A Methodological Framework for Airport Outbound Passenger Flow Modelling

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***Abstract*— The airport is a logistics hub that handles several flows. Passengers are the common customer of all the actors of the airport chain. Thus, and considering growth of passenger air traffic, airport managers must find rational solutions with optimal use of available resources and infrastructures; hence the opportunity for a modeling study and an optimization of passenger circuits. This article took the initiative of presenting the passenger flow model with a holistic approach starting from airport access to the boarding gate and following, for the first time, a confirmed methodological framework which is the ASDI methodology (Analysis, Specification, Design and Implementation). This methodology relies on a system decomposition in three subsystems: SSP physic, SSL logic and SSD decision-making. This study was conducted on Mohammed V International Airport of Casablanca, the first airport in Morocco, by building its generic model of knowledge of outbound passenger flow; a model that can be reused and reproduced on other flow, even other airports.**

***Keywords*—** *Passenger flow, Modeling, Methodological framework, ASDI, UML, BPMN.*

1. Introduction

Faced with the growth of air traffic, international airports must be easily absorbed by the system of control of fluidity and management of processes. Without a policy accompanying this growth, the saturation of the whole system is inevitable. Then, how to reconcile this fluidity required by passengers and the airport process? Several solutions have been improved namely: technological solutions [1], [2] for the automation of certain automated procedures or solutions requiring significant investments to build new terminals or to carry out extension projects for existing terminals. Such decisions have led some governments to cede their airports to privatization; for example, Italy, Australia, New Zealand, Denmark, Mexico, ... [3]. Finally, there is a more rational solution, which consists not only in developing the existing network, but also in making it more optimal [4], a solution that does not entail a significant financial cost but which tries, with the resources and available equipment, to offer the best passenger circuit by reducing waiting times in different points with long waiting records [5]; such a solution requires a good analysis of the passengers flow. This analysis can give us an idea of the right decisions to make, whether through the development of the infrastructures, the technologies to use or only the implementation of improvements on operating procedures and existing passenger circuits. For example, a passenger arriving at an airport terminal that does not have good airport signalization, can waste time and arrive late, and even miss his flight. He will become an unsatisfied passenger. He may not be coming back to this airport and will have a bad reputation on this airport, and on the country in general, only because of bad signaling.

In Morocco, a developing country, ambitious programs have been drawn up for its openness to a new tourism strategy. Thus, after the "Azur Plan" (launched in 2001) and Vision 2010, the Vision 2020 plan launched in 2010 aims to make Morocco among the top twenty global tourist destinations; with 18 to 20 million passengers a year. This objective was actually significantly exceeded in 2017 [4]. Morocco, particularly at the Mohammed V International Airport of Casablanca (MIAC), the international airport ranked No. 1 in Morocco, is constantly in need of one or even several solutions, which can optimize its passenger flows; solutions guaranteeing passenger satisfaction, safety and security with a minimum investment cost. It's in this perspective that our work is based on the development of the departing passenger circuit of

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this airport, through an in-depth analysis of this circuit and the proposal of an optimized model most appropriate to the installations put in place.

Before starting any work of improvement or optimization, it is first necessary to model and formalize the system. In fact, the purpose of this article is to develop the flow of passengers at the Departure Circuit “DC”. Thus, through a literary review dealing with the flow of passengers, we found that all the existing works, despite their volume and the importance of their results; have treated only fragmented parts of the passenger circuit. Also, they followed a modeling work that goes directly to the model of action (simulation or optimization...) and did not use any known and proved modeling methodology. Therefore, our global goal aims to make a contribution to overcome some of the shortcomings identified by the literature in the field of airport operations and to carry out a modeling and optimization study by simulating all the subsystems of “departure process”, not just one or two fragmented sub processes; and also make use of the scientific wealth in terms of methodologies and know-how to model the departure flow of passengers. These are the strengths of the originality of our approach. Indeed, a well-confirmed methodology will be beneficial to help us describe the functioning of the current system and to direct the necessary future changes. Thus, in this manuscript, in the absence of a recognized methodology for modeling flows in the field of air operations, we will apply the ASDI methodology (Analysis, Specification, Design and Implementation), used in the field of logistics operations and especially in hospitals logistics. In the present article, we will build the generic model of knowledge, according to two complementary approaches, one dynamic and the other static, with an application to the passenger DC of MIAC, our case study.

2. Airport passenger traffic: importance, growth and issues

Alexandre de Juniac, General Manager of IATA (International Air Transport Association), announced on October 24, 2018 that “Aviation is growing, and it brings tremendous benefits to the world. If the number of passengers doubles in the next 20 years, it could support 100 million jobs worldwide”. Thus, projections for 2037 year indicate that the number of air passengers will almost double, reaching 8.2 billion [6]. This growth is due to several factors like: the globalization, the liberalization of the space and the technological progress. Actually, at the international level, the largest airports account for an average annual passenger traffic of nearly 80 million passengers [7]. As a result, the management of airport passenger flows has become a major issue for both operational control and safety [8]. In fact, the airport is a large multi-stakeholder platform that manages multiple flows and serves millions of passengers from many different cultures. Such a multicultural structure presents different constraints and major issues, notably: quality of service [9], [10].

Thus, since the attacks of 11 September 2001, there is an increase in security measures prior to embarkation, which was a major constraint that the airport manager must take into account during the flight planning (additional control periods) and in managing various airport operations [11], [12].

There is also the constraint of the airport capacity [4] and finally the financial cost, mainly the cost of investments to develop, build and procure new infrastructure, new facilities, new equipment’s for safety and security...

3. Opportunity behind modeling airport passenger flow of the MIAC

MIAC is the international airport number one in the Moroccan Kingdom. Like international airports, it is experiencing a significant growth in passenger traffic. Table 1 shows numbers achieved between 2014 and 2018 for all Moroccan airports. Table 2 shows forecasts for the next 20 years with an expected increase of 215% of total air traffic (241% for MIAC) between 2018 and 2030 [13].

Table 1: Air traffic carried by Morocco between 2014 and 2018 [13]

Year	Passengers	Movements
2014	17.294.871	156.138
2015	17.607.491	159.995
2016	18.237.272	161.837
2017	20.406.160	175.304
2018	22.534.771	189.784

Table 2: Activity forecast of Morocco's air traffic 2018-2030 [13]

	Passengers	Movements
2018	20.078	151.976
2020	21.705	173.839
2025	31.299	250.175
2030	43.311	346.205

4. Flows circulating at MIAC and their separation

The Mohammed V airport terminal in Casablanca, like international airports, processes several flows, including:

- Passenger flows at departure, on arrival and in correspondence or transit;
- Baggage flows at departure, on arrival and in correspondence or transit.

Figure 1 shows the so-called circulating flows at the MIAC. To these flows are added other flows whose impact in terms of capacity is less than those mentioned above. These flows are those of the operating staff of the terminal and the various stakeholders working there; also the flow of passenger companions on departure passengers or welcoming them on arrival. The influence of the presence of these pedestrians in the treatment of the flows circulating at the airport is limited to certain parts of the public zone, such as the public hall and the esplanade (doors of entry and exit of the passenger terminal).

