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Dissertation presented as a partial requirement for the qualification of the Professional Master's Degree in Applied Computing

Advisor
Prof. Dr. André Luiz Peron Martins Lanna

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# Abstract

Airport's slot allocation has impact for both airport revenue generation and airlines' level of service. When flights demand exceed the available airport's infrastructure capacity, and there is no opportunity to expand it, the slot coordination has to distribute the required flights thought a transparent approach, that efficiently uses the airport capacity without impacting the airlines' flights network. This paper aims to presents methods, focusing in models using integer programming (IP) and Machine Learning (ML), used to solve the airports' allocation problem for different perspectives. *Method:* Through a systematic literature review (SLR) of how this problem has been approached, the paper produced a review protocol, a research data and a report showing the knowledge assessed through multiple points of view, methods used, and the gaps for future research. *Results:* It was presented the main motivation for the problem approaches and methods used. Through a discussion it was showed an opportunity to include the ML methodology in order to obtain other perspectives, using past information. *Conclusion:* The SLR showed that there are several perspectives about the airports' slot allocation problem, such as for a small, medium and large airports, and for a single or multiple airport approach. For those airports, which the demand is not high, direct methodology have been applied, solving the optimization problem. For congested airports, the problem have been addressed through heuristics methods and there are yet gaps for computational optimization. The method (IP) is extensively applied in the problem, but there are yet opportunities, where the data is available, to apply ML methodology, using past information to extract data.

**Keywords:** Airports' slot allocation problem, Systematic literature review, Integer programming, Machine Learning, and Optimization

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# Chapter 1

# Introduction

## 1.1 The continuous growth of the air transportation industry

The air transportation industry has been growing since 1945. It passed through several economic and geopolitical crises, the most recent being the COVID-19 pandemic. The latter has significantly impacted the world passenger traffic, reducing the industry by 40%, when comparing 2021 against 2019, before the spread of the virus. This diminish of the sector cost approximately 324 billion dollars of gross passenger operating revenue for airlines (HASEGAWA, 2022) The COVID-19 also influenced the airport's revenue and operations. At the beginning of the pandemic, the close sky policies allowed only essential flights, reducing the use of the airport's infrastructure. Sanitary measures also changed the aircraft movement itinerary, due to mandatory cleaning and inspections before and after transporting passengers, which directly affected the demand that could be accepted by the airports. Even through all these negative indicators, it is estimated a recovery of almost 103% of worldwide passenger transportation in 2024, when comparing against 2019 (IATA, 2022). Some regions, such as Central America, have projections that surpass the passenger demand of 2019 at the end of 2023. Therefore, even with this uncertainty, the increasing demand required by the airlines, to compose a better network, will result in congestion of several airports, thereat old discussions of how to efficiently resolve the distribution of aircraft operations at airports come back into evidence.

## 1.2 Airport Conception

In order to better understand this study's main problem, it is important to have knowledge of the basic concepts of airport's operation. The prototypical airport is composed of

2 parts: an (i) airside and (ii) landside (SHERRY, 2009). From an operational airport's perspective, the aircraft movement starts at the airside, when it approaches the runway through the commands of the Air Traffic Management (ATM). After the landing at the runway, the aircraft continues the movement, now at the ground level, through the taxiways. The aircraft approaches the apron in the direction of the parking stand. When it is positioned at its designated stand, the aircraft parks and bridges or airstairs are attached to the equipment in order to disembark the passengers, leading them to a gate. After the gate, the passengers are at the landside, in the airport terminal. There, they may enjoy the commercial stores (e.g., convenience stores, restaurants, and car rental agencies) before collecting their luggage and leaving the airport by ground transport or connecting to other flights.

The opposite movement is also possible: the passengers arrive at the airport using ground transportation, they may also use the airport's parking lots; they access the terminal, after check-in procedures and security inspections; they may enjoy the commercial stores, before embarking to the aircraft; at the airside, the aircraft pushes back, after it gets disattached from the airport bridges or airstairs; it proceeds through the taxiways until it arrives at the runways; and finally it takes-off, ending its movement at the airport.

With the prototypical airport conception, it is possible to start the discussion about two main concepts: (i) how the airport generates revenue, and (ii) what are the main limitations of the airport infrastructure. These two are main components of the airport's slots allocation problem.

## 1.3 Airport Revenue Generation

The airport revenue is mainly generated through aeronautical and non-aeronautical sources, both of which are directly related to the aircraft traffic volume. The former is composed by: the fare paid by each passenger using the airport infrastructure, usually included in the flight cost paid to the airlines; and the movement charge, which is paid by the airline when it lands, uses the infrastructure (e.g., hangar and terminal), and takes-off from the airport. The latter is the revenue generated by: the commercial concession at the terminal, such as rental fees for the retail at the airport area; the real estate exploitation, which includes hotels, restaurants, and parking lots at the airport perimeter; and services offered to passengers and airlines. A market equilibrium between the two revenues sources is needed, since reduction of the aeronautical charges commonly means stimulation to the non-aeronautical revenues, through passenger demand increments, but it does not guarantee the a overall maximum return (ICAO, 2013).

In Europe (2019), it is shown by ACI (2021) that 54% of the overall airport revenue was generated by aeronautical sources. ICAO (2013) points out that 63% of the aeronautical income comes from charges directly applied to passengers. The article also argue that airport users do not pay the full cost of the infrastructure the use, explaining that, in 2012, 69% of the airports worldwide were loss-making. Seeking to profitability, the airports have increased the variety of commercial activities. It can cushioning the impact of lower passenger and freight volumes, due to its higher profit margins. This creates a cross-subsidization between aeronautical and non-aeronautical revenues sources, since profits from commercial exploitation, for example, can be reinvested in airport infrastructure, increase the demand of passenger or aircraft that can be accepted at the airport, reducing capital needs and overall cost.

Knowing that airport are important for a country social-economic-growth and, as it was said, with an efficient management it can achieve profitability, governments have decided that, under the right economic conditions, they can included private sector participation (e.g., outright ownership, short or long-term concessions, public-private-partnership schemes, and management contracts) for the financing and operation of an airport infrastructure. The airports, under this new ownership model, have sought for better ways to compete for both passenger and airlines. The aviation community agrees with the need of infrastructure investments to accommodate the growth of the industry, increasing the profit margins. Since most of the infrastructure added are in large increments, and the time needed for these ventures is extensive, the airports are exposed to considerable risk (ICAO, 2013). Even with the constant pressure for the airport expansion, most of the administrator have to better manage its current infrastructure, until the investment risks are reduced to an acceptable level.

## 1.4 Airport's infrastructure capacity

The limitation of the airport's infrastructure use is related with (ARC, 2021; IATA, 2020b):

1. How many aircraft movements the airport's runways can accept in a certain period (e.g., one hour, 30 minutes, 15 minutes, and 5 minutes);
2. How many stands are available at the airport, and what are their category (e.g., cargo or passenger commercial flights);
3. How many gates are available for the passenger movements;
4. How many passengers can be processed through the security inspection at the check-in;

5. How many passengers are acceptable for the terminal area available; and
6. How many aircraft can use the infrastructure through time slot and environmental restrictions.

The most restrictive infrastructure capacity can be used to accept movements at the airport, or a combination of several limitations can be best suited for the task to distribute slots without damaging the airport's level of service, such as movement delays and congestion at the taxiways.

## 1.5 Problem statement

The present study introduces two main reasons to elevate the efficiency in the initial slot allocation in an airport. The first reason is related to the airport's ways to generate revenue. The two main ways of an airport generates revenue (i.e., aeronautical and non-aeronautical) are directly related to the passenger traffic volume. In (GRAHAM, 2009), for example, it is discussed the importance of the commercial revenues, which represented (2017) 52.9% of the total airport revenue to Africa and the Middle East, 45.7% to Asia and Pacific, 38.1% to Europe, 52.6% to North America, and only 29.0% to Latin America and the Caribbean. The article blames the small exploitation of airports' commercial areas in Latin America and the Caribbean on the lack of airport traffic stimulus, which results in the full dependence of the regulated airport fares, and non-development in both commercial and aeronautic areas. In the Economic Commission for America Latin and the Caribbean (PLANZER; PÉREZ, 2019), it is demonstrated the growth of the worldwide air transportation market, before the COVID-19 pandemic (2017), which, by International Civil Aviation Organization (ICAO), would reach 10 billion passengers per year by 2040. Despite the great projection, the report also describes the Latin American and the Caribbean challenges to build airport infrastructure, the major impediment to the development of the local sector. The International Air Transport Association (IATA) has urged the local aviation authorities to ensure, between several highlighted topics, the efficient use of the available airport's capacity in the region. When the expansion of infrastructure it is no possible, the optimization of the allocation in the available slots is strongly sought by the airport administrator, to improve the revenue generation prospects. Some regions have already implemented more restrictive on-time performance goals for airlines (RAVIZZA et al., 2014), which aims to enhance aircraft's taxi times, take-off sequencing, and allocating push-back time, thus affecting the demand of movements that an airport can accept.

The second reason is related to the impact of the operational performance improvement in the airlines. As it was mentioned, the operational capacity of an airport, i.e., the ability

to absorb the demand of flights, is directly related to its infrastructure (e.g., number of runways, gates, aircraft stands, and terminal areas). Although the mentioned features of an airport can be used to determine its capacity, a lower limit is set to mitigate the negative impacts of the airport's main partners, the airlines. This measure goes in the opposite direction of the first reason. When the limit is set greater than it should be, operational impacts are raised (e.g., delays). Most airlines interconnected their flights in a network. Therefore, a delay, for example, does not only impact the airline locally, but it can also spread its repercussions through other airports, impacting several aircraft itineraries and elevating the airline's operational costs. This topic is discussed in (BALL et al., 2010), where it is described that the airline's costs of crew management, disrupted passenger accommodation and aircraft re-position, due to delays, can reach 20 billion dollars a year (2017). Another negative impact is related to intense and not planned aircraft taxi traffic. In (NIKOLERIS; GUPTA; KISTLER, 2011), it is reported that the fuel consumed in the stop-and-go situations, resulting primarily from the congestion on the airport's taxiways system, can be approximately 18% of the fuel used during the whole operation.

For that reason, while both airports and air operators want to expand their operations, a balance between accepted demand, which increases revenues (for airports), and operational efficiency, which mitigates high operational costs (for airlines), is needed.

As it is highlighted in (CAVUSOGLU; MACARIO, 2021), there are three predominant processes for the airports' capacity allocation: (i) administrative management, with slot distribution processes through a set of specific prioritization rules; (ii) economic management, where the airport's congestion price is established, slot sales and exchanges are allowed, or auctions are made; and (iii) no regulatory mechanism, relying only on some infrastructure constraints as parameters (e.g., LaGuardia Airport and Ronald Reagan Washington National Airport as presented by (FAA, 2000)).

The administrative management is the most used mechanism for slots. It is often use the Worldwide Airport Slot Guidelines (WASG), published by IATA(RIBEIRO et al., 2018). There are also applications of WASG variations through local resolutions, as is the case of Brazil, where the local regulator is theNational Civil Aviation Agency of Brazil (ANAC). Therefore, this chapter will: (i) present administrative mechanisms, through the WASG and its allocation practices in congested airports, discussing the differences and similarities between the resolution covering Brazilian airports and the best practices developed by IATA; (ii) briefly explain the characteristics of the economic management, which contains market-driven mechanisms; and (iii) review advantages of slot management mechanism applications compared to airports with almost no restrictions.

## 1.6 Administrative demand management

Demand management has been demonstrated in several works as one of the main processes to distribute air operators' movements in the airports' available infrastructure, dealing with the lack of capacity, delays and operational service level decaying due to congestion (ZOGRAFOS; MADAS; ANDROUTSOPOULOS, 2017; RIBEIRO et al., 2018).

The administrative demand management approach aims to increase airport efficiency with allocation prioritization. Based upon optimization techniques, such practices have as objective to allocate in a certain number of available resources (airport slots), the dependent activities, i.e., air operators' arrivals and departures movements. The allocation, made through the distribution of slots, must satisfy specific conditions (explained in 1.4) (ZOGRAFOS; MADAS; ANDROUTSOPOULOS, 2017).

At the strategic level, the administrative management develops a cooperation practice where actions are coordinated between stakeholders, with bilateral communications and frequent reviews, so that the allocation may take place in accordance with all parties. The general objective is to match the requests made by the air operators with the declared infrastructure capacity, maximizing the number of accepted movements and, at the same time, minimizing the air operators' operational cost to when they need to reschedule its flights outside the planned hours, due to the restrictions imposed at the airport (GILLEN; JACQUILLAT; ODONI, 2016). As it was explained, the main administrative management strategy is the IATA's WASG, which has been adopted by local authorities in several countries (ZOGRAFOS; MADAS; ANDROUTSOPOULOS, 2017; FAIRBROTHER; ZOGRAFOS, 2018; CAVUSOGLU; MACARIO, 2021).

### 1.6.1 Worldwide Airport Slot Guidelines (WASG) - IATA

To provide a standard for slot management and operations planning, the IATA, together with Airports Council International (ACI) and Worldwide Airport Coordinators Group (WWACG), publishes the WASG(IATA, 2020b).

In general terms, the proposal to coordinate airports through the WASG aims to: (i) improve the connectivity of air services, promoting competitiveness in congested airports; (ii) provide slot schedules that meet demand and are consistent across seasons; (iii) ensure a fair, transparent and non-discriminatory slots allocation; (vi) promote efficient use of airports' infrastructure; (v) guarantee market access to new air operators; (vi) provide a flexible slot management system for the industry, which can be adapt through local regulations and market conditions; and (vii) minimize congestion and delays caused by the allocation of slots with no parameters.

