsymbol{r}$ is the proportion of passengers arriving by narrow-body aircraft (0.2; IATA, 1995).

3. *Length of the claim band*
For narrow-body aircraft: 30 – 40 m
For wide-body aircraft: 60 – 70 m

To collect the baggage around the baggage claim band, each individual is considered to need a space of approximately 50 cm, which is slightly larger than the standard width between the shoulders of men, aged 18 to 65 (41.43 cm; Ávila et al., 2007). Considering the effective perimeter in the current T-configuration of the baggage claim band (it has a 20 m length, which is below the recommended value), 32 passengers can be at the same time waiting for their baggage on the perimeter of the band.

Table 4 compares the information of the claim area determined for PBC airport from the above-mentioned comfort indicators, as compared to the observed situation.

Table 4. Information on PBC's baggage delivery service (Consultation year 2018)

Variable	Determined/observed value
Declared capacity (pax/h)	450
Required number of baggage claim devices	1 (30 m minimum – equation 2)
Installed number of baggage claim devices	2 (1 inactive)
Length of the claim band	Device 1: 20 m Device 2: 8 m
Number of passengers waiting simultaneously	Device 1: 32 passengers Device 2: Inactive
Required baggage claim area	405 m² – equation 1
Installed baggage claim area	374 m² – visual inspection

Considering that PBC airport receives mostly A320 aircraft, that baggage delivery takes on average 30 min and that, at present, the baggage of aircraft is served sequentially, a maximum of 180 simultaneous passengers is expected in the baggage claim room. It's size of 374 m^2 indicates that the present service level in the baggage claiming area corresponds to 2 m^2 per passenger (an A-classification; IATA, 1995). IATA considers this an excellent level of comfort or conditions of free flow. As only one claiming device is used at the moment, an increase in flight frequency might lower this classification considerably.

3.2. Baggage claim system

PBC airport has a semi-automatic system for unloading baggage for A320 aircraft, but for smaller planes unloading is done manually; that is, the use of the auxiliary belt to lower the baggage to the transport cart is omitted. Figure 5 shows the manual unloading procedure.

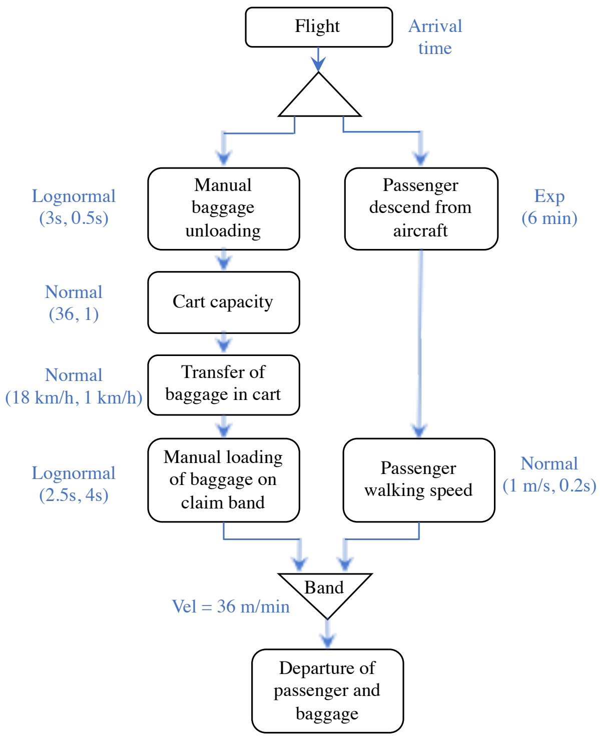

Figure 5. Manual baggage unloading at PBC airport

The human factor is an essential part of the baggage delivery process, since 90% of the operations are carried out by individuals. PBC has a current baggage claim area of 374 m^2, a 20-meter main baggage band and an 8-meter auxiliary band, with a configuration like the one shown in Figure 6.

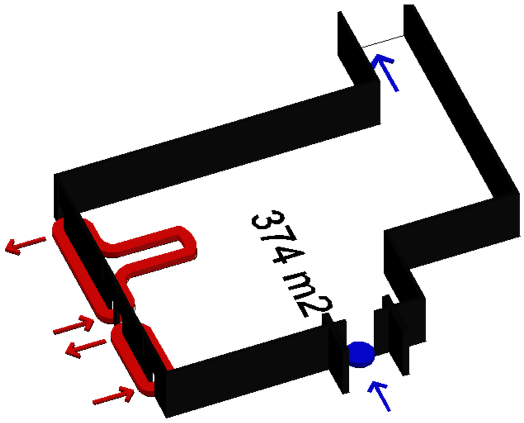

Figure 6. Configuration of the claim band and waiting room

3.3. Check-in system

In an interview, boot personnel of Volaris and Calafia Airlines informed us that approximately 80% of passengers document baggage and, most commonly, only one suitcase. Based on the above, the simulation model considers that, for passengers on an A320 aircraft, on average 144 of the 180 passengers document their baggage. The corresponding standard deviation was fixed at 8 (+/- 5%). Other assumptions are that only one suitcase per person is considered and that oversized bags are unlikely to be transported to PBC.