In application of some safety principles in its terminal, there is a total and perfectly sealed separation between the circuit of the departing passengers who passed the filtering inspection…, and the arrival passenger circuit (similarly for hold baggage).

For safety purposes, the passenger treatment spaces within the MIAC are divided into two areas:

- A public area which is open to all users (passengers, staff and any other visitors of the MIAC), without any restriction: esplanade, public halls.
- A controlled access (Restricted Area), which includes "critical parts" in which only passengers or staff who have undergone a screening inspection can travel.

In addition, and as shown in figure 1, certain formalities at departure or arrival are mandatory and common to all passengers; others depend on the nature of the flight. In fact, there are two routes: a "domestic" type for national destinations where passengers are not subjected to any administrative formalities on the part of the State services and an "International" type route for passengers who enter or leave the national territory from MIAC to another country (including in transit) and who are subject to cross-border control formalities by the Moroccan Police and to a possible control by the customs.

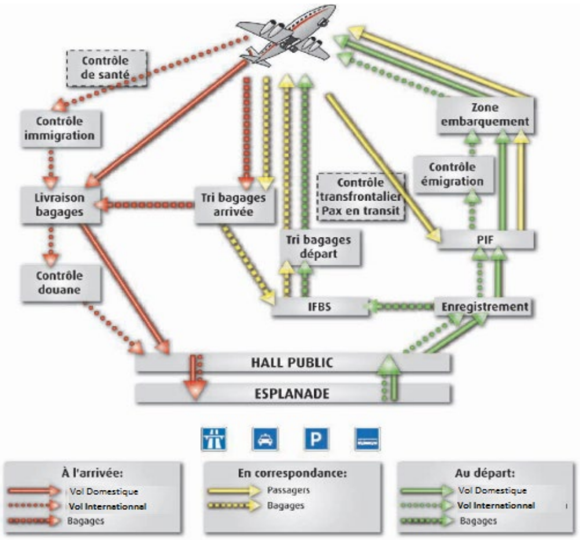

Figure 1: Passenger routing domestic and international flights, for the circuits Departure, Arrival and Correspondence [4]

MIAC airport is composed of 3 terminals (T1, T2 and T3). According to the model currently in place, T1 is dedicated to the national airline "Royal Air Maroc" (RAM) which uses dedicated checking-in mode, that is to say, any passenger customer of the RAM can go to any check-in counter and register there; this reduces the problem of waiting time. Thus, this terminal is equipped with self-check-in kiosks of the same RAM Company. This mode of operation can alleviate congestion at check-in counters. Terminal T2 is used for all international flights of airlines other than RAM. The particularity of this terminal lies in the management rules (opening and closing of the check-in desks) which presents a significant constraint to the model of passenger's flow. Finally, there is Terminal T3 which only opens during seasons with heavy traffic (pilgrimage season ...).

We chose to work on Terminal T2 being, as mentioned above, a terminal with more management constraints. This makes it a fertile ground for study and improvement for an optimized processing of departing passenger flows and makes it a reference model to adopt for all other airport terminals of the Kingdom of Morocco, or even a generic model for any international airport.

5. The ASDI methodology

The role of the methodology is to combine several approaches, several methods, several tools, several languages of several domains and horizons in order to integrate them into a single logical and structured approach [14], [15]. In fact, the methodology ASDI (Analysis, Specification, Design and Implementation) was created to facilitate the development of decision support tools. It was proposed and presented by [16], and used in large numbers of works in industry [17] especially in the hospital logistics field [14], [15], [18]–[20]. The conceptual framework of this method is based on the explicit separation of the collection of knowledge and its exploitation [15] by following four main phases. Figure 2 schematizes the general framework of the ASDI methodology and its four main steps as well as the resulting entities.

The ASDI methodology follows these main phases:

- The knowledge model: formalizes knowledge of the system [19] and builds a library of software components. It models the decomposition of the studied system into three complementary sub-systems which communicate through their complementary components (the SSL logical subsystems, physical SSP and SSD decision-making).
- The model(s) of action: the so-called software components resulting from the generic knowledge model are used to generate an action model (computer program). This is realized from the models of evaluation of the performance (analytical model, meta-heuristic model and simulation model), optimization methods (mathematical model...) or models of coupling approach (optimization coupled with simulation);
- The results model: allows from the action model to obtain the necessary indicators to help the decision and possibly act on the system (structure, installations, locations…).

6. Construction of the generic model of knowledge of passenger’s flow in a methodological framework: application to the MIAC.

While processing airport passengers, there exist two most important circuits: the DC that starts from the access to the terminal until boarding, and the arrival circuit which starts from the unboarding of the plane until the exit of the terminal. Between these two circuits, the DC has always attracted the attention of researchers by its complexity, its importance, requiring more time and also by its composition of multiple facilities and processes involving several stakeholders (the airline, the handler, the airport operator, the customs, the police, etc.) [21]. The ASDI approach gives an interesting systemic decomposition. Here, we are

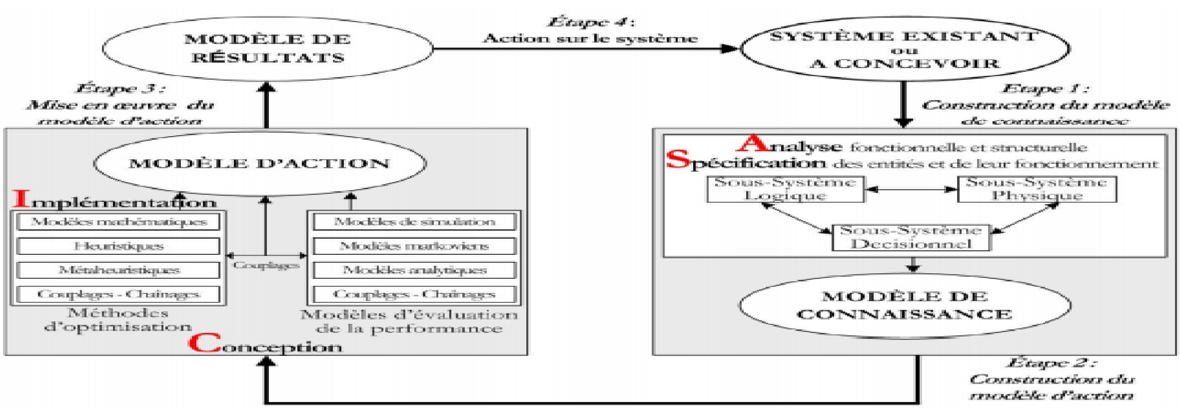

Figure 2 : ASDI mapping-cycle view [18]