### Slot Stakeholders

Slot management impacts several groups that are interested in the growing demand and the efficiency of the airport infrastructure use. Among them, the WASG highlights:

1. The air operators, the origin of the movement demand in the airports;
2. The airport administrator, responsible for balancing the number of slots that will be made available and the adequate operational level;
3. The authorities responsible for airspace control;
4. Coordinators or facilitators responsible for managing slots at the airport; and
5. The government responsible for the airport use regulation.

The Figure 1.1 illustrates the relationship of stakeholders, showing the information that is exchanged during the slot management process.

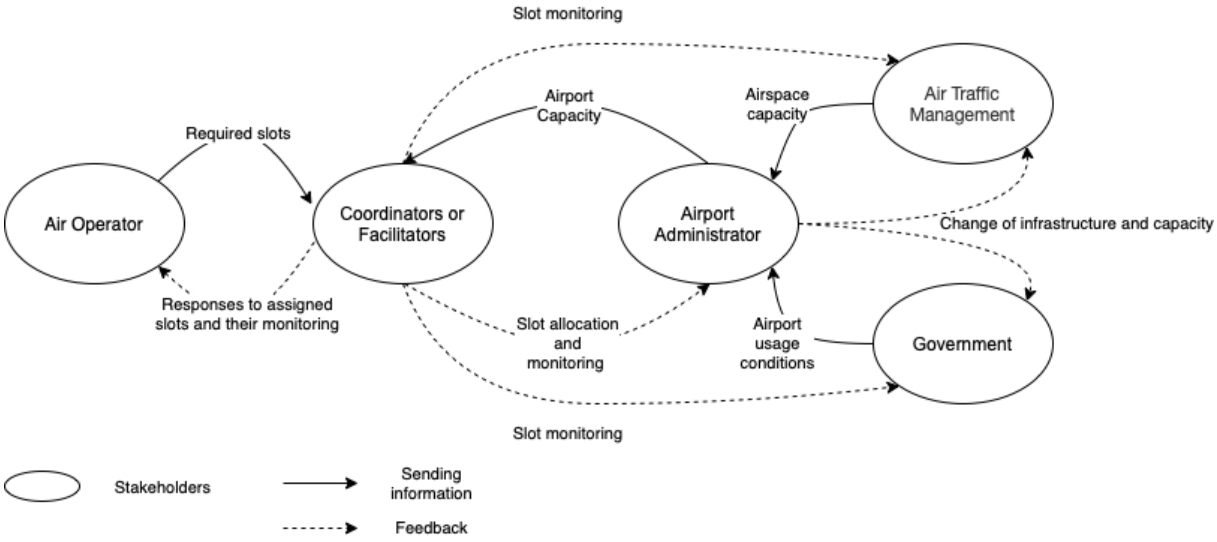


Figure 1.1: Relationship between stakeholders in the management of slots through the direct use of WASG.

Air operators have the responsibility to send requests for desired slots through a message, detailing the operations, and to prepare to cases where congestion is present in the airport and offers with different slots are sent as a response to the request. They also must follow the calendar of coordination activities and local regulations, monitoring the slots allocated to always mitigate the risk of airport infrastructure misuse.

The coordinator or facilitator are responsible to allocate the air operators slots in a transparent and non-discriminatory way. They must ensure that the allocation is made in

accordance with the capacity declared by the airport and the priority criteria established in the WASG. During the activities, the they assist the understanding of the coordination parameters, local guidelines, regulations, and any other criteria used in the allocation. They must make available the list of the slots allocated and the offers sent, explaining why the requests were not fulfilled. They must attend the conferences, in order to better approach the needs of the air operators, trying to find a middle ground between competitors. They also must perform slot monitoring, to mitigate infrastructure misuse and to apply the use-or-lose-it rules, creating the historical slots.

The airport administrator must provide support to the facilitator or coordinator, assisting in their tasks. Airports must provide the infrastructure information so that capacity is filled with adequate demand. If there is any special limitation present in their capacity, airports must communicate with the other stakeholders, especially if the demand projection shows to exceed the available capacity in future seasons. Capacity updates must be presented at least twice a year, following each season's activity calendar. The airport must send the monitoring of the slots to the airspace authorities and local regulators.

The authorities responsible for air control must communicate to the airport administrator the airspace capacity that modifies the airport infrastructure capacity parameters. The government that concedes the airport, must, through regulations, send the airport operator the conditions for using the infrastructure, as well as inform the investments that the airport operator needs to do in order to meet the projected target demand.

### Capability Analysis

Prior to the slot allocation, a demand and capacity analysis is performed. This analysis must be carried out promptly for the declaration of capacity, one of the season's official activities. It takes into account the airport's ability to absorb movement demand, together with airspace limitations, in a level that the quantity of movements accepted in the airport infrastructure does not degrade its service levels, i.e., does not promote congestion and delays. The result is constraints regarding the runway(s), stand(s), terminal(s), gate(s), among many other relevant airport infrastructures.

Another important limitation of capacity is environmental, i.e., the airport discusses the need to reduce the number of slots available when there is a relevant environmental impact (e.g., periods without movement due to noise pollution or due to environmental events that affects the aircrafts' visual operations).

One of the objectives of the capability statement is to understand which level the airport is at, i.e., Level 1, Level 2, and Level 3. The level indicates the the airport's coordination criticality.

In order to better understand the the slot management process, Table 1.1 shows a glossary containing the main terms used by WASG.

Table 1.1: Glossary of relevant terms in WASG's slot management (IATA, 2020b).

| # | **Term** | **Definition** |
|---|---|---|
| 1 | Slots | A permission that is given by a coordinator for a planned operation to use an airport's infrastructure at a specific date and time. |
| 2 | Airport Level | There are three airport levels: (1) for those whose demand does not exceed the infrastructure capacity; (2) for those whose demand causes certain congestion at specific times (e.g., hours, days, days of week), but which can be resolved through mutual agreements between the facilitator and air operators; and (3) for those whose demand exceeds the airport capacity limits, requiring a coordinator for the slots allocation, using WASG's best practices and prioritizing allocations for better market competitiveness. |
| 3 | Infrastructure capacity and airport parameters | Compiled of the necessary parameters for the coordination of slots. Through these, it is possible to identify the operational capacity for allocation that does not exceed the demand limit, providing an adequate service level (e.g., maximum operations per hour / 30 min. / 15 min. / 5 min. on the runway, number of aircraft parking positions available on the apron, number of available gates, airspace limitations, environmental limitations, etc.). |
| 4 | Seasons | There are two specific periods where operations take place. The (1) Summer Season, which starts on the last Sunday of March, and the Winter Season, which starts on the last Sunday in October. |

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Table 1.1 - Continued from previous page.

| # | Term | Definition |
|---|---|---|
| 5 | Series of slots | A minimum of 5 slots allocated for approximately the same time on the same day of the week through a season. |
| 6 | Slot pool | All slots that will receive allocation priority at level 3 airports, after the historical slots are properly allocated. |
| 7 | Historic Slots | Slots with operating precedence at the allocated airport, acquired by a regularity above 80% in the equivalent previous season. |
| 8 | Facilitator | The one responsible for collecting data and adjusting movement at level 2 airports. |
| 9 | Coordinator | The one responsible for data collection and coordination of slots at level 3 airports. |
| 10 | Activity Calendar | Deadlines and Events that manage the process of coordinating movement and slots for each season. It is established two per year. |
| 11 | Previous Equivalent Season | Last Season of the same name, i.e., if the current season is a summer season, the previous equivalent season is the prior summer season. |
| 12 | New entrants | Air operators that have a small number of operations (less than 7) for each day of a season, or companies that do not operate yet and are requesting operations. |
| 13 | Annual movements | Are all movements that have specific times in both Summer and Winter seasons. |

Continued on next page.

Table 1.1 - Continued from previous page.

| # | Term | Definition |
|---|---|---|
| 14 | Messages | Reference to data shared between coordinator, facilitator and air operators (IATA, 2020a). The messages are usually standardized in a format recognized by the industry (e.g., SSIM), containing critical information about the slot, i.e., operations' start date, operations' end date, air operator IATA's code, equipment type (e.g., Boeing 737 MAX), number of seats offered, type of movement air (e.g., Passenger or Cargo), frequency of operation during the week, hours of operation (slots), among others. |

**Airport level definition**

At Level 1, due to the availability of adequate schedules for every demand, the allocation becomes free of priorities.

At Level 2, the following allocation priority is applied: (i) movements that operated regularly in the previous equivalent season; (ii) annual movements, i.e., those which have operated with high regularity in the immediately preceding season; (iii) movements with more schedule operations for the current season; (iv) temporary operations; (v) movements restricted by operational factors; and (vi) any other type of movement. At Level 2, as well as a Level 3, a waiting list can be instituted for already congested periods.

For Level 3, WASG proposes a mechanism that grants access to the high-demand market, opening opportunities for new operators to obtain slots at coveted times. For these, the allocation is made prioritizing a series of slots, temporary slots, and other operations. The series of slots can be allocated prioritizing: (i) historical slots with no changes, with changes other than in coordination parameters, or with changes that impact the coordination parameters within a flexibility range period; (ii) slot pool, containing a consistent division of the remaining slots for new entrants and non-new-entrants operators; and (iii) other movements. It should be noted that additional allocation factors are commonly applied to the Level 3 slot pool, such as annual movements within a flexibility range, movements with more operations for the current season, movements that are restricted to certain schedules due to regulation, movements with longer time at waiting lists, movements that have a specific type of service (e.g., passengers and cargo) or market

(e.g., regional, long-distance and international destinations), movements with the greater number of frequencies, among other factors established by a stakeholders' committee.

Each airport level has a different allocation priority. The Figure 1.2 illustrates the allocations by airport level, specifying the prioritized movements.

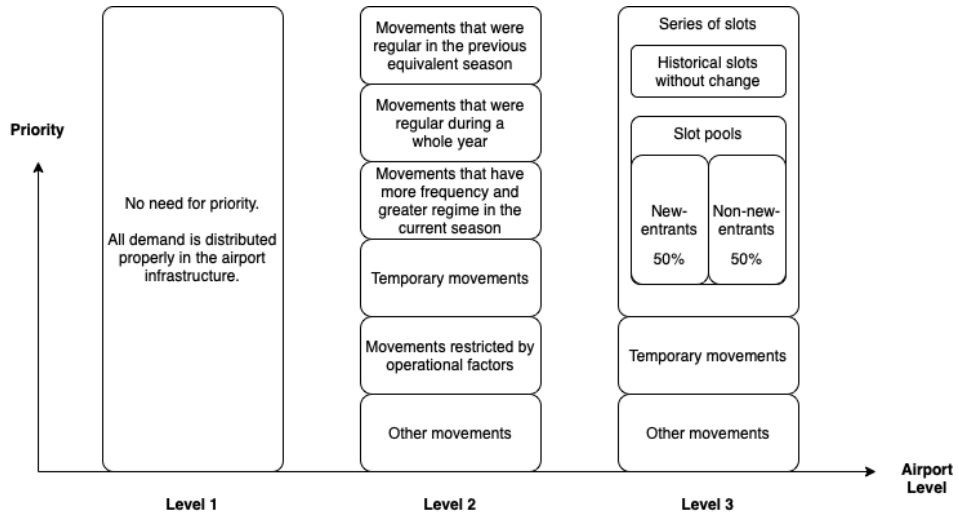



Figure 1.2: Allocation priority for each airport level.

### Slot allocation: calendar activities

The slot allocation process, defined by the WASG activity calendar, has the following steps:

1. The calendar is published by the regulator for the immediately following season;
2. Airports must declare their capacity and coordination parameters within 7 days of initial submission;
3. Coordinators must provide details of historic slots through standard messages (SHL);
4. Air operators must review the historic slots received (AHD), contacting the coordinators if they disagree with the SHL, which results in an open communication between stakeholders;
5. The air operators send the initial submission with the requested slots (ISD);
6. The coordinators inform the air operators of the result of the initial submission, i.e., the airport's network after the distribution of demand (SAL);
7. Coordinators and air operators enter into dialogue to adjust offers for more advantageous slots, which can be done in a conference (SC), where exchanges of slots

can occur between air operators, when local regulations allow them and when it is confirmed the advantage by the coordinator;

8. After the conferences, a continuous reallocation process begins until the limit for the return of slots (SRD), where any movement that will not be operated must be canceled;

9. With the reinstate of non-operational slots, the reference base (BDR) is created on which the 80% regularity will be required for historic status for the next equivalent season; and

10. The last step takes place through operational planning, where the airline community plans the airspace, stands, and gates, among others infrastructure need to be prepared to receive the movements.

After all the steps, new slots can be requested if feasible allocation. The season starts with the first planning operation on the last Sunday of October (Winter Season) or on the last Sunday of March (Winter Season). Simultaneously, the planning for the immediately following season takes place. The Figure 1.3 illustrates the season system, with each season indicated by specific colors. Note that during the activities of a specific season, the activities related to the immediately following season are already started, in a continuous process.