3.4. Input variables and probability distributions

Table 5 shows the probability distributions used for different model variables.

Different considerations were made: a passenger was assumed to be waiting on average 6 minutes before being able to descend from the plane, for both A320 and A321 aircraft. An exponential distribution was used, expressing passenger descent as an interarrival time. Walking and driving speeds were considered to follow a normal distribution. For walking speed, a speed slightly slower than the standard speed of approximately 90 m/minute (Causa directa, 2013) was considered. For the cart moving speed, we considered that, in general, the carts are driven at speeds very close to the speed allowed in the airside part of the terminal (20 km/h).

The lognormal distribution is used to model a multiplicative sequence of operations that presents variations in time with respect to the average; in our simulation it is used to model the time required for the bag unloading and loading processes. The used baggage carts have a maximum capacity of 900 kg, or, on average, 36 bags of 25 kg each. Finally, the baggage claim velocity is fixed by normativity at 36 m/min.

Table 5. Distribuciones por módulo de simulación

Model variable	Distribution	Parameters
Passenger descent from aircraft	Exponential	λ = 6 min = 300 s
Passenger walking speed	Normal	μ = 1 m/s σ = 0.2s
Passenger picking up baggage item	Uniform	[10s; 20 s]
Manual baggage unloading from aircraft	Lognormal	μ = 3s σ = 0.5s
Cart capacity	Normal	μ = 36 σ = 1
Baggage cart moving speed	Normal	μ = 18 km/h σ = 1 km/h
Manual loading of baggage on claim band	Lognormal	μ = 2s σ = 0.3s
Baggage claim band velocity	Constant	36 m/min

4. MODEL DEVELOPMENT AND RESULTS

The simulation model represents the current conditions of the airport in terms of the baggage delivery service. Currently, PBC receives almost only narrow-body aircraft, and with a relatively low flight frequency. Under these conditions, an excellent level of service is maintained with little damage to suitcases (approximately 1 in 200) and with baggage delivery times under 30 min.

However, poorly controlled factors (basically those performed manually, such as baggage unloading from the aircraft) add a significant portion of uncertainty and variability to the process.

The simulation considers the current conditions of the airport, using the probability distributions specified in table 5 for the different modules of the baggage delivery process. Passengers move on foot to the terminal building. Approximate passenger transfer speed within the system, baggage cart transfer speed and routes from the plane to the baggage claim band were obtained from the field visit. The corresponding distance was obtained with Google maps, according to the arrival position of the aircraft (table 6).

Table 6. Distance to the baggage claim area from different aircraft positions

Position	Passenger route (m)	Baggage route (m)
1	80	140
2	50	100
3	90	60
4	130	60
5	180	100
6	241	150

The simulation considers that each passenger must take his own baggage from the claim band. Fallen or damaged baggage was taken to be 1 piece per flight, according to information obtained from airport personnel; this is considered in the model as a failure of the server with a restauration time of on average 2 min.

The model does not include the handling of special baggage (sports equipment, musical instruments, ...) due to the type of passenger demand, mainly industrial in PBC.

PBC airport has sufficient baggage delivery capacity for current demand. However, the airport continues to grow, as seen in table 2. As a member of the Metropolitan Airports System, it might also receive larger aircraft in the future, such as those included in Table 7, typical for low-cost airlines.

Table 7. Most common aircraft used by low-cost carriers

Aircraft	Max. number of passengers
A319	144
A320	180
A321	220
B737	215
B757	280
B767	375

Based on the previous information, two scenarios were considered in this preliminary stage of the project:

- *Scenario 1, 360 passengers served*
  Baggage unloading from two A320 aircraft (maximum capacity 180 passengers) arriving a few minutes apart in positions two and three. The A320 is currently the critical aircraft in PBC. Although its simultaneous arrival is not currently scheduled, this scenario is viable if the demand for PBC as a secondary airport within the Metropolitan Airports System increases; in this case, also bigger aircraft could be expected.
- *Scenario 2, 440 passengers served*
  Baggage unloading from two A321 aircraft (maximum capacity 220 passengers) arriving a few minutes apart in positions two and three.