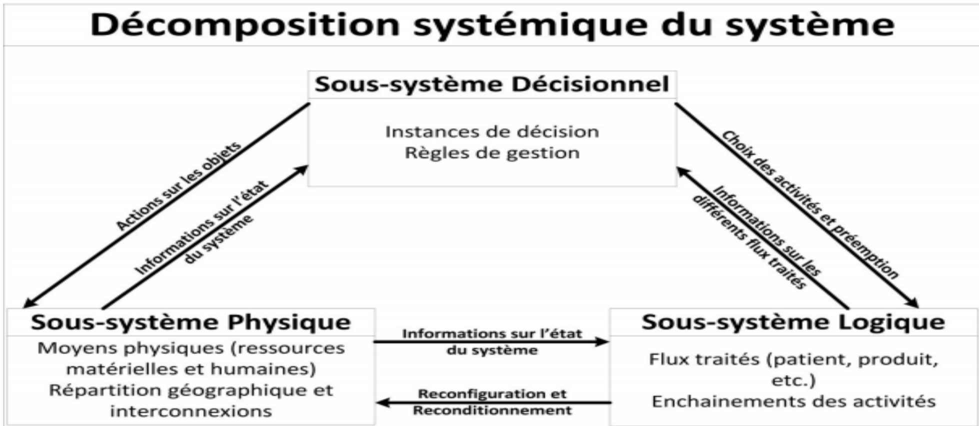

Figure 3: Interdependence of subsystems of the ASDI methodology [18]

interested in the generic knowledge model, which must remain consistent and valid over time, regardless of its level of finesse and whatever changes are made to the system when it is used. In this step, as illustrated in figure 2, the generic knowledge model encompasses the first two phases of the approach, namely the Analysis phase and the Specification (AS).

As already stated above, the knowledge model contain a decomposition creating three interdependent subsystems (figure 3):

- A physical subsystem also noted (SSP): defines all the physical means, material and human for the functioning of the studied system, their geographical distribution as well as their interconnection [15], [17];
- A logical subsystem (SSL): this subsystem is made up of many entities that the system must deal with, all the operations (basic activities) concerning the processing of transaction flows, as well as entries in the system that relate to it;
- A Decision Subsystem (SSD): this management subsystem is structured in centralized decision centers for the three levels: strategic, tactical, and operational [17]. Its role is to identify the set of management rules, to specify the rules of operation and the laws governing the management of the system.

After explaining the main guidelines of the ASDI modeling process, we will try, in this article, to build the generic model of knowledge of our system and to apply our approach on the "departure" circuit of the passengers of the MIAC. To get results, figure 4 explains the approach followed during our modeling:

- Define actors and entities;
- Formalize the departure process macro and its sub-processes: Dynamic modeling;
- Break down the departure system into three subsystems: SSL, SSP and SSD: Static modeling.

The "Departure" process for passengers covers the flow of passengers from the terminal entrance to the boarding gate. It's a macro process that we have spread over four sub-processes, essential for international flights and necessarily operated in the direction shown in figure 5.

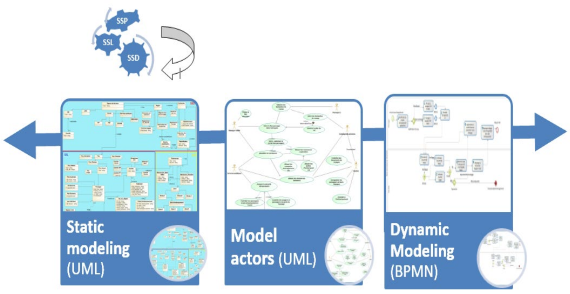

Figure 4: Our approach for construction of the generic model of knowledge

Figure 5: Passenger departure process and its sub processes

6.1 The actors of the "Departure" process

Passenger flow management at MIAC airport is a coordination process between several stakeholders and actors acting on the passenger transport system and mainly their flow in a terminal. Indeed, the actors are the heart of the process of passenger processing, in general, and particularly the

"Departure" process, even if their visions to this process remain different, because each actor is only concerned with the phase that concerns him. These actors are:

- **ONDA:** The National Office of Airports, a public service company that assumes the responsibility and animation of all the Moroccan airport sites, the manager of the platforms of their infrastructures, their equipment's as well as their services.
- **Public services:** made up of Customs to fight against fraud and the police to guarantee airport security.
- **Airlines** that are transporters of passengers and goods. They are responsible for their passengers (customers) from check-in at the airport of departure until delivery of their luggage to the airport of arrival.
- **Handler:** For a better control and focus on their core business which is the transport, the airlines subcontract the activity of treatment of the ground passenger (Ground handling) to a company specialized in the field which is the "Handler". In order to present the different actors of our system as well as their link, we have opted for the use case diagram of the UML (Figure 6):

6.2 Dynamic Process Modeling by BPMN

In order to better understand the processing of the departing passengers circuit and to better communicate with the airport operators' managers, we have chosen to model the sub-processes of this system using the BPMN tool, a graphical modeling tool that model the "dynamic" state of the DC.

We presented a macroscopic view of the international departure process in figure 7, with the sequence of steps that a passenger traveling from Mohammed V airport to another airport outside Morocco must validate to access the edge of the plane. In addition, a detailed description of each sub-process will be presented in the following sections.