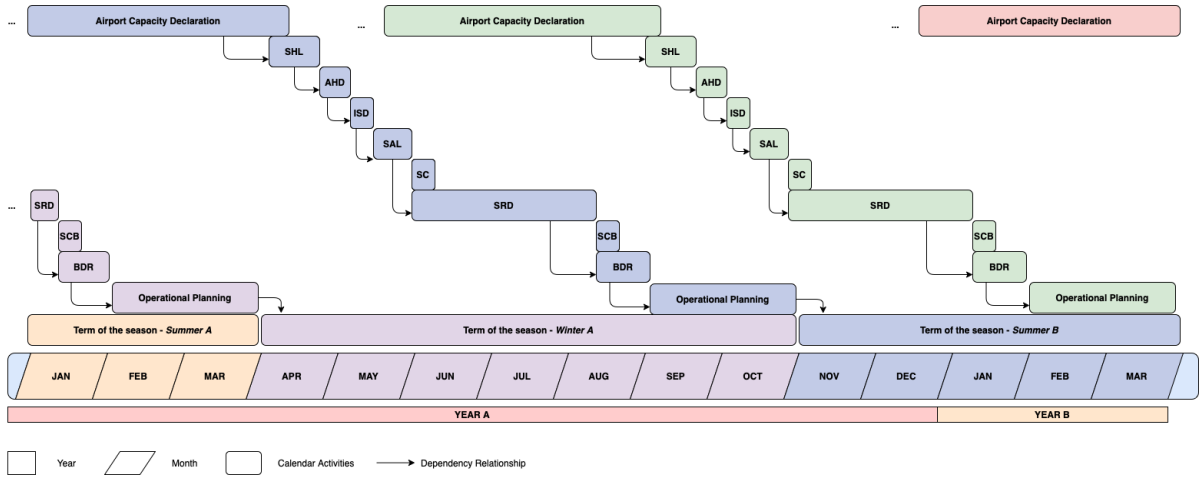



Figure 1.3: Illustration of the calendar of activities stipulated by the WSGA.

### Slot Monitoring

For the slots monitoring, WASG recommends that it should be divided into (i) pre-operation analysis, which identifies the slots misuses before the day when the movements

occur; and (ii) post-operation analysis, which identifies whether a misuse has occurred and whether the operator has achieved the historic right in its slots. The objective is to ensure proper operation, avoid the waste of airport infrastructure, and open communication channels between stakeholders.

### 1.6.2 Local Regulations: Brazil

As recommended by WASG, the application of good practices must consider the regulations in place where the airport is located. Thus, as the present work studies airports in Brazil, it is necessary to understand the rules established by the ANAC, highlighting their similarities and differences.

ANAC establishes, through Resolution No. 682, of July 07, 2022, the regulations and procedures for allocating slots at airports coordinated and facilitated. As established in WASG, coordinated airports would be Level 3 airports, and airports of interest would be level 2 airports, with their specificities explained in resolution (ANAC, 2022).

The principles of slot coordination are stipulated to minimize the effects of infrastructure congestion at Brazilian airports, focusing on transparency, non-discrimination, impartiality, and efficient use of the declared infrastructure of each airport. It also establishes an activity calendar containing the declaration of capacity, distribution of slot requests, allocation responses, and slots monitoring.

Unlike WASG, the resolution established an ANAC team that will be responsible for activities related to slot coordination at the level 3 airports. The Figure 1.4 illustrates the relationship between stakeholders via ANAC regulation. Thus, if the level of congestion at a given Brazilian airport exceeds the limit of its infrastructure capacity to absorb demand, in any of its allocation parameters (e.g., runway, patio, or terminal), or at due to the request of an interested party, ANAC can declare it as coordinated. In this case, although the agency is also the government agency responsible for monitoring the development of the airport exploration plan, a separate ANAC team will also be in charge of the administrative management of slots.

Another relevant difference in the distribution of slots in Brazil is that during the initial submission ISD only requests that constitute a series of slots are processed, making temporary requests impossible. The order of priority also differs from WASG, starting with (i) historic slots, (ii) historic slots that have changed, and (iii) new requests (respecting the division of the slots pool). Being the last one allocated in SAL, prioritizing the continuation of the immediately previous season followed by the new operations.

Some criteria, in addition to those mentioned above, can subsidize priority when there is a tie or conflict in slot allocation (not in order of priority): (i) the number of operations during the season; (ii) the largest aircraft, i.e., the number of seats or by the amount of

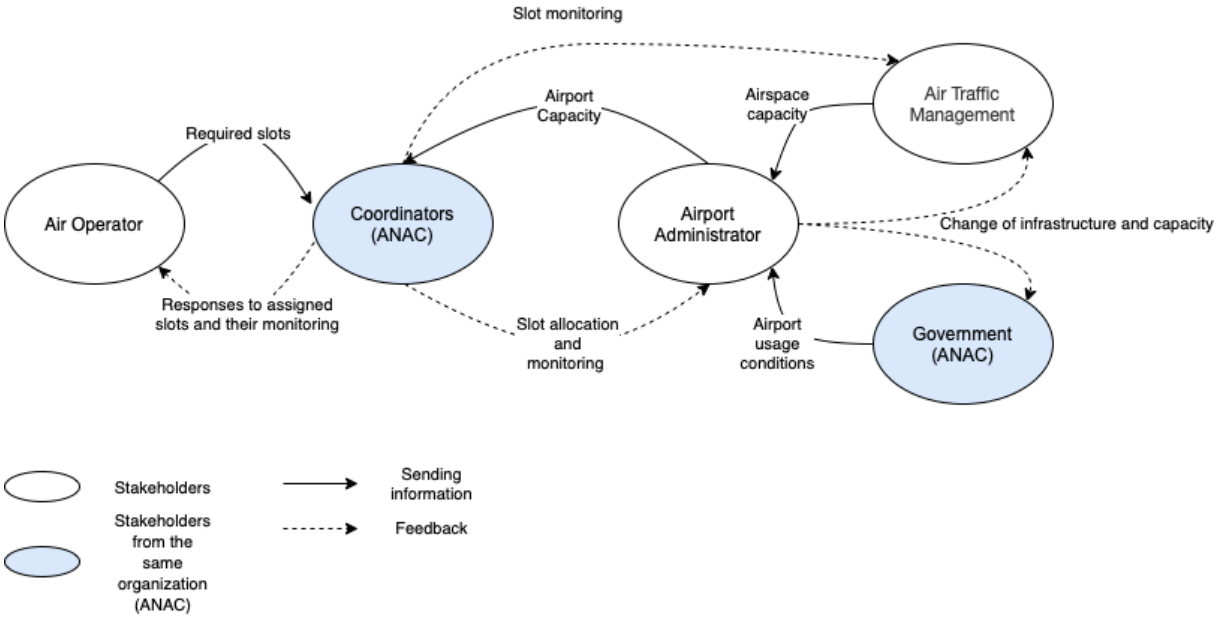



Figure 1.4: Relationship between stakeholders in the management of slots through the use of Brazilian resolution (level 3 airports).

cargo that can be transported; (iii) the operational efficiency in the previous equivalent season; (iv) best environmental efficiency; and (v) requests that best promote the airport competition, i.e., reduction of the Herfindahl-Hirschman Index (HHI).

For the analysis of operational efficiency, the resolution presents a comparison of the reference base BDR with the current base of slots for the season, taking into account the operations that did not use the available infrastructure without valid justification. The Regularity Index (IR) is calculated using the Equation 1.1. The IR will be used to determine the historic status of the slots for the next equivalent season.

$$IRs = \frac{Used\ slots}{Slots\ allocated\ in\ the\ BDR} \tag{1.1}$$

Similar to WASG, if the company falls below the minimum regularity target (in this case established by the coordinator), as well as when the intentional misuse of allocated slots is identified, the company may lose the historic slot. In the ANAC's regulation, when misuse happens, if the slots are requested at the next equivalent season, they would be inserted in the slots pool.

ANAC also mitigates the misuse of slots through regulations on infractions and their respective administrative measures. If an air operator obtains a slot that it does not intend to use, wasting the airport infrastructure above the imposed limit, it will be considered an infraction punishable by fines established by the agency, as well as the impediment to

obtain historic slots.

In Brazil, it is set to facilitated airports (i.e., level 2 airports) to prioritize the allocation of air operators' slots series that operated in the last season (i.e., the annual movements). Since there are no historic slots, the resolution recommends lower priority for operators who misuse airport infrastructure. The Figure 1.5 illustrates the stakeholders in an facilitated airport configuration stipulated by ANAC. Note that both the airport and the slot facilitator are the same entity.

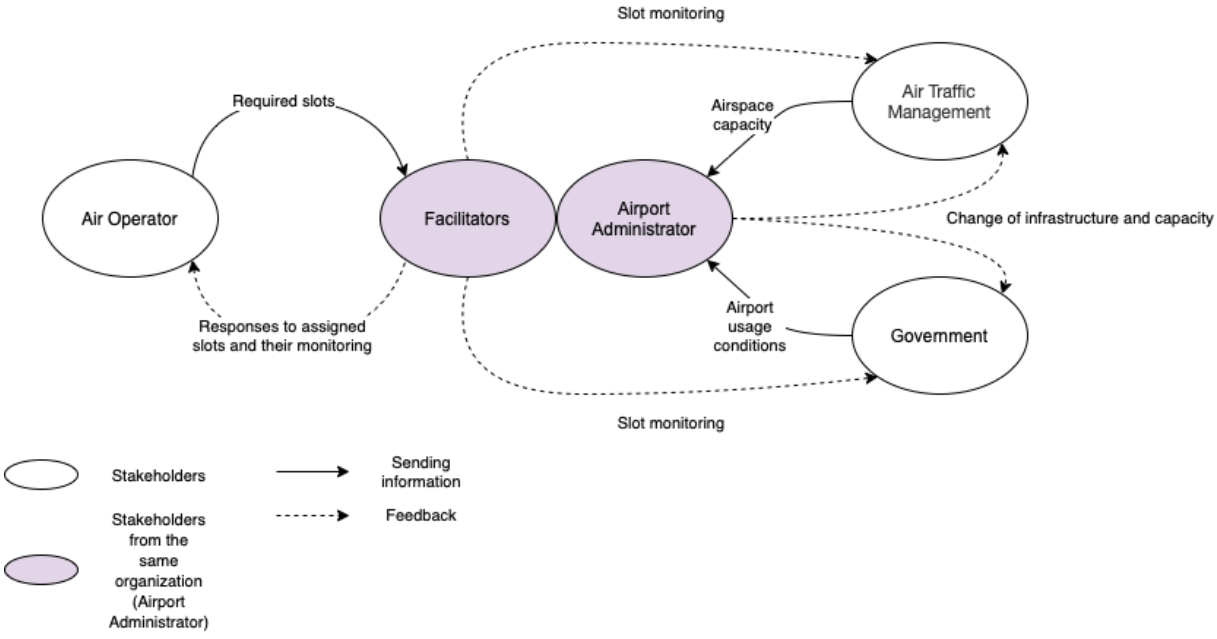



Figure 1.5: Relationship between stakeholders in the management of slots through the use of Brazilian resolution (level 2 airports).

## 1.7 Economic demand management

Although it is not the scope of the present study, research with market-driven approaches, i.e., economic, has been developed, despite not being widely applied in practice, to solve the problem of increasing demand allocation in airports. The main objective is to address challenges not solved by the administrative mechanisms (BALL; DONOHUE; HOFFMAN, 2006).

The article (GILLEN; JACQUILLAT; ODONI, 2016) cites two primary mechanisms for the economic management of the exposed problem: (i) Congestion pricing, where the cost of using the overloaded infrastructure is passed on to the air operators, which are interested to gain access to the airport; and (ii) auction of slots, as well as in the administrative management of demand, the airport declares the number of slots available

through airport parameters, and it is given access to the air operator with the highest monetary offer.

### 1.7.1 Congestion pricing

The Figure 1.6 demonstrates the idea of price mechanisms, illustrating the relationship between the marginal cost of delay and the marginal benefit of allocation (GILLEN; JACQUILLAT; ODONI, 2016). Therefore, when the congestion price is not present, air operators can allocate "A" movements, resulting in a marginal delay cost "W". However, the total marginal cost, "Y", exceeds the allocation benefit. Reducing the amount of the number of moves allocated to "B" $\leq$ "A", the total marginal cost is equal to the benefit of allocation "Z", having an internal marginal cost "X". There are, however, some difficulties with this demonstration, as (GILLEN; JACQUILLAT; ODONI, 2016) points out: (i) developing the congestion pricing scheme is complex, i.e., measuring the internal and total marginal cost is not trivial; and (ii) there are uncertainties regarding how the allocation of air operators varies with the congestion price.

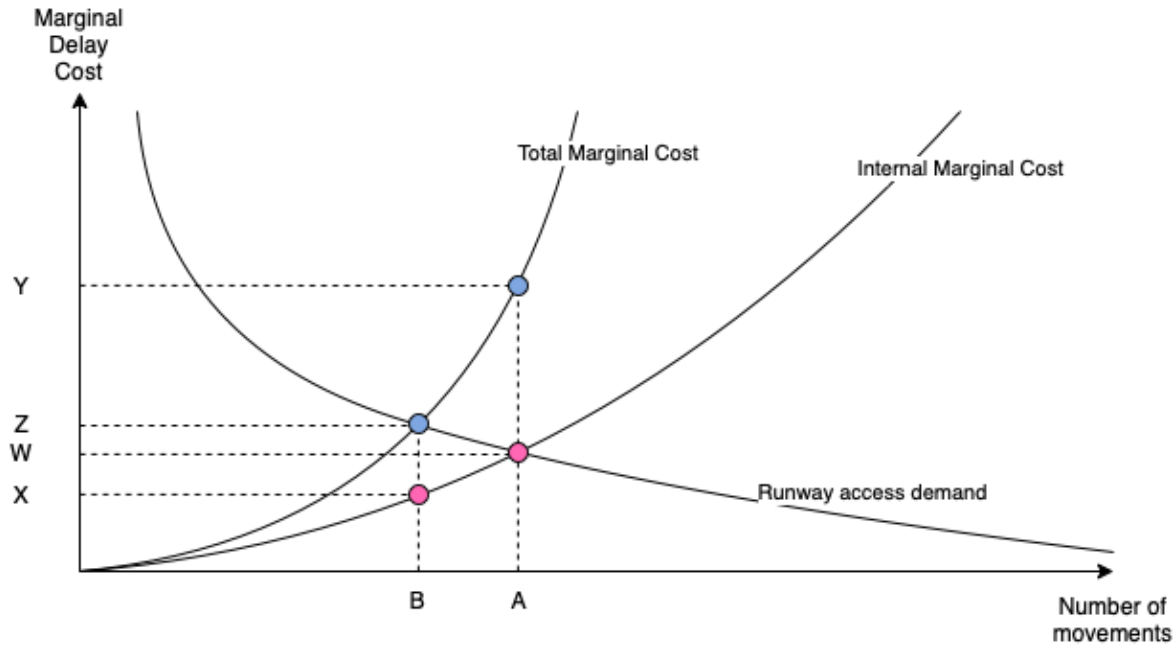



Figure 1.6: Congestion pricing as an alternative for external delay correction and slot allocation. Source: (GILLEN; JACQUILLAT; ODONI, 2016).