Figure 7 visualizes the simulation model developed in SIMIO® for the analysis of baggage delivery, using the data specified in figure 5 and table 5.

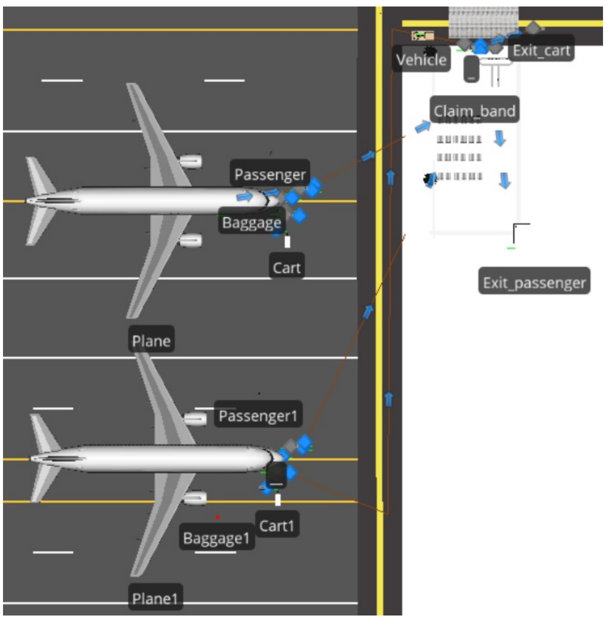

Figure 7. View of the simulation model.

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The number of replications was determined to be 100. Simulation results include the length of passenger and baggage queues, bottlenecks, failures and possible system collapses, as well as the current comfort level of the baggage delivery service of PBC airport. The flexibility of the model allows to easily introduce different aircraft types and occupation levels, as well as to include different baggage types and to increase cart or personnel capacity. Also, the arrival logic can be replicated to include a larger number of aircraft. Therefore, it can be generalized to other semi-manual baggage claiming services or airports without too much effort.

Table 8 shows the required conditions of the room and the baggage claim band to meet the IATA comfort requirements in each of the simulated scenarios.

Table 8. Comparison of IATA comfort requirements

Variable	Existing	Required according to IATA	
		Scenario 1	Scenario 2
Baggage claim area	374	356 m^2	436 m^2
Maximum number of pax in the claim area	180	183	221
Comfort classification	A	A	C

In addition to the decrease in comfort classification for de baggage claim area, also baggage delivery process time increased from 28.5 minutes on average for an A320 aircraft to 43.1 minutes when a second A320 arrives within 15 minutes. For the second scenario, baggage delivery time was 41.2 minutes when one aircraft A321 arrives, while this increased to 65.4 minutes for the second aircraft. The main problem is that baggage delivery is performed sequentially with a claim band that is too short according to IATA standards.
The process time increased by 51.2% for the first scenario, and by 58.7% for the second.

5. CONCLUSIONS

Simulation is a useful analysis tool in short, medium, and long-term decision making. Its results are based on the analysis of different scenarios that will not necessarily be implemented in the real system.

In this study, the simulation was implemented to analyze possible problems in the baggage delivery service of PBC airport, and that can only be studied in virtual environments close to reality. In our case, SIMIO® provides the necessary conditions for an appropriate approach of the problem and the corresponding result determination.

Given the current problem of air traffic and saturation of Mexico City airport, questions arise about the way in which the airports of the Metropolitan Airports System can be enhanced, according to their characteristics and without negatively affecting the passenger.

In this study we analyzed PBC airport, located in the southeast of Mexico City. It's expected increase in demand suggest areas for improvement, while passenger's comfort level should be maintained within international standards. The analyzed subsystem was the baggage delivery service, that should finish processing all flight's baggage within a 30-minute interval after arrival.

PBC's current operating conditions, aircraft types and flight frequencies allow the airport to have an acceptable service and comfort level in the baggage claim area. However, the simulation showed that the simultaneous arrival of different aircraft, as well as the arrival of larger aircraft, means a decrease in the service quality. Preliminary results show that, depending on the aircraft occupation, baggage delivery times can increase from 31.2 minutes on average for an A320 aircraft to 47.1 minutes when a second A320 arrives within 15 minutes, increasing the process time by almost 50%. For larger aircraft such as the A321, this delay in baggage delivery increases considerably.

The main problem detected is that the baggage claim band violates IATA standards and that baggage delivery occurs sequentially. If similar situations to the presented scenarios arise in the future, an increase in band length as well as a configuration change should be considered. Other possible improvements to the baggage delivery process may include a more careful baggage handling by the personnel, as well as an increase in the baggage cart capacity.

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