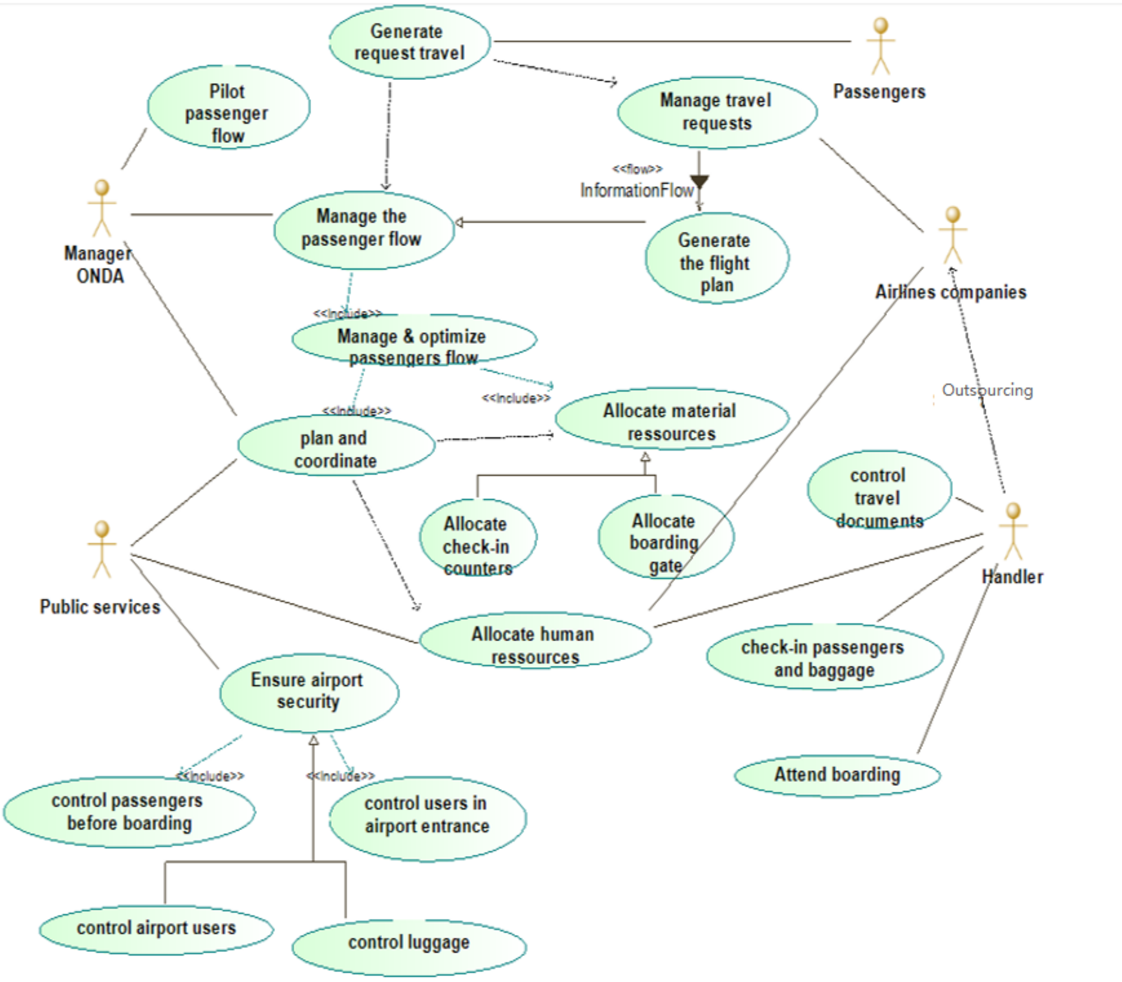

Figure 6: UML diagram - Use case of DC at MIAC

6.2.1 Mapping of the sub process "Access to the terminal"

There are several profiles of people who access the MIAC (figure 8): the passengers in the first place, their companions and the personnel of the entities working at the terminal: Airline companies, Handlers, Police, Customs, ONDA, staff companies' outsourced operations (cleaning, guarding, assistance to passengers...).

For airport security and following the terrorist attacks in Brussels in April 2016, which left 14 dead and at least 92 injured, the MIAC has banned non-travelers from its terminal. This has, in a way, lowered the people flow entering the terminal and even circulating in the public hall. This decision has just been canceled in February 2019, thus increasing the flow of people in these places. The means of access to the MIAC are shuttle buses, taxis, personal cars and the train. According to a survey conducted in 2014, based on 384 passengers [22], the results say that the main means of transport for passengers to MIAC airport is the car (51.7%) followed by the train (21.1%), taxis (20.6%) and finally the bus (6.7%). ONDA has implemented several improvement actions on these parking infrastructures: outsource T1 and T2 parking management to specialized companies and set up the minute deposit system. For passengers arriving at the airport by train, the MIAC terminal has a direct access train station at level -1. For each terminal, there is only one entry door for passengers arriving by road, and another for passengers arriving by train. Each entrance door is equipped with two safety control devices, the commissioning of these two devices depends on the flow of passengers accessing through each door. Whatever the door chosen to access the

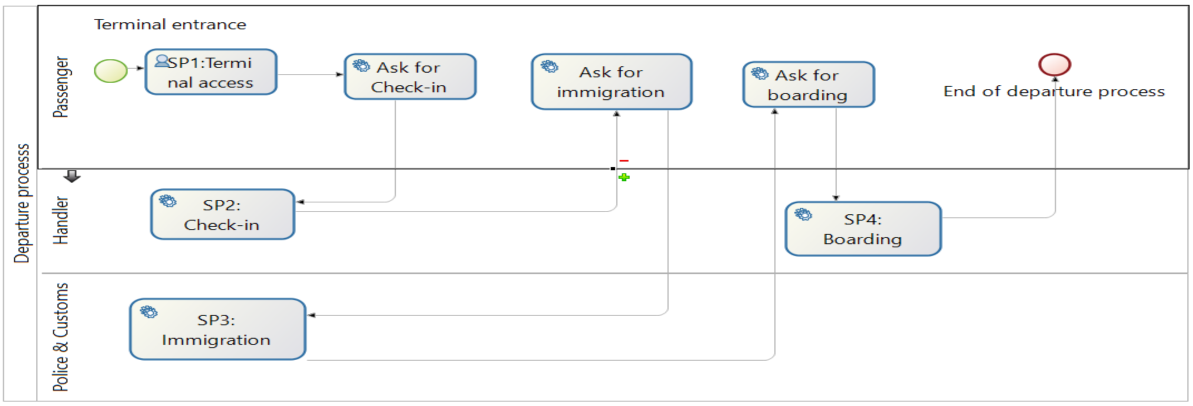

Figure 7: Cartography of the "Departure" process at MIAC- International Flight

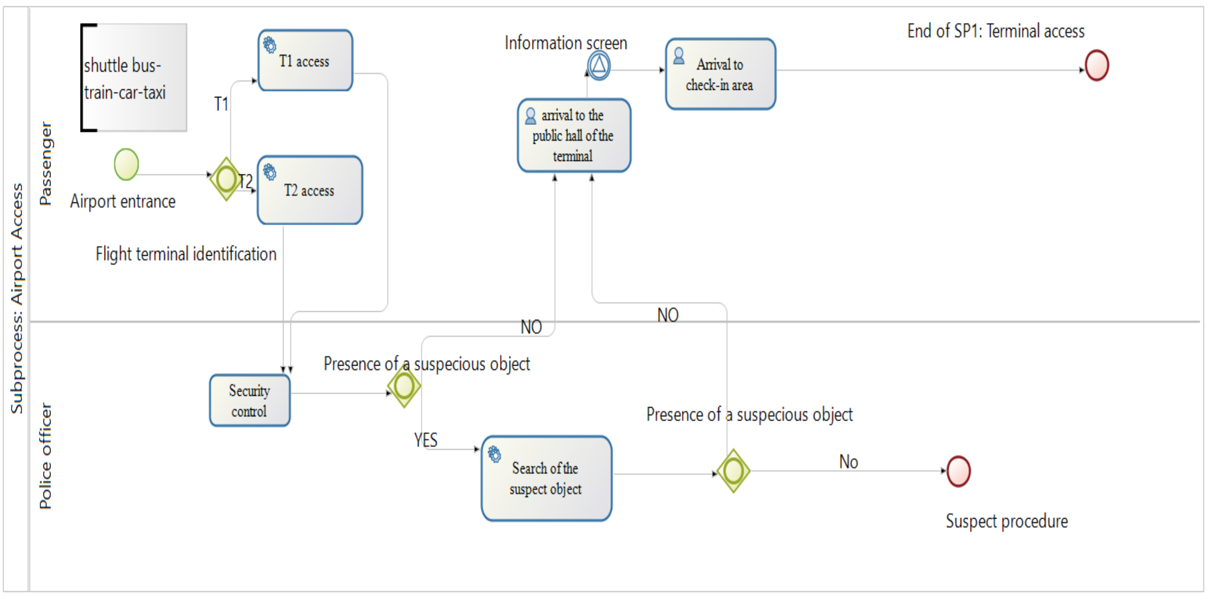

Figure 8: BPMN mapping of the access process to the MIAC airport terminal

terminal, once the security check is successful, the passenger goes directly to the public hall of the MIAC where there are check-in counters and other non-aviation activities, such as cafes, banks, restaurants...