To better understand the problem of economic management, it is important to point out that typically air operators allocate several movements in a short period, imposing congestion costs on themselves. It can be argued that airport systems containing hubs of few air operators, i.e., reduced competition, have a high internalization of congestion cost,

reducing the price per slot, and making impacts related to economic demand management negligible (BALL; DONOHUE; HOFFMAN, 2006; GILLEN; JACQUILLAT; ODONI, 2016). However, for these airports, where the internal marginal cost is equal to the total marginal cost due to the lack of competition, it is shown higher rates of delays since overschedule are made by the monopolist air operator, that allocates demand which the operational cost cannot be totally internalized (BALL; DONOHUE; HOFFMAN, 2006).

The Figure 1.7 demonstrates the relationship between competition and increased cost per slots. In a non-competitive airport system, the cost of delay is internalized and there are no incentives to manage demand. However, introducing competition, it makes the cost per slots increase, distribution mechanisms that search for a balance between accepted moves and total delay cost are needed.

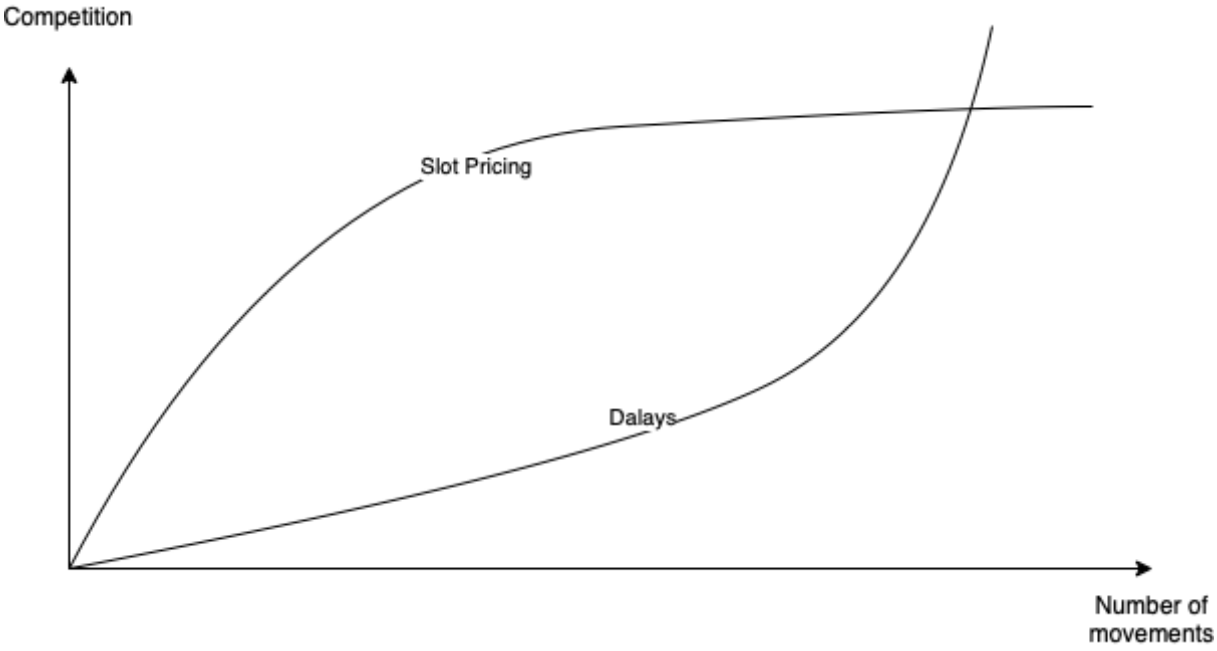



Figure 1.7: Relationship between the price of slots and costs related to competition. Source: (BALL; DONOHUE; HOFFMAN, 2006).

Since congestion pricing is a topic that still requires further studies, due to its complexity in measuring the internalization of delays and designing the congestion pricing scheme for each modality of air operator (GILLEN; JACQUILLAT; ODONI, 2016), other economic management mechanisms would be the auctions of slots. These would also not be atomized, i.e., each slot auctioned individually, due to the risk of exposure to the air operator if arrivals and departures at a given airport do not end up coupled with each other and among other movements at other airports. This brings the need for combinatorial auctions, which need to be mutually exclusive.

### 1.7.2 Auction of slots

The knowledge that the slot will be auctioned in the future brings the continuous need to evaluate the market and the slots' price, limiting the negative sides of the administrative management of slots: (i) inefficiencies guaranteed by historic; (ii) legal difficulties in congested airports to appoint holders of newly released slots; and (iii) limitation of market entry for new air operators, as they have a less economic impact on the airport. It is worth mentioning that the revenue generated by the auction is related to the market value due to the scarce system, paying for the cost of the used infrastructure. However, a slot auction system should focus primarily on encouraging competition, rather than maximizing revenue (BALL; DONOHUE; HOFFMAN, 2006).

For the auctions mechanism, (BALL; DONOHUE; HOFFMAN, 2006) points out limitations in 5 pillars:

- ***Capacity***: the number of slots available for auction is related to demand, which is unknown before the auction takes place. Therefore, before declaring slot holders, it is necessary to ensure that the combination of slots granted does not exceed airport parameters.
- ***Ownership***: it is necessary to specify the period of slots ownership, together with their acceptable operating range, which also influences the capacity. Regulation that allows secondary auctions, where ownership over the slot can be transferred between operators, is also needed. Daily transfers between operators may also be possible, allowing better use of airport infrastructure.
- ***Value***: although the value of a slot is present to air operators, its value during an auction is unknown. Therefore, the market will evaluate and pay the slot holder an amount that will be corrected over time.
- ***Market Power***: it is necessary to design auctions that have a regulation that encourages competition, preventing offers to buy a monopoly.
- ***Implementation***: even if the transition from administrative management to an economic management system is organized in phases, i.e., auctioning a percentage of the slots in a congested airport, it will impact operators' connection networks airlines as a whole, and their losses to the market may be greater than the benefits.

A hybrid use is possible, i.e., combining the advantages of administrative management with economic management. Thus, the allocation could first come from an administrative allocation process (e.g., WASG and adaptations made by the local authorities), selling at congestion price or auctioning the remaining slots. This would add up to three important

benefits of administrative mechanisms: (i) it helps air operators to project future decisions related to slots; (ii) it makes the process less complex by following the activities calendar, which proposes allocations twice a year; and (iii) it assists in the long-term industry projection, which can easily predict the growth of competition and the market, with the incentive of congestion pricing and slot appreciation, offered by economic management. However, it is worth mentioning that the disadvantages of both management would also be aggregated, where regulatory needs for slot distribution, ownership definition, and market access would be evident, and could be disputed in court by airline operators, as occurred in 2008 in an attempt to auction 10% of New York airports' slots (CAVUSOGLU; MACARIO, 2021; GILLEN; JACQUILLAT; ODONI, 2016; BICHLER et al., 2021).

## 1.8 Airports free of demand management mechanisms

As well as economic demand management, the approach to airports with systems free of demand management mechanisms goes beyond the scope of this work, but it has been applied in American airports and its cost-benefits have been highlighted (CAVUSOGLU; MACARIO, 2021; GILLEN; JACQUILLAT; ODONI, 2016).

There are two objectives to be achieved at airports in terms of demand and slots: (i) maximize the number of movements accepted in the airport infrastructure, adapting required schedules to possible operating hours; and (ii) minimize congestion-related costs, which are present in high-demand airports in different forms (e.g., delays) (CAVUSOGLU; MACARIO, 2021). It is noted that the objectives are inversely proportional because as the number of movements in an airport increases, projecting growth in revenue, the delays and impacts for the air operators increase, as illustrated in the Figure 1.8 (ZOGRAFOS; MADAS; ANDROUTSOPOULOS, 2017; SWAROOP et al., 2012; GILLEN; JACQUILLAT; ODONI, 2016).

Although airports with high movement acceptance, and without demand management, are the simplest solution for allocation distribution, taking better advantage of the airport infrastructure (GILLEN; JACQUILLAT; ODONI, 2016), the approach also has risks and disadvantages.

The indiscriminate use of infrastructure helps generate revenue from stakeholders, who invest in the growth of the industry. In (ZOGRAFOS; MADAS; ANDROUTSOPOULOS, 2017) the authors argue that demand management often constrains the declared capacity of the airport, which in turn affects not only the slots accepted but the distance between the desired times of movements, i.e., the quality of slots in the airport in an air operator perspective. Thus, reducing management provides a greater frequency of movement, competition between operators, opportunities for new entrants, and better use of scarce

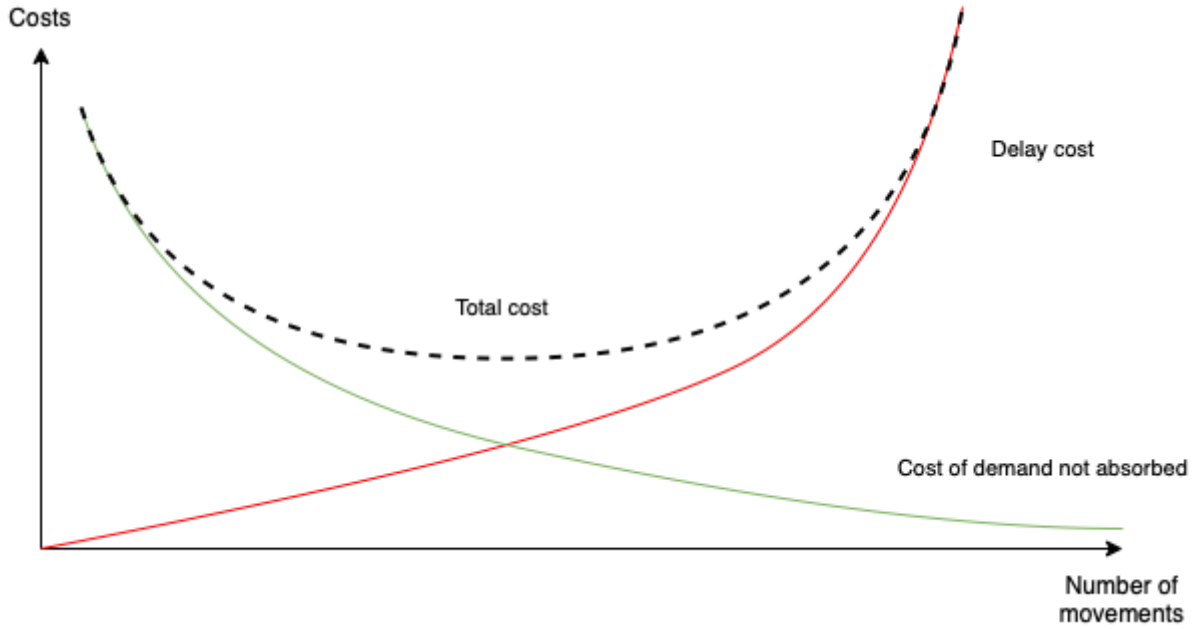


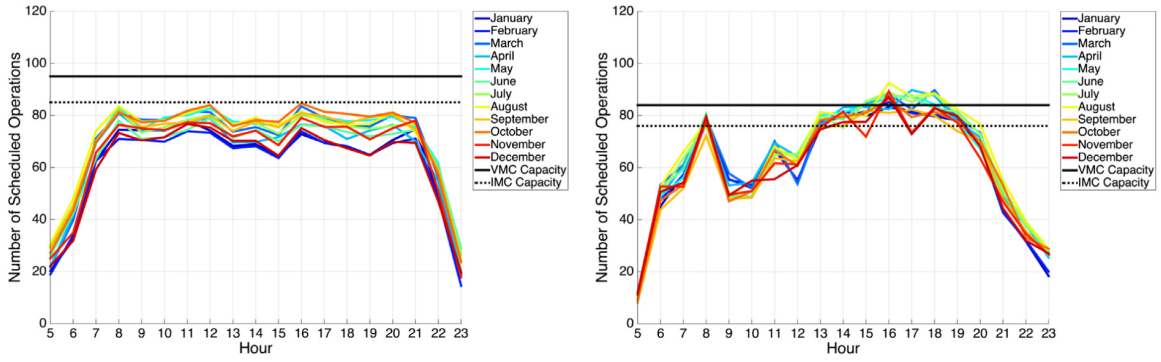

Figure 1.8: Cost-benefit of accepting movements in congested airports. Source: (SWAROOP et al., 2012; GILLEN; JACQUILLAT; ODONI, 2016).

infrastructure. On the other hand, the opening would also reflect on delay costs and slot reliability.

In (SWAROOP et al., 2012) the cost-benefit of applying demand management in airports with few mechanisms (e.g., LGA) was studied. It brings a methodology to simulate the cost related to increased movement and the costs generated by delays. Adding the benefits of 16 US airports in the simulation, the reduction in delay costs for passengers would be more than 200 million dollars annually. The study also proposes a reduction in infrastructure capacity, i.e., fewer movements during congested hours, resulting in a projection greater than 600 million dollars annually in benefits for passengers. However, the authors make it clear that, although the use of demand management mechanisms can generate financial benefits and a better level of service for passengers, by excluding movements, they could seriously harm the network of affected air operators. The costs generated with the implementation of these mechanisms were also not added. Although, intuitively, reducing delay costs also reduce operating costs, consequently the price of tickets for passengers.