6.2.2 Mapping of the sub process "Check-in":

Arriving at the public hall (figure 9), the passenger can consult display screens that indicate: flight numbers, scheduling, destination airports, names of airlines and also the numbers of counters allocated to each flight. After having identified his flight, he then goes to the airline's counter(s) designated for his flight to proceed with his check-in.

At terminal 2, only the "traditional" check-in type, i.e. at the check-in counter, is operational and the check-in is done by the check-in agents of the handler agreed by the airline. These agents are mainly based on an activity of checking the travel documents and validating the information of the reservation on the check-in system. However, there is also online check-in, little used and when it was it's especially from passengers who do not have luggage to put in the hold; otherwise they will be forced to go through the counter to check their luggage.

Once the passenger has completed the check-in process, he can move to the security zone to proceed to the "Immigration" process.

6.2.3 Mapping of the sub process "Immigration"

Once the passenger is checked-in, and according to the amount of time he has left to complete his travel formalities, he has the choice to do extra aeronautical activities (excluding formalities) like: a tour in the public hall of the terminal, eating in one of the restaurants or a cafeteria installed in the public access area, or go directly to the second stage of the DC, which is the security and immigration control (figure 10) located in the restricted area. Only passengers who are checked-in can access this area. The Immigration sub-process, is a rather long process in the DC [23] because it includes four very important operations which are:

- Pre-check: identity check;
- The Customs control;
- Police Security Check: PIF (Police Inspection Filtering);
- Border control: doing by Border Police, also called in French language "PAF" ("Police Aux frontières").

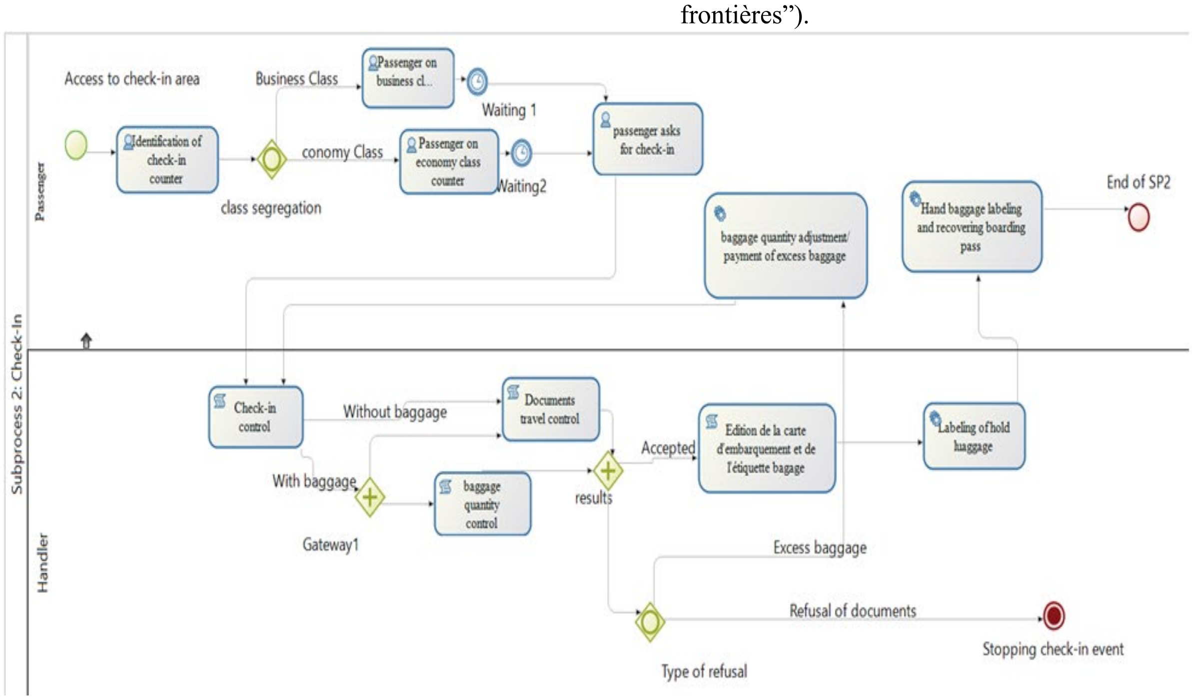

Figure 9: BPMN Mapping of the MIAC "Check-in" Process

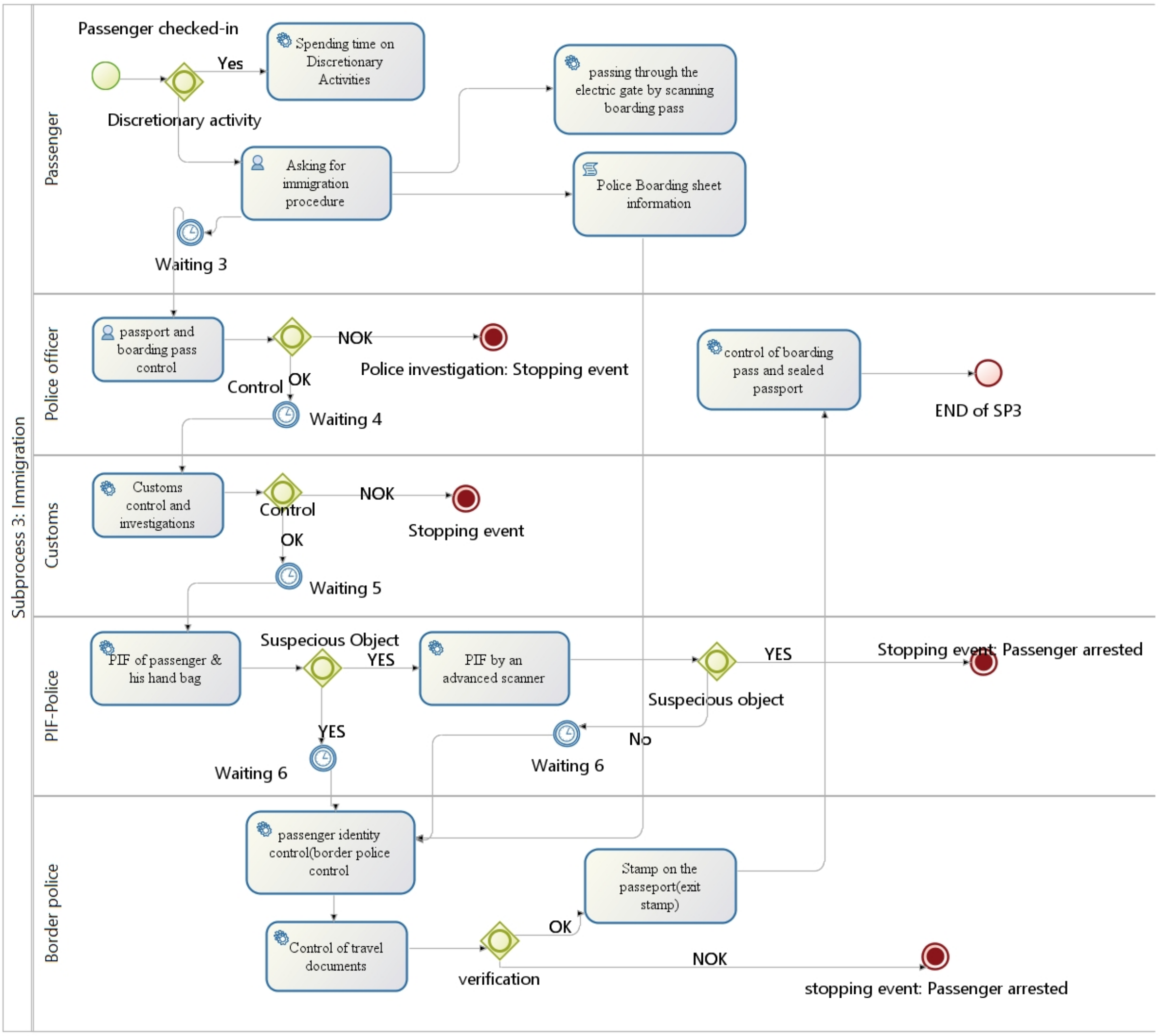

Figure 10: BPMN mapping of the "Immigration" sub-process of the MIAC

These operations concern all passengers whatever their flight, their destination, their airline, their types of check-in. Only passport and boarding pass are required.

- Pre-control: conducted by a police officer, placed right outside the restricted area door. Once the passenger arrives at this door, the police officer checks his passport with the boarding pass by checking the time of the flight, the photo and the name on the passport and on boarding pass. Once this micro-check is done, the police officer authorizes the passenger to access to the restricted area door to go through customs control.
- Customs control: Customs officers have the right to check the identity of the people they control by verifying their declaration of money coming out of the Moroccan territory.
- Security check (called in French language PIF: "Police Inspection & Filtrage"): It is mandatory in any flight and at any airport. The passage is made through a queue, organized and guided by streamers. Each station is equipped with a gantry scanner that scans each passenger and an X-ray machine that detects suspicious objects. The passenger can also be controlled manually.
- Immigration Control (PAF): This control is dedicated only to passengers on an international flight. Thus, the international passenger goes to the immigration checkpoints, he follows the queue, once arrived at the police officer installed in an immigration booth, he will be invited to present his passport and his boarding card and to provide the boarding form, also known as the "police form". The information in this sheet is not mandatory in the international regulations of travel, but to ensure better control of entry and exit of Moroccan territory, the Moroccan Border Police force any passenger leaving Morocco to inform this sheet and submit it to cross the immigration checkpoint. This check is marked by a stamp of exit on passenger passport with the name of the country of departure which is Morocco, in our case.

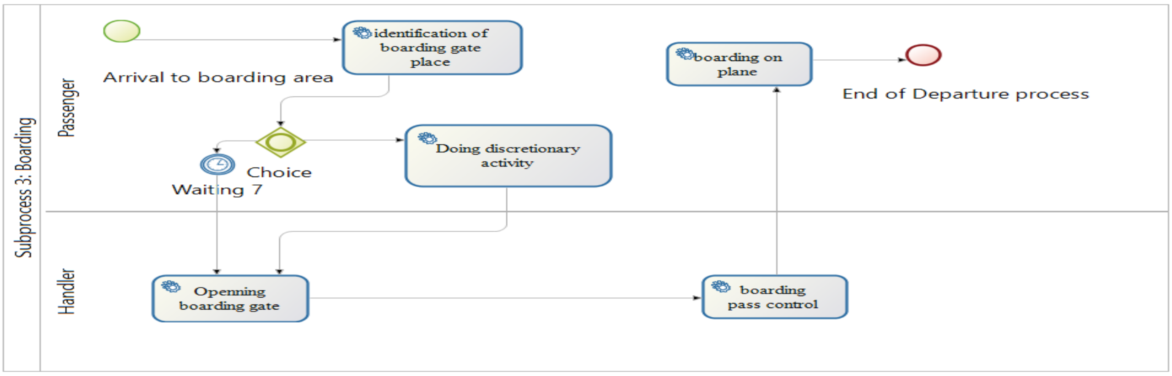

Figure 10: BPMN mapping of the MIAC "Boarding" process

6.2.4 Mapping of the sub-process "Boarding"

Once the passenger passes customs, security and immigration control, he accesses the boarding area. If he has enough time, he can shop, eat and look for interesting things in the boarding area, a large space where the sale is duty-free. After that the passenger goes directly (figure 11) to his boarding gate bearing the same number indicated on his boarding pass. At the boarding gate, the staff of the airline and / or its representative (the handler) checks the identity of the passenger before he/she enters the aircraft through a check of the boarding card and identification pieces (passport).

Depending on the capacity of the aircraft, the boarding gate opens between 30 and 60 minutes before the flight. Passengers are invited to arrive at least 15 minutes before the flight boarding time to avoid last-minute confusion.

6.3 Static process modeling: SSP, SSL and SSD decomposition.

Through the ASDI methodology, the objectif of the author is to model the "Departure" process on a microscopic level of detail because it is possible to go from a microscopic, mesoscopic and then macroscopic modeling in a very fluid and logical way; even if it generates, most of the time, a loss of information [18]. In the opposite direction, it is more complex or impossible without another formalization work. First, we will present the dynamics of the DC on several microscopic maps tracing the sequence of the operations and the different circulating flows by using the BPMN language. Then, in order to have an exhaustive view, we will carry out a static modeling which decomposes the domain of the system of passenger's flow processing in the form of a diagram of UML analysis classes, where each entity is represented under the shape of a class whose attributes reflect its specificities. We have opted for a three subsystems division composing the generic model of knowledge. The first one is the decision-making subsystem (SSD) which defines the management rules concerning the activity, resources and flows taking into account the various constraints. The second is the physical subsystem (SSP) and the third is the logical subsystem (SSL) which have the fundamentals of the system and which send back to the SSD the information regarding the use of resources, activities and flows. Figure 12 presents this decomposition for the whole DC.

6.3.1 The SSP-Physical Subsystem:

(a) Ressources

"Resources" class is used to model the resources at the macroscopic level of the model by distinguishing between the "human resources" HR class and the "Material Resources" MR class. These two classes take into account the specificities of each of the resources, the common attributes of the "resource" is the minimum quantity to be put in place to manage a given flow and the maximum quantity limited by the available in terms of space and resources. The material resources MR are characterized by a name, a quantity of units set up and a Boolean operating state (operational or not-operational MR): the check-in counters, the control scanners of security... In a same manner, human resources HR are characterized by a name and a first name, the name of the busy function (policeman, customs officer, check-in agent, handling agent...) and finally the quantity of HR allocated. The resources are assigned to a specific "Operation" constituting one of the DC sub-processes. Each HR is assigned to a single MR, while an MR can be served by multiple HRs.