Another important topic brought up by demand management mechanisms is capacity declaration. When an airport without these mechanisms is compared with coordinated airports, such as Frankfurt Airport (FRA) and Newark Liberty International Airport (EWR), which have the similar infrastructure, Figure 1.9, there is a concentration of movements in EWR, while FRA has a more balanced distribution. This characteristic is

common in uncoordinated airports, where there are periods which scheduled movement exceeds the recommended limit of demand absorption, even in Instrumental Meteorological Conditions (IFR), i.e., adverse weather conditions of operation. In EWR, there is overutilization in the night period and underutilization in the rest of the day, showing inefficiency in the allocation. This factor affects the airport's punctuality performance, which, due to the non-linear relationship between the number of movements and delays when the airport operates close to its capacity limit, makes certain American airports perform worse when compared to equivalents in Europe (GILLEN; JACQUILLAT; ODONI, 2016).




(a) FRA (b) EWR

Figure 1.9: Average weekly movements per month for EWR and FRA airports in 2007. Source: (GILLEN; JACQUILLAT; ODONI, 2016).

The article (CAVUSOGLU; MACARIO, 2021) also points out that airports subject to coordination mechanisms tend to use the Visual Meteorological Conditions (VMC) operational limit of the runway as their maximum capacity, i.e., normal weather conditions. This is due to infrastructure overload due to adverse weather when delays are frequent. Operating above this conditional, as shown in the 1.9 part (b), even in VMC, already configures acceptance of excessive delays and low confidence in slot schedules, which would worsen in situations of IFR. In addition, the study (ZOGRAFOS; MADAS; ANDROUTSOPOULOS, 2017) points out that common concentrations in small time slots also increase the operational delay. By reducing infrastructure capacity, movements would be spread over new slots, minimizing the airport's overall delay. The Figure 1.10 illustrates the movement of the largest airport in Greece, where a reduction from 85% (part a) to 71% (part b) has a considerable impact on the airport's peak delays.

Although there are difficulties in demand management systems (e.g., inefficiencies in the general use of infrastructure guaranteed by history, market opening, capacity declaration, and implementation) its mechanism provides a better definition of infrastructure

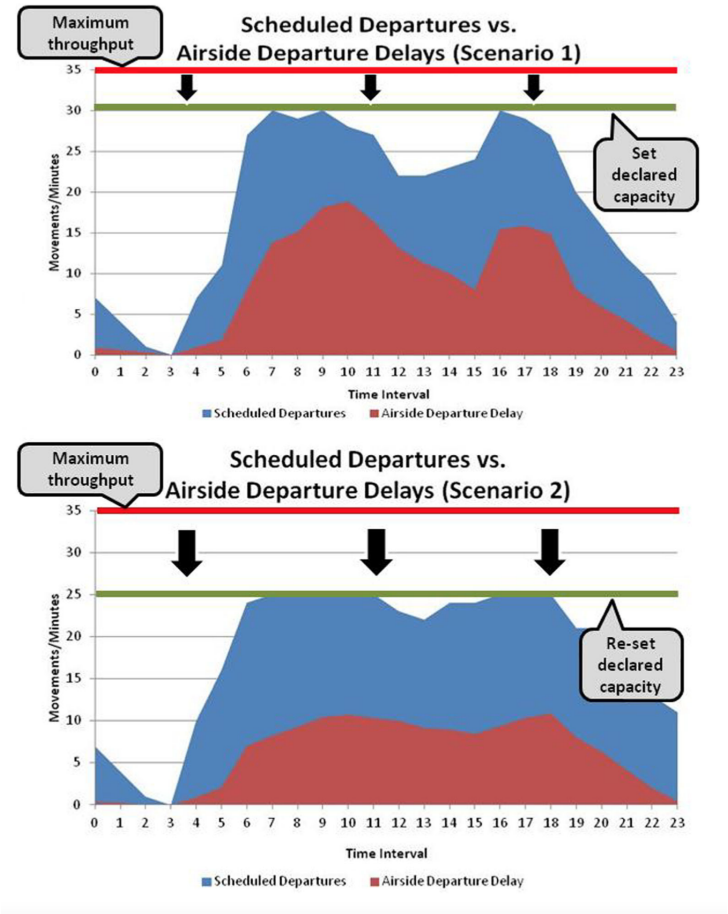



Figure 1.10: Modeling the effects of capacity declaration on congestion-related delays. Source: (ZOGRAFOS; MADAS; ANDROUTSOPOULOS, 2017).

parameters, which as consequence provides better demand absorption at adequate service levels (MORISSET; ODONI, 2011).

# Chapter 2

# Systematic Literature Review

## 2.1 Planning the review

To collect all the information needed for a better understanding of the main problem and approaches that have been used, a Systematic Literature Review (SLR) was conducted through a transparent process, avoiding biases and increasing reliability.

The three steps process used in the literature review were: a (i) planning stage, where the need for a review was addressed, the researches questions were summarized into search terms, and a specific review protocol was created beforehand; therefore the (ii) review was conducted, identifying the researches which aimed to solve the slot allocation problem, selecting the primary studies, verifying their quality assessments, extracting the data, and synthesizing its information; after the (iii) review result was presented, in order to state what are the main researches in the central problem, and how the methods here presented can fulfill some of the gaps left in the previous literature.

A better understanding of the airports' slot allocation problem, through a literature review, is needed in order to identify, analyze and interpret the different perspectives of the problem and how it has been approached, aiming to set the historical context and present how this paper can contribute for the problem solution. To achieve this objective, through a process that mitigate bias, conducting the data gathering in a transparent way, the review criteria and its steps were planned before their execution, following the guidelines presented in (WOHLIN et al., 2012). The Figure 2.1 presents the processes followed and their deliverables.

### 2.1.1 The need for a review

The first step was the identification of the need for a review, i.e., understand how the problem has been addressed in past research and what are the previous limitation. It is

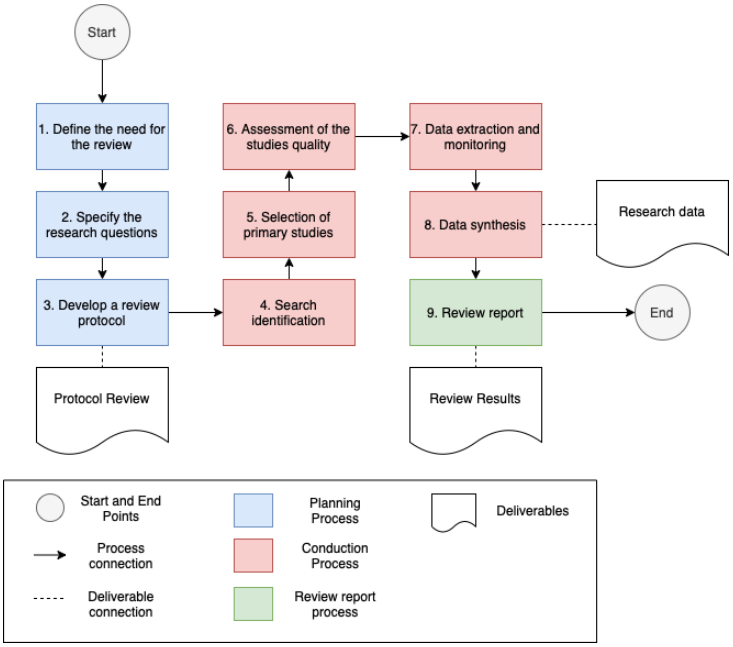



Figure 2.1: The literature review processes and their deliverables Source: (WOHLIN et al., 2012).

common for airports to have different infrastructure configurations, i.e., runways, taxiways, gates, terminals. Also, different airports are placed in different environments, such as populated areas, which plays a critical role in their demand. Such specificities can introduce different points of view for the slot allocation, and it is expected different proposed solutions. Since the current paper raises a well-established problem, it is necessary to understand how it has been historically managed. Although a literature review could be achieved directly through a *snowballing* process, it would only collect some points of view, introducing a search bias that could affect its reproducibility. A systematic review provides a better approach, resulting in a comprehensive understanding of the problem, delivered by a step-by-step protocol, which can be reviewed and improved. In this step of the review, it is assumed that no systematic review was made before, but if encountered it would be evaluated its contributions and limitations

### 2.1.2 The SLR researches questions

The second step was the specification of research questions for the search conducted in the literature review. These questions set focus for the identification of the primary studies, as well as the extraction and analysis of the studies' information. To guarantee focus, PICO was used to break the questions down to their essential parts. It was also set an experimental design in the intervention part, in order to clarify what was the present

paper approach, in the case it has been already used. In this step were produced the following research questions for the literature review:

- **RQ1:** For the airports' slot allocation problem (P), what are the current approaches (I) that can provide an optimization in the initial slot allocation process (O)?
- **RQ2:** For the airports' slot allocation problem (P), can a methodology using integer programming or machine learning (I) provide the better optimal solution, reducing negative impacts for airlines' initial allocation (O), than the current approaches (C)?

The question one can be divided in three specific question: (i) what the methodology used to solve the airport slot allocation problem? (ii) what are the constraints to the approaches? (iii) Are there any gaps or assumptions that could be explored? The second question wants to collect all information about models of the problem and how experimentation with algorithms are helping to tackle them.

### 2.1.3 Review protocol

The third, and last step for the planning part, was the development of a review protocol. This section acts not only as a backbone for the present paper research review but also is important for its reproducibility and validity evaluation. The following items, beyond the background and research question for the review addressed above, were taken into consideration:

#### Search strategy for primary studies

The main activities in this step are specifying the search string through the research question for the literature review, and applying this string in databases. The string used is a composition of the keywords: Airport, Slot, allocation, integer programming, machine learning, optimization, and solution. Treating the bag of words with search operators, the following search string was created:

*(airport* **AND** "slot allocation" **AND** optimization **AND** ("machine learning" **OR** "integer programming")).*

#### Search sources

This string should be used in the following databases in order to collect the primary researches:

1. ACM Digital Library;
2. Bielefeld Academic Search Engine (BASE);
3. EBSCO;
4. ScienceDirect;
5. Scopus;
6. Transport Research International Documentation (TRID);
7. Web of Science;
8. CiteSeerX;
9. Digital Bibliography & Library Project (DBLP);
10. Directory of Open Access Journals (DOAJ);
11. IEEE Xplore;
12. JSTOR; and
13. Springer Link (Article section).

There are two main criteria for selecting these databases: (i) they cover multidisciplinary subjects, or their specialized field are related with computer science or transportation studies, which are the main areas of the present paper; and (ii) these databases were described in (KITCHENHAM; CHARTERS, 2007) by their coverage and capability to perform systematic searches via queries and filter, so that the final result of using this databases is a reproducible, with high recall and precision.

The (GUSENBAUER; HADDAWAY, 2020) presents the databases as primary if they fulfill all the necessary quality requirements, such as the possibility of query refinement, string size criteria, server response criteria, use of Boolean operators, functionalities and reproducibility, otherwise they are considered supplementary. The databases 1 to 7 are primary databases and the other ones are supplementary. Additional search can be conducted in specific journals and conferences, as well as contacting researchers for aggregating material yet not published and grey literature. All additional material must be specified with its origin, in the interest of maintaining the reproducibility of the review.

In this step, all identifiable false positives and duplicates between databases have to be removed. To validate the search string, the article (RIBEIRO et al., 2018), which was already evaluated as a positive result, must be contained in one of the results of the databases, otherwise, a string reformulation is needed.

**Study selection criteria**

Some selection criteria of inclusion and exclusion were established beforehand to mitigate bias. Using the "First pass" approach (KESHAV, 2007) all the primary papers' titles, abstracts,introductions and conclusions will be read. Articles are going to be included if they contain:

1. Any aspect of airport's slot allocation problem (models, perspectives, constraints, methods, technical consideration, etc.); and
2. Any solution for the airports' slot allocation problem using integer programming or machine learning.

**Study exclusion criteria**

Articles are going to be excluded if:

1. They are duplicates or old versions (If it is found in more than one primary and/or secondary, it is kept in the databases sorted as shown in the topic 'Search sources' and removed from the others);
2. They were produced before 2001 (Commercial flights market regulation after the September 11 attack);
3. They are introducing new slot guidelines besides those explained in the IATA's WASG (IATA, 2020b);
4. They contain methods that solve Airports' slot problem through auction (Economic approaches);
5. They are not accessible in full-text;
6. They are not related with the research questions, nor are tackling the main problem, but adjacent areas (ground delays, weather impacts in airports, etc.);
7. They have a specific context (September 11 attacks, COVID-19 pandemic, etc.); and
8. They are not in English nor Portuguese.

**Study selection procedures**

The first step of the selection is remove all papers that are obviously not relevant. After, it will be conducted by the main research assessment of each paper, using the selection and exclusion criteria, with a random samples of the paper. If more than one section

of the paper fail to be relevant for the present review, the paper will be removed and a justification will be written.

### Study quality assessment checklist and procedures

In addition to the selection procedures, it was established the assessment of the quality of the primary studies. The quality provides a better understand of the differences between studies, given importance to those which follow high level criteria. Kitchenham and Charters (2007) present a quality questionnaire based on 5 issues affecting the quality of the study, given 5 for a 'Yes' and 0 for a 'No' answer:

- **QQ1:** Is the data analysis process appropriate?
- **QQ2:** Did studies carry out a sensitivity or residual analysis?
- **QQ3:** Were accuracy statistics based on the raw data scale?
- **QQ4:** Was the data selected at random (not selected for convenience) from several airports?
- **QQ5:** How many datasets were used? Evaluation: More than 10 = 5; More than 1 but less than 10 = 1; and only one dataset = 0.