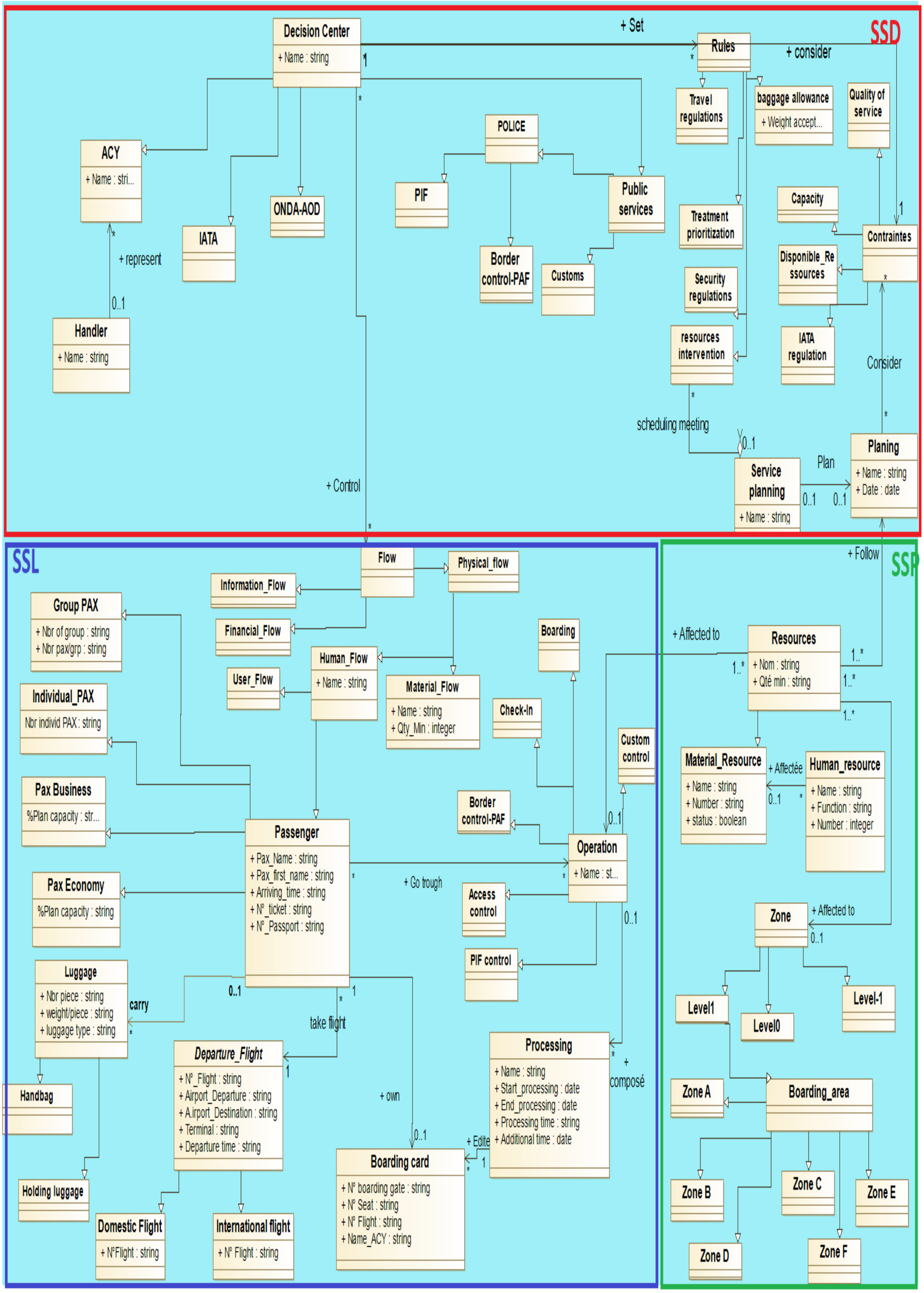

Figure 12: Systemic decomposition (SSP, SSL and SSD) of the passenger's DC at MIAC

(b) The zones

The introduction of the zone concept in our model allows the localization of one to several resource(s) and where one or more human resource(s) can work. Each resource is assigned to a single zone of Terminal T2; remember that T2 contains 3 levels:

- N-1 level: to accommodate passengers accessing the terminal through the train;
- N level: to accommodate the passenger accessing through the door of the T2 (from the parking side);
- N+1 level: to check-in passengers of foreign companies other than the RAM as well as all the other formalities of the DC. In the same level, there is the zone of boarding which is also identified by its "boarding gates".

6.3.2 The SSL-Logical Subsystem:

SSL encompasses all logical flows that circulate through the system, including information flow, physical flow, and financial flow. A flow is controlled by 0 to several decision-making bodies in terms of tactical, strategic and operational planning and decisions.

(a) The physical flow:

It's the most important flow of our study and the heart of our model composed of material flows and human flows:

- Material flow: refers to the flow of hand luggage and hold baggage and all similar items. The luggage attributes are the number of pieces and the weight.
- Human flow: made up of passengers and airport users. The term "user" refers to the accompanying passengers and the staff of the various actors of the airport chain involved in the DC.

Passengers, the common customer's number 1 of all the airport actors, perform "activities" by crossing the departure circuit. The attributes of the "passenger" class are:

- Name, first name;
- Time of arrival at the terminal;
- Ticket number;
- Passport number.

The configuration of the "passenger" class depends on whether the passenger has come individually or in a group: "individual Pax" or "group Pax". In the latter case, group sizes must be known by specifying the attribute "number of pax per group". We note the example of organized tours or destinations of "Alomra" or "Pilgrimage" where one person represents the group in certain activities of the circuit.

Another classification of passengers is the class of ticket purchased where the passenger is classified as either a "Pax Economy class" or a "Pax Business class". Both classes have a separate queue and a specific treatment making the processing and waiting times different for the two cases.

Each passenger takes a single "flight" identified by a number, the names of the airport of departure (MIAC) and the airport of destination, the name of the Terminal (for our study we take T2), the time of departure and the time of arrival and the nature of the flight, whether it is "domestic flight", also called national flight, or "international flight" operated to another country. For the case of Terminal T2, our case study, only international flights are operated.

In the logical system, we introduced a class called "operation" that encompasses all the activities of the DC, namely "access control", "Check-in", "Customs control", "PIF control", "PAF control" and "Boarding".

Each "Operation" is composed of one or more elementary "treatment" whose attributes are:

- Name;
- Start of treatment time;
- End of treatment time;
- Duration of treatment;
- Additional processing time (in the case of an exceptional problem, for example, exceeding the amount of baggage according to the allowance granted by the airline during the check-in operation. In this case, the passenger must either readjust the quantity of the part or pay the surplus. This operation will generate additional service / processing time).

We can note that "the boarding pass" is an important document in the entire departure process. In fact, with the exception of the sub-process access to the terminal or the said card is not yet printed (except in the case of an online check-in where the boarding pass is already printed), all the treatments carried out or check this card that accompanies the passenger until boarding the plane.

This card is also important to make purchases in free tax in the restricted area of shopping at the boarding space; each passenger must present it to the store to be able to benefit for a purchase in this zone.