It was also cited the reporting quality based on 4 questions (KITCHENHAM; CHARTERS, 2007), which were giving less weight, (1) for a 'Yes' and (-1) for a 'No' answer, than those that measure the study quality:

- **RQ1:** Is it clear what projects were used to construct each model?
- **RQ2:** Is it clear how accuracy was measured?
- **RQ3:** Is it clear what cross-validation method was used?
- **RQ4:** Were all model construction methods fully defined (tools and methods used)?

### Data extraction strategy

Data extraction was defined as a set of information that should be extracted for each study. This data are important for any attempt to summarize the results.

The following data, and their specific contexts, will be extract:

1. (Design) Method used
2. (Conduct) Description of the data collection methods

3. (Conduct) If two "groups" are being compared, were they treat similarly in the study?
4. (Analysis) Was the statistical significance assessed?
5. (Conclusion) Are all the answered question answered?
6. (Conclusion) Are negative findings presented?
7. (Conclusion) How do results add to the literature?

## 2.2 Conducting the review

This section reports the outcome of the systematic search and selection process. It also presents the validity checks, including the data extraction and quality assessment process.

### 2.2.1 Identification of research

The research found 176 sources in 13 databases. It was found 30 duplicates (17.04%), which were excluded from the review, resulting in 146 unique sources, as shown in the Table 2.1.

Table 2.1: Search results per database

| # | **DATABASE** | **SOURCES FOUND** |
|---|---|---|
| 1 | ACM Digital Library | 20 |
| 2 | Bielefeld Academic Search Engine (BASE) | 8 |
| 3 | EBSCO | 20 |
| 4 | ScienceDirect | 74 |
| 5 | Scopus | 8 |
| 6 | Transport Research International Documentation (TRID) | 8 |
| 7 | Web of Science | 6 |
| 8 | CiteSeerX | 0 |
| 9 | Digital Bibliography & Library Project (DBLP) | 8 |
| 10 | Directory of Open Access Journals (DOAJ) | 3 |
| 11 | IEEE Xplore | 1 |
| 12 | JSTOR | 1 |
| 13 | Springer Link | 19 |
| | **TOTAL** | 146 |

Most of the studies were found in the primary databases 81,81%, being the main source the ScienceDirect with 42,04% of total. The more specialized sources performed worst, collecting less studies related with slot allocation in airports, such as TRID (transportation) and IEEE Xplore (computing science), which found 4.54% and 0.56% of the total, respectively.

Therefore, scrutiny was necessary to streamline these studies to relevant ones. Using the "first pass" (WOHLIN et al., 2012), the title of each study and their contents were briefly analyzed separately and randomly. Hence, all the papers that do not reflect the discussion about airport slot allocation problem or were unable to pass through the exclusion criteria were removed. The result was the identification of 47 primary studies, which is 26.70% of the total first found.

For the exclusion criteria:

1. One editorial was removed due to its scope being very wide, not detailing methods (1.01%);
2. One article was not accessible (1.01%);
3. Two articles were removed due to the year of publication (2.02%);
4. 18 studies were not related with the airports' slot allocation problems (18.18%);
5. 30 studies were solving the slot allocation problem with economic approaches (30.30%), such as auctions (25 out of 30); and
6. 46 studies were focusing in adjacent area (47.47%), such as ground delays (10 out of 47).

After the selection procedure, the SLR resulted in 47 primary studies, showing a high number of primary false positives studies, i.e., studies that were brought by the research string but should not have been. The table 2.2 shows the primary studies per database and the false positive result, after the removal of the duplicates. After the duplication removal and exclusion criteria, Scopus, Web of Science, IEEE Xplore, and JSTOR ran out of studies. The overall primary false positive result was of 67.81%, indicating that the search was comprehensive.

Table 2.2: Primary studies per database and the false positive results.

| # | **DATABASE** | **PRIMARY STUDIES** | **FALSE POSITIVES** |
|---|---|---|---|
| 1 | ACM Digital Library | 4 | 80.00% |

Continued on next page.

Table 2.2 - Continued from previous page.

| # | DATABASE | PRIMARY STUDIES | FALSE POSITIVES |
|---|---|---|---|
| 2 | Bielefeld Academic Search Engine (BASE) | 4 | 50.00% |
| 3 | EBSCO | 3 | 83.33% |
| 4 | ScienceDirect | 30 | 58.33% |
| 5 | Scopus | 0 | - |
| 6 | Transport Research International Documentation (TRID) | 2 | 0.00% |
| 7 | Web of Science | 0 | - |
| 8 | CiteSeerX | 0 | - |
| 9 | Digital Bibliography & Library Project (DBLP) | 1 | 66.67% |
| 10 | Directory of Open Access Journals (DOAJ) | 1 | 33.33% |
| 11 | IEEE Xplore | 0 | - |
| 12 | JSTOR | 0 | - |
| 13 | Springer Link | 2 | 88.89% |
| | **TOTAL** | 47 | 67.81% |

The number of studies by year of publication is depicted in Figure 2.2. The topic "airports' slot allocation" have been highlighted in recent years with 74,47% of the studies selected being published in the last 5 years (2016-2021). The studied selection procedures are illustrated in the Figure 2.3.

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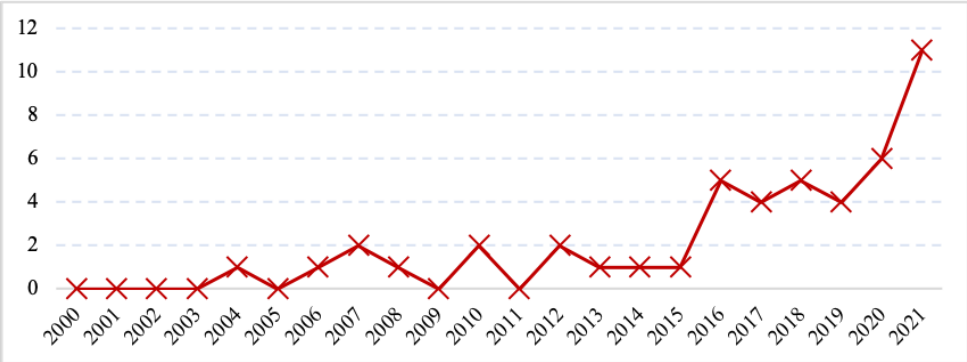


Figure 2.2: Number of papers by year of publication.

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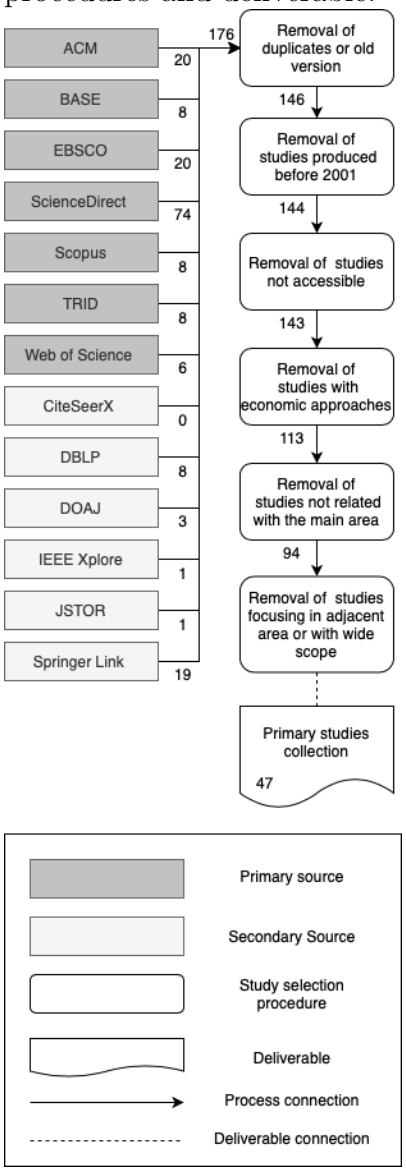
Figure 2.3: The studies selection procedures and deliverable.



# Chapter 3

# A Classe `UnB-CIC`

Este capítulo descreve a classe `UnB-CIC`, e demonstra os comandos disponíveis. A última versão foi atualizada pelo Prof. Ralha, em 2008 (vide Annex I). A melhor forma de entender o funcionamento é observar o arquivo principal deste documento (`monografia.tex`).

## 3.1 Gerando o PDF

Para gerar corretamente as referências cruzadas, é necessário processar os arquivos mais de uma vez com a seguinte sequência de comandos (supondo que o arquivo principal seja `monografia.tex`).

```
pdflatex monografia
bibtex monografia
makeglossaries monografia
pdflatex monografia
```

O primeiro comando processa os arquivos, indicando quais referências foram citadas no texto (bibliográficas ou cruzadas), o segundo comando processa o arquivo `.bib` que contém as informações bibliográficas, o terceiro gera o índice de siglas/abreviaturas, e o último comando junta todas estas informações, produzindo um texto com referências cruzadas funcionais.

## 3.2 Opções

O documento é gerado em função do curso dado como opção [obrigatória] a classe. Os cursos disponíveis são:

**bacharelado** Bacharelado em Ciência da Computação

**licenciatura** Licenciatura em Computação

**engenharia** Engenharia de Computação

**mestrado, ppginf** Mestrado em Informática

**doutorado, ppginf** Doutorado em Informática

**mestrado, ppca** Mestrado Profissional em Computação Aplicada

No caso dos cursos de pós-graduação, há o *exame de qualificação* do discente, a qual deverá constar a definição, pertinência do projeto, a sua abrangência, comprovação da eficiência e eficácia da metodologia proposta, uma revisão bibliográfica detalhada e o cronograma para conclusão do projeto (PPGI/UNB, 2013). Para gerar o documento referente a este exame, use a opção **qualificacao**.

## 3.3 Informações do Trabalho

O passo seguinte é definir as informações do trabalho, identificando os autores e os membros da banca (atenção a definição do gênero!). Por exemplo, para este documento foram utilizadas as seguintes definições:

```
\orientador{\prof \dr Guilherme Novaes Ramos}{CIC/UnB}%
%\coorientador{\prof \dr José Ralha}{CIC/UnB}
\coordenador[a]{\prof[a] \dr[a] Ada Lovelace}{Bibliothèque universelle de Genève}%
\diamesano{24}{dezembro}{2014}%

\membrobanca{\prof \dr Donald Knuth}{Stanford University}%
\membrobanca{\dr Leslie Lamport}{Microsoft Research}%

\autor{Guilherme N.}{Ramos}%
```

Sobre o texto, definiu-se:

```
\titulo{UnB-CIC: Uma classe em LaTeX para textos do Departamento de
Ciência da Computação}%

\palavraschave{LaTeX, metodologia científica}%
\keywords{LaTeX, scientific method}%
```

O título, apesar do tamanho reduzido, deveria apresentar uma ideia clara de todo o trabalho. As palavras-chave devem indicar os conceitos genéricos mais relevantes utilizados, e servem para indexação e busca de documentos que tratam os mesmos temas.

## 3.4 Arquivos

Os seguintes arquivos são exigidos:

**tex/abstract.tex** Contém o *abstract* do texto.

**tex/agradecimentos.tex** Contém os agradecimentos do autor.

**bibliografia.bib** Contém as referências bibliográficas no formato BibTeX[1].

**tex/dedicatoria.tex** Contém a dedicatória do autor.

**tex/siglas.tex** Contém as definições de siglas/abreviaturas.

**tex/resumo.tex** Contém o resumo do texto.

Os alunos dos Programas de Pós-Graduação da Universidade de Brasília devem incluir a ficha catalográfica em seus documentos, gerada pela Biblioteca Central (BCE). Neste caso, o aluno deve substituir o arquivo PDF **doc/BDM.pdf** pelo fornecido pela BCE. *Atenção*, para que o arquivo seja incluido automaticamente pela classe, o nome deve ser *obrigatoriamente* **BDM.pdf**.

Demais arquivos não são inseridos automaticamente, mas a classe oferece comandos para inclusão, facilitando a organização destes.

## 3.5 Documento

Todo documento em LaTeX é delimitado pelo ambiente *document*. O caso aqui não é diferente, mas a interação é simplificada. Basicamente, a classe `UnB-CIC` funciona "automagicamente" em função dos comandos e dos nomes dos arquivos.

### 3.5.1 Capítulos

O texto de cada capítulo deve estar em seu próprio arquivo, dentro do diretório correto `tex`. A inclusão do texto é feita pelo comando:

```
\capitulo{arquivo}{título}%
```

Os dois argumentos são:

**arquivo** argumento obrigatório que define o nome do arquivo que contém o texto do capítulo.

[1] <http://www.bibtex.org>

**título** argumento obrigatório que define o título do capítulo.

Por exemplo, este texto está no arquivo `2_UnB-CIC.tex`, e para criar os dois capítulos vistos até agora, o documento seria:

```
\begin{document}%
  \capitulo{1_Introducao}{Introdução}% inclui o arquivo 1_Introducao.tex
  \capitulo{2_UnB-CIC}{A Classe \unbcic}% inclui o arquivo 2_UnB-CIC.tex
\end{document}%
```

Para incluir um terceiro capítulo neste texto, cujo conteúdo trata de trabalhos conclusão de curso, basta criar o arquivo `tex/3_TCC.tex` e adicioná-lo com o comando descrito.

No caso de apêndices ou anexos necessários, o texto de cada um deve estar em seu próprio arquivo, também dentro do diretório `tex/capitulos`. Para facilitar as referências cruzadas, estes devem ser inclusos com os seguintes comandos (respectivamente):

```
\apendice{arquivo}{título}%
\anexo{arquivo}{título}%
```

Os dois argumentos funcionam exatamente como `\capitulo`. Desta forma, o exemplo de um documento "completo" seria:

```
\begin{document}%
  \capitulo{1_Introducao}{Introdução}%
  \capitulo{2_UnB-CIC}{A Classe \unbcic}%
  \capitulo{3_TCC}{Trabalho de Conclusão de Curso}%

  \apendice{Apendice_Fichamento}{Fichamento de Artigo Científico}%
  \anexo{Anexo1}{Parte da Documentação Original}%
\end{document}%
```

Usando estes comandos, o rótulo de cada capítulo/apêndice/anexo é criado automaticamente a partir do nome do arquivo para posterior referência cruzada. Por exemplo, este capítulo pode ser referenciado com o comando `\ref{2_UnB-CIC}` (cujo resultado é: 3), mas a classe oferece opções mais interessantes. Os comandos para referenciar çapítulos são:

```
\refCap{referência}%
\refCaps{referência inicial}{referência final}%
```

Onde os argumentos são:

**referência** nome da referência do capítulo.

**referência inicial** nome da referência do capítulo inicial da sequência de capítulos.

**referência final** nome da referência do capítulo final da sequência de capítulos.

O Chapter **??** é referenciado com o comando:

```
\refCap{1_Introducao}%
```

Considerando Chapter **??** e também o Chapter 3, é possível referenciar a *sequência* de Chapters **??** a 3 com o comando:

```
\refCaps{1_Introducao}{2_UnB-CIC}%
```

Embora estes comandos não "simplifiquem" a inclusão de figuras, eles certamente facilitam a referência a elas com um padrão uniforme, e nada impede o uso dos comandos padrões.

### 3.5.2 Figuras

Para manter a organização dos arquivos de seu documento, as figuras devem ficar separadas no diretório `img`. As funções de inclusão de figuras permanecem as mesmas, mas a classe `UnB-CIC` oferece uma forma mais simples de inserir uma figura (e de referenciá-la). Basta executar o comando:

```
\figura[posição]{arquivo}{legenda}{referência}{tamanho}%
```

Os 5 argumentos são:

**posição** argumento [opcional] para posicionar a figura no texto[2].

**arquivo** nome do arquivo da imagem.

**legenda** legenda da figura.

**referência** nome da referência da figura para referências cruzadas.

**tamanho** tamanho da imagem[3].

Por exemplo, a Figure 3.1, inserida com o seguinte comando:

```
\figura[!h]{contorno_preto}{Marca P/B}{unbPB}{width=0.5\textwidth}%
```

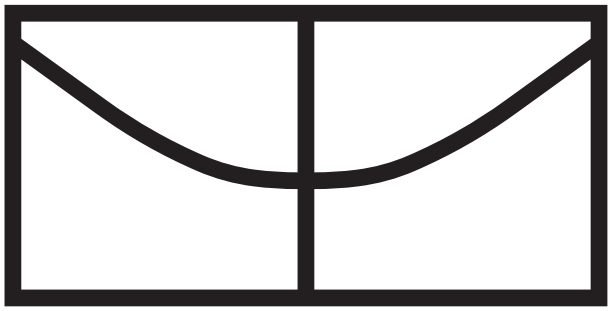


Figure 3.1: Marca P/B.

Os comandos para referenciar figuras são:

```
\refFig{referência}%
\refFigs{referência inicial}{referência final}%
```

Onde os argumentos são:

**referência** nome da referência da figura.

**referência inicial** nome da referência da figura inicial da sequência de figuras.

**referência final** nome da referência da figura final da sequência de figuras.

A Figure 3.1 é referenciada com o comando:

```
\refFig{unbPB}%
```

Figure 3.2: Marca colorida.

Considerando a Figure 3.2 e também a Figure 3.3, é possível referenciar a *sequência* de Figures 3.1 a 3.3 com o comando:

```
\refFigs{unbPB}{unb2}%
```

[2]Mais informações na documentação do ambiente *figure*, mas este é um bom começo: <http://en.wikibooks.org/wiki/LaTeX/Floats,_Figures_and_Captions>.

[3]Mais informações na documentação do comando `\includegraphics`.

Algumas vezes deseja-se usar a figura de uma das referências bibliográficas. Neste caso, utilize o comando:

```
\figuraBib[posição]{arquivo}{legenda}{bib}{referência}{tamanho}%
```

Os argumentos são os mesmos do comando `\figura`, acrescidos de:

**bib** nome da referência bibliográfica que originou a figura.

Por exemplo, a Figure **??** foi gerada com o comando:

```
\figuraBib{miktex}{\LaTeX\ vs MS Word}
{pinteric_latex_2004}{latexvsword}{width=.45\textwidth}%
```

Embora estes comandos não "simplifiquem" a inclusão de figuras, eles certamente facilitam a referência a elas com um padrão uniforme, e nada impede o uso dos comandos padrões.

Figure 3.3: Outra marca colorida.

### 3.5.3 Equações

As funções de inclusão de equações permanecem as mesmas, mas a classe `UnB-CIC` oferece uma forma mais simples de inserir uma equação (e de referenciá-la). Basta executar o comando:

```
\equacao{referência}{fórmula}%
```

Os 2 argumentos são:

**referência** nome da referência da equação para referências cruzadas.

**fórmula** a equação em si.

Por exemplo, a Equation 3.1, inserida com o seguinte comando:

```
\equacao{pitagoras}{a^2 + b^2 = c^2}%
```

$$a^2 + b^2 = c^2 \tag{3.1}$$

Além disso, é possível quebrar em linhas, como na Equation 3.2, com o mesmo comando:

```
\equacao{pit2}{a = (x+y)^2\\b= (x*y)^2}%
```

$$\begin{aligned} a &= (x+y)^2 \\ b &= (x*y)^2 \end{aligned} \tag{3.2}$$

Os comandos para referenciar equações são:

```
\refEq{referência}%
\refEqs{referência inicial}{referência final}%
```

Onde os argumentos são:

**referência** nome da referência da equação.

**referência inicial** nome da referência da equação inicial da sequência de equações.

**referência final** nome da referência da equação final da sequência de equações.

Considerando a Equation 3.1 e também a Equation 3.3, é possível referenciar a *sequência* de Equations 3.1 a 3.3 com o comando:

```
\refEqs{pitagoras}{eq}%
```

Embora estes comandos não "simplifiquem" a inclusão de equações, eles certamente facilitam a referência a elas com um padrão uniforme e nada impede o uso dos comandos padrões.

$$d = c^3 - \frac{a}{b} \tag{3.3}$$

### 3.5.4 Tabelas

As funções de inclusão de tabelas permanecem as mesmas, mas a classe `UnB-CIC` oferece uma forma mais simples de inserir uma tabela (e de referenciá-la). Basta executar o comando:

```
\tabela{legenda}{referência}{especificações}{tabela}%
```

Os 4 argumentos são:

Table 3.1: Exemplo de tabela.

| **Item** | **Descrição** |
|---|---|
| 1 | Descrição 1 |
| 2 | Descrição 2 |
| 3 | Descrição 3 |

Table 3.2: Exemplo de tabela.

| **Item** | **Descrição** |
|---|---|
| 1 | Descrição 1 |
| 2 | Descrição 2 |
| 3 | Descrição 3 |

**legenda** legenda da tabela.

**referência** nome da referência da tabela para referências cruzadas.

**especificações** alinhamento de cada coluna da tabela.

**tabela** o conteúdo da tabela[4].

Por exemplo, a Table 3.4, inserida com o seguinte comando:

```
\tabela{Exemplo de tabela}{exemplo}{| c | c |}%
  {\hline
  \textbf{Item} & \textbf{Descrição} \\\hline
  1 & Descrição 1 \\\hline
  2 & Descrição 2 \\\hline
  3 & Descrição 3 \\\hline}%
```

Os comandos para referenciar tabelas são:

```
\refTab{referência}%
\refTabs{referência inicial}{referência final}%
```

Onde os argumentos são:

**referência** nome da referência da tabela.

**referência inicial** nome da referência da tabela inicial da sequência de tabelas.

**referência final** nome da referência da tabela final da sequência de tabelas.

[4]Mais informações na documentação do ambiente *tabular*.

Table 3.3: Matriz de Decisão de Eisenhower (Fonte: (COVEY; MERRILL; MERRILL, 1995)).

| | **Urgente** | **Não Urgente** |
|---|---|---|
| **Importante** | Crises | Planejamentos |
| **Não importante** | Interrupções | Distrações |

Table 3.4: Outro exemplo de tabela.

| # | A | B | Comentário |
|---|---|---|---|
| 1 | $a_1$ | $b_1$ | comentário 1 |
| 2 | $a_2$ | $b_2$ | comentário 2 |
| 3 | $a_3$ | $b_3$ | comentário 3 |

Considerando a Table 3.1 e também a Table 3.4, é possível referenciar a *sequência* de Tables 3.1 a 3.4 com o comando:

```
\refTabs{exemplo}{exemplo2}%
```

Algumas vezes deseja-se usar a tabela de uma das referências bibliográficas. Neste caso, utilize o comando:

```
\tabelaBib{legenda}{bib}{referência}{especificações}{tabela}%
```

Os argumentos são os mesmos do comando `\tabela`, acrescidos de:

**bib** nome da referência bibliográfica que originou a tabela.

Por exemplo, a Table 3.3[5] foi gerada com o comando:

```
\tabelaBib{Matriz de Decisão de Eisenhower}
{covey_first_1995}{EisenhowerTable}{ r | c | c }{%
                    & \textbf{Urgente} & \textbf{Não Urgente} \\\hline%
\textbf{Importante}     & Crises       & Planejamentos \\\hline%
\textbf{Não importante} & Interrupções & Distrações%
}%
```

Embora estes comandos não "simplifiquem" a inclusão de tabelas, eles certamente facilitam a referência a elas com um padrão uniforme, e nada impede o uso dos comandos padrões.

[5]Vale a pena assistir o vídeo da palestra *Time Management* de Randy Pausch: <http://www.cs.virginia.edu/~robins/Randy/>

### 3.5.5 Abreviaturas e Siglas

Abreviaturas e siglas devem ser definidas no arquivo `tex/siglas.tex`, e a inserção feita com o comando:

```
\sigla{sigla}{descrição}%
```

Onde os argumentos são:

**sigla** a própria sigla/abreviatura.

**descrição** definição completa do que representa a sigla/abreviatura.

Por exemplo:

```
\sigla{CIC}{Departamento de Ciência da Computação}%
```

A inserção de uma sigla/abreviatura no texto é simples, e pode ser feita de três formas diferentes:

| | |
|---|---|
| `\acrshort{CIC}` | CIC |
| `\acrlong{CIC}` | Departamento de Ciência da Computação |
| `\acrfull{CIC}` | Departamento de Ciência da Computação (CIC) |

# Chapter 4

# Trabalho de Conclusão de Curso

Este capítulo oferece sugestões para produção de um documento descrevendo um Trabalho de Conclusão de curso...

## 4.1 UnB

A Universidade de Brasília oferece diversas informações em seu sítio[1]. O texto existente em 21/11/2014 é reproduzido a seguir:

*Os cursos de graduação, especialização e pós-graduação têm como objetivo formar o aluno e prepará-lo para o exercício profissional. Como avaliação do aprendizado, a universidade exige um projeto que mobiliza os estudantes a colaborar com a pesquisa acadêmica. Desde a escolha do tema até a apresentação do trabalho final, o tempo do aluno é ocupado quase integralmente. Para facilitar a vida desses estudantes, o Portal UnB preparou uma série de dicas de professores especialistas no assunto.*

### 4.1.1 Os tipos

*A monografia, a dissertação e a tese são, respectivamente, os trabalhos de conclusão de curso de graduação ou especialização, mestrado e doutorado. A grande diferença é a profundidade exigida no projeto, aumentada de acordo com a importância do título de cada nível acadêmico. Mas, em todos os casos, a pesquisa deve abordar o tema selecionado com coerência, consistência e referencial teórico adequado.*

*Alguns cursos de graduação não exigem monografia, mas um relatório de estágios realizados, como acontece nas licenciaturas. A metodologia de pesquisar e apresentar resultados se mantém, como é exigido em todo projeto final.*

[1] <http://www.unb.br/oportunidades/projeto_final_de_curso>

*Uma monografia é, genericamente, um relatório de pesquisa sobre o assunto estudado. É específico a um tema pré-definido dentro de uma área de conhecimento e aborda questões e análises de um problema, a construção de uma teoria ou o desenvolvimento de um produto.*

*Exigida no mestrado, a dissertação cobra do futuro mestre um conhecimento mais profundo. A pesquisa deve ser o resultado em relatório que representa o trabalho experimental ou exposição científica com um tema bem delimitado, e demonstrar o conhecimento de literatura existente sobre o assunto.*

*A mais densa entre todos os projetos finais, a tese de doutorado exige mais no que diz respeito a teoria e metodologia do tema pesquisado. Deve apresentar contribuições reais para o desenvolvimento específico da especialidade em questão. A base do estudo demanda uma investigação original.*

### 4.1.2 Teoria e prática

*Todo projeto de conclusão de curso exige um relatório escrito baseado em teorias, mesmo que o assunto estudado seja algo prático como uma campanha publicitária ou um projeto arquitetônico. Porém, o inverso não se aplica.*

*As divisões dos tipos de trabalho variam entre cada área de conhecimento. Em suma, o projeto pode ser teórico, prático ou uma união dos dois. Na primeira situação, o aluno pode fazer estudo de caso - pesquisar sobre um fato histórico ou evento importante - ou formular uma teoria - por meio de pesquisa ou reavaliação das semelhantes.*

*O projeto prático se dedica a criação e construção de um produto, que pode variar de um novo motor a uma composição musical. O curso de graduação costuma oferecer a opção de um trabalho prático aos alunos. No caso dos cursos de mestrado e doutorado, nem todos os departamentos da universidade dispõem de linhas de pesquisa que permitam um projeto que vá além da teoria acadêmica.*