(b) The information flow:

This flow gathers data and information circulating and feeding the information system. The information system basically contains all of the passenger's travel data. Indeed, at the MIAC level, there are several information systems SI, a typology managing the passenger's check-in and the management of the resources of the aircraft (number of seats, baggage weight allowed, etc.) namely Altea... These SI are installed by the airlines companies and differ from one company to another. There is also another typology of customs and police information systems that use their own information systems to alert suspects, wanted persons and boarding records (police files).

(c) The financial flow:

The financial flow exists in any system. It represents the costs of the services provided of the operations processed. In our case of treatment of the passenger flows we have: fare tickets, remuneration of resources and other airport charges. In our model, we are not directly interested in financial flows which can be the subject of a specific study of management control and in-depth financial analysis.

We chose not to integrate the last two flows (information and financial) because that did not fit into our objectives and they are discussed in other work [24] . However, to take them into account where necessary, it is also easy to add attributes and methods to our class diagram.

6.3.3 The SSD Decision-making Subsystem

A decision subsystem receives information and transforms them into actions [25]. Thus, our decision-making subsystem is the brain of decisions controlling the passenger's flow at the departure. It communicates, two by two, with the other subsystems SSP and SSL. It consists of decision centers, constraints and management rules.

The decision-making bodies that come into play in the macro-departure process are the various actors in the airport chain; notably: IATA, the airline company (ACY), represented by the handler, the public services composed of the customs and the police (for the control of Passenger Safety (PIF) and Immigration Control (PAF)) and finally, but not least, ONDA represented by the MIAC's "AOD" Airport Operations Department. These decision-making bodies set the rules and consider the constraints of different natures and objectives, in particular:

(a) Management rules:

- The prioritization of treatment: for example, the operation of passenger's check-in flights with a closer departure time is a priority, or at the level of access to the terminal or to different points of the terminal, the passage of personnel with a certain number of authorization of access, has priority to the passage;
- Safety and security rules: International air transport organizations as well as the Moroccan police who set the safety and security rules for passengers;
- Baggage allowance: The airline companies that set the baggage allowance that the passenger must meet;
- Travel regulations: The airline companies or the countries of destination that set rules on travel documents and their conditions of eligibility. These rules are not fixed and they differ from one country to another. For example: the United States set a number of criteria that each passenger going there must respect, otherwise it will be refused from the airport of departure. Thus, the representatives of airline companies to US destination can even interview the passenger before boarding the plane by the simple argument that they have the right to do so and that it cannot board the plane by mere intuition. Also, there are a few countries that require a certain number of months of validity of the visa or passport of the passenger remaining before the date of the flight in question;
- Intervention of resources: All the actors of the sub-process start realizing daily meetings (on the eve) to decide on the human resources and material to set up the next day to answer the need of the traffic or to intervene during the breakdowns, blockages and unusual circumstances.

(b) The constraints:

The decision-making bodies, by setting the airport's management rules, consider some of the constraints that we have presented above, which list all the issues that the airport manager has to face on a daily basis. Among these constraints we quote:

- The quality of service: At the area of passenger flow processing, the decision-making process is more perplexed because of the large number of stakeholders having only one common client [26], who is the passenger, but different and sometimes contradictory objectives as regards the assessment of the performance of that flow. For example, a higher level of security (management rules) gives rise to lower risks but also to increased waiting time and thus lower quality of service which subsequently produce an unsatisfied customer. Thus, in our model, the wait time is considered as the main performance indicator to be improved.
- IATA regulations: In 2004, IATA and ACI set

some international standards called Level of Service LoS, which the airport manager must meet in terms of terminal design (size, capacity and infrastructure, ...) and in terms of management and waiting times in the different terminal facilities [27]. In 2015, they set new standards with four levels of service "Overdesign", "Optimum", "Sub-Optimum" and "Under provided" (see figure 13) whose goal is not excellence (oversizing airports, installation of equipment and infrastructure not operated all year round) but aimed an "optimal" level. Thus, our model also aims to comply with this new standard in terms of waiting time [27].

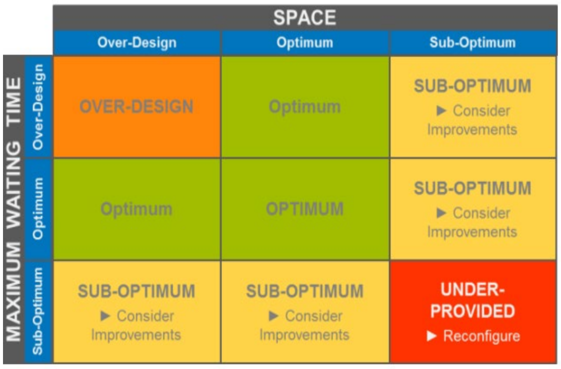

Figure 23: Two-dimensional matrix of LoS evaluation [27]

- The available resource: in front of the so-called contradictory objectives of the airport actors with the example of the airline company which wants to offer the best service to its customers and the airport manager who must provide this service within the limits of the available resources that it is human or material resources (check-in desks, luggage racks, safety filters, etc.) and in view of the enormous growth in air traffic and the development of aircraft capabilities, decision-makers have become very constrained to manage these available resources effectively [28]–[31]
- Terminal capacity: Indeed, the constraint of the capacity of the terminal is decisive and common between the other aforementioned constraints, it is related to the rules imposed by the IATA in terms of quality of service and different metrics called level of service (LoS); i.e. the available space per passenger, the speed at which passengers can move inside the terminal, the length of the queues, etc. [29].

(c) Planning

Rules and constraints guide the decision-making bodies to carry out the necessary planning. Thus, a "planning service", carried out on the basis of a flight plan of the day and during planning meetings in consultation with the various representatives of the decision-making bodies, in particular, the public services, the airport operation department of the ONDA. This department realizes the watch, a schedule in terms of quantity and time of service of the various resources related to the departure process to set up, be it material or human resources while considering all the constraints of satisfaction of the passengers in terms of security regulations, reception capacity and the availability of material and human resources in place and also operational human resources at the police level during planning and resource allocation meetings.

7. Conclusion

Through this article, we have been able to build a generic model of knowledge, modeling the passenger outbound flow, the novelty of this work is its use, the ASDI, a methodological framework model with a microscopic level of detail. In this paper, we works only on the knowledge model, in fact, the application of the ASDI methodology drives two approaches: a dynamic modeling by the BPMN tool supplemented by a static modeling by UML. Also, the resulted model has been presented through decomposition into three subsystems, physical SSP, logical SSL and Decisional SSD, subsystems, three subsystems communicating with each other. Thus, thanks to this generic knowledge model we can move on to the next phase of the ASDI methodology, which is the action model and the construction of a software library for the program (simulation/optimization) Also, we find that our generic model of knowledge, formalized by the ASDI methodology has an interesting advantage which is its option of "reproducibility" and "reusability" emanating from its power to be repeated over several airport sub processes (baggage processing) or system (arrival circuit, other terminals) and thus allowing to carry out a study further or to be applicable to other international airports with different characteristics.

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