*A união dos dois gêneros é comum quando o universitário relata a experiência de estágio ou na simulação de um projeto, como a construção de maquetes ou esquemas computacionais. As opções são vastas e o aluno deve explicar como e o que se deve fazer para que o projeto se torne possível.*

### 4.1.3 Começo do projeto

*Parece óbvio, mas muitos alunos esquecem a questão principal na hora de escolher o tema: o assunto deve interessar e estimular a pesquisa. Conviver meses com um tema que não agrada torna o trabalho mais complicado. Porém, escolher um bom tema não é abraçar*

*e desenvolver sobre tudo que ele é e engloba. É preciso delimitar o assunto de forma específica.*

*Um trabalho sobre a história do mundo, por exemplo, está fadado a se tornar superficial. Além de extremamente amplo, é grande o volume de informações a ser levantado e estudado. É importante ter foco para desenvolver um projeto coeso e com credibilidade.*

*Além disso, o estudante necessita desenvolver um problema e traçar uma hipótese. Em um exemplo bem simples: a Guerra no Iraque (tema) e o terrorismo mundial (problema) – o aumento dos ataques depois da invasão americana (hipótese); ou seja, o que o aluno quer tratar e onde ele espera chegar na pesquisa. A não comprovação da hipótese não inviabiliza o trabalho, desde que o desenvolvimento da análise enriqueça os conhecimentos sobre o tema tratado.*

*A prática essencial para o desenvolvimento de qualquer projeto é a pesquisa bibliográfica. As consultas às bibliotecas respaldam a parte teórica do estudo e podem elucidar diversas questões, sejam específicas do projeto ou sobre metodologias científicas. Nesse ponto, o papel do professor orientador é fundamental para a condução da pesquisa. Além da seleção dos livros, o docente analisa as melhores possibilidades de desenvolver o assunto, em todas as suas fases. Ele também pode indicar a aplicação de entrevistas e outros elementos de apoio ao conteúdo do projeto.*

*Atualmente, o meio mais difundido de pesquisa é a Internet. Além de facilitar o acesso a documentos, pela rede é possível saber quanto o tema escolhido já foi objeto de estudo de outros acadêmicos. Mas essa facilidade deve ser utilizada para indicar um caminho.*

### 4.1.4 Estrutura e regras

*Antes do próprio trabalho escrito, o estudante deve fazer um projeto ou plano de pesquisa. O documento identifica o que deve ser feito, o porquê, como e onde será realizado o levantamento. Não há um modelo rígido para a apresentação do projeto de pesquisa, mas os seguintes elementos devem ser respondidos no texto:*

1. *Definição do objeto de estudo (tema/problema da pesquisa)*
2. *Justificativa*
3. *Hipóteses de trabalho*
4. *Discussão teórica*
5. *Metodologia*
6. *Pesquisa Bibliográfica*

*Seja monografia, dissertação ou tese, a parte escrita possui uma estrutura semelhante, embora cada uma tenha características próprias referentes à profundidade do tema estudado.*

*De acordo com a Associação Brasileira de Normas Técnicas (ABNT), um trabalho acadêmico deve englobar os elementos pré-textuais (como resumo e índice), pós-textuais (bibliografia, anexos, entre outros) e textuais. Esses últimos compõem a parte central do trabalho - introdução, desenvolvimento e conclusão.*

*A introdução é a parte inicial do texto e deve constar o objeto de pesquisa, os objetivos, a justificativa da escolha do tema e outras informações que sejam necessárias para esclarecer o assunto.*

*A parte principal do trabalho está concentrada no desenvolvimento. É uma exposição sistematizada e ordenada de toda o estudo desenvolvido, apresentando análise e interpretação das informações e dados obtidos. A conclusão é a etapa final do texto. Nela, são apresentados os resultados tendo como referência os objetivos e hipóteses da pesquisa.*

*Em todo o trabalho a linguagem utilizada deve ser interessante, sem apelar para a linguagem coloquial. O trabalho deve estar de acordo com as normas da ABNT. Procure livros sobre estrutura e regras do tipo de projeto final específico de seu interesse.*

### 4.1.5 O projeto está pronto. E agora?

*Após a finalização do projeto, chega o momento de preparar a apresentação. Em geral, a banca examinadora é formada por três docentes, sendo um deles o professor orientador do projeto. Também é comum aos alunos o direito de escolha dos avaliadores, desde que seja pertinente ao assunto e ao objetivo do estudo.*

*Esses professores recomendam uma apresentação resumida do projeto, pontuando as características essenciais e como se chegou às conclusões. É sempre bom explicar o cronograma de todo o trabalho. É preciso, também, ficar atento ao tempo. Não é necessário explicar os conceitos já citados no projeto e pode influenciar a nota final. Lembre-se que as explicações são voltadas para os avaliadores, que já leram o seu trabalho.*

*Durante as considerações da banca examinadora não se deve interromper a avaliação dos professores, exceto quando eles dirigirem diretamente uma pergunta ao aluno. Educação e conhecimento dos procedimentos acadêmicos são essenciais para uma boa apresentação. Após a avaliação, os professores pedem para os presentes se retirarem da sala. É feita uma reunião onde será decidida a nota do projeto.*

*Cada departamento possui regras e orientações para a apresentação dos trabalhos de conclusão. Cabe ao aluno perguntar à coordenação do curso e ao orientador todas as etapas do processo de elaboração do projeto final.*

# Chapter 5

# Apresentações

Este capítulo oferece sugestões de como fazer a apresentação do trabalho. Uma apresentação é necessária ao final do curso, é nela que se mostra os resultados obtidos de forma resumida e, preferencialmente, simplificada. Embora o "verdadeiro" resultado seja o texto técnico, que de fato representa a contribuição científica obtida, a apresentação serve para divulgar seus resultados e incentivar outros a se interessarem por seu trabalho.

## 5.1 Falando em Público

A ideia de uma apresentação não é mostrar todos os detalhes técnicos ou tentar impressionar o público com seu conhecimento. O objetivo é apresentar suas principais ideias de forma intuitiva, de modo que os presentes entendam o que foi feito e se interessem em conhecer as minúcias lendo o texto técnico.

Vale lembrar que embora você veja seu trabalho como extremamente interessante, geralmente seu público [ainda] não acha, e provavelmente têm coisas melhores para fazer... É preciso atrair e manter a atenção deles, bem como garantir que eles se lembrem do que foi dito (pelo menos da ideia principal).

Algumas noções importantes:

**Motivação:** Qual o problema e por que ele merece atenção?

**Ideia Principal:** Clara e explicitamente especificada.

**Exemplos:** A melhor forma de passar informações (ilustram motivação, funcionamento, casos extremos, limitações, etc.).

*Slides* são uma excelente ferramenta **de apoio** ao apresentador, mas muitas vezes tomam vida própria e se tornam o elemento principal. É essencial, embora um pouco difícil, evitar a "morte por Powerpoint"[1].

Existem muitas sugestões para fazer uma boa apresentação[2], por exemplo, imitar um bom apresentador[3], boas práticas na elaboração de slides[4], como organizar o conteúdo de um slide[5] (ou mesmo "vida após a morte"[6]). Entretanto, as duas noções mais importantes são: você nunca se prepara demais para fazer uma apresentação, e a única regra de uma apresentação é a de atenção[7].

Olivia Mitchell sugere as seguintes formas de manter a atenção da platéia[8]:

1. Fale sobre algo que interesse a platéia.
2. Diga porque deveriam prestar atenção.
3. Não apresente algo muito fácil ou muito difícil.
4. "Mudanças" prendem a atenção.
5. Conte estórias.
6. Faça pausas.
7. Seja breve.

Demonstrações ao vivo são impressionantes, desde que funcionem corretamente e não evidenciem as limitações do seu trabalho. Lembre-se que eventos importantes são, em sua maioria, regidos pela *Lei de Murphy*.

Por fim, lembre-se que é normal ficar nervoso perante uma platéia, e não há uma cura genérica para este problema. Há muitas sugestões de como lidar com isso[9], inclusive uma que diz que o problema é você[10]. Tente descobrir o que funciona melhor para si (boa sorte!).

[1] <http://www.smallbusinesscomputing.com/biztools/article.php/684871/Death-By-Powerpoint.htm>
[2] <https://hbr.org/2014/11/how-to-give-a-stellar-presentation>
[3] <https://www.youtube.com/watch?v=2-ntLGOyHw4>
[4] <https://www.youtube.com/watch?v=Iwpi1Lm6dFo>
[5] <https://hbr.org/2012/10/do-your-slides-pass-the-glance-test>
[6] <https://www.youtube.com/watch?v=lpvgfmEU2Ck>
[7] <http://finiteattentionspan.wordpress.com/2009/11/02/the-only-rule-about-giving-presentations-that-matters-is-th
[8] <http://www.speakingaboutpresenting.com/content/7-ways-audience-attention-presentation>
[9] <http://www.wikihow.com/Overcome-Stage-Fright>
[10] <http://seriouspony.com/blog/2013/10/4/presentation-skills-considered-harmful>

## 5.2 BEAMER

A classe BEAMER, disponível no CTAN[11], é a recomendada para criar apresentações. Não só possibilita um resultado visualmente interessante, como também aproveita parte do texto escrito em LaTeX. O manual[12] oferece instruções sobre o uso da classe e, principalmente, diretrizes para criar apresentações (especialmente as Seções 4 e 5 do Capítulo I).

[11] <http://www.ctan.org/pkg/beamer>
[12] <http://www.ctan.org/tex-archive/macros/latex/contrib/beamer/doc/beameruserguide.pdf>

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# Appendix A

# Fichamento de Artigo Científico

UnB Departamento de Ciência da Computação

# Fichamento de Artigo Científico

*Prof. Guilherme N. Ramos*

Um fichamento reúne elementos relevantes do conteúdo, apresentando a estrutura do texto, e deve seguir a seqüência do pensamento do autor, destacando suas ideias, argumentos, justificativas, exemplos, fatos, etc.

## 1 Artigo Científico

Geralmente, um *artigo científico* é escrito com a seguinte estrutura (buscando responder algumas questões):

I. Introdução

- Qual o contexto do problema? (O que? Onde? Quando?)
- Qual a principal questão ou problema colocado? (Por quê? Como? Qual?)
- Qual o objetivo visado? O que se pretende constatar ou demonstrar? (investigar, analisar, refletir, contribuir,...)

II. Referencial Teórico

- Quais são os autores/teorias/conceitos que já estudaram os principais assuntos abordados e que sustentam ao texto?
- Quais os resultados mais recentes relacionados a eles?

III. Metodologia/Desenvolvimento

- Quais os procedimentos metodológicos adotados? (natureza do trabalho: empírico, teórico, histórico) – (coleta de dados: questionário, entrevista, levantamento bibliográfico).
- Como a pesquisa foi desenvolvida? Quais as principais relações entre teoria e prática?
- Havendo artefato proposto, ele está disponível para utilização e/ou modificação?

IV. Resultados

- Houve validação (por meio de experimentação)? Como foi feita?
- Os resultados obtidos são corretos/válidos?

V. Conclusões

- Qual o problema atacado?
- Quais os resultados obtidos para os objetivos propostos?
- Quais conclusões podem ser tiradas destes resultados?
- Quais as limitações da metodologia utilizada?
- Quais as possibilidades de trabalhos futuros para o problema?

# 2 Fichamento

Neste contexto, um fichamento deve conter a seguinte estrutura:

1. ***Identificação do aluno:*** indicação precisa de quem é o autor do fichamento.
2. ***Identificação do texto:*** indicação precisa de quem são os autores do texto analisado e dos detalhes do documento, de modo que se possa buscá-lo para uma leitura completa.
3. ***Pontos-chave:*** noções mais relevantes do texto analisado. *Proposta* (o que é apresentado?), *mérito* (por que é relevante?), *validação* (como verificar a utilidade?), e *perspectivas* (o que pode ser melhorado?).
4. ***Palavras-chave:*** expressões que identificam o assunto abordado.
5. ***Sinopse do texto:*** resumo *com suas palavras*. Deve ser mais detalhado que um *abstract*, geralmente apresentando pelo menos um parágrafo por seção do texto original. No caso de inclusão de trechos, o texto deve ser identificado entre "aspas" e concatenado através de suas próprias palavras.
6. ***Análise crítica:*** posicionar-se em relação as seguintes questões: pertinência do assunto; forma como foi abordado; comparação com outras abordagens do mesmo assunto (caso conheça). Junto ao *resumo*, é a parte mais interessante para o leitor, pois apresenta uma avaliação do conteúdo apresentado.

## 2.1 Exemplo

1. ***Identificação do aluno:***Alan Mathison Turing, 00/000000
2. ***Identificação do texto:***Guilherme N. Ramos, Yutaka Hatakeyama, Fangyan Dong, and Kaoru Hirota, Hyperbox clustering with Ant Colony Optimization (HACO) method and its application to medical risk profile recognition, Applied Soft Computing, Vol. 9, Issue 2, pp 632-640, 2009. (doi:10.1016/j.asoc.2008.09.004)
3. ***Pontos-chave:***

   **Proposta:** HACO - método para aglomeração de dados utilizando hipercaixas com posicionamento otimizado via algoritmo de colônia de formigas.

   **Mérito:** apresenta uma nova forma de fazer agrupamentos considerando a topologia do espaço de dados e fornecendo resultados intuitivos e facilmente utilizáveis.

   **Validação:** comparação com algoritmos conhecidos em testes com dados padrões e com dados de infecção viral para diagnóstico auxiliado por computador.

   **Perspectivas:** adequação das dimensões das hipercaixas, diminuição de parâmetros.

4. ***Palavras-chave:***colônia de formigas, hipercaixa, otimização, reconhecimento de padrões.

5. ***Sinopse do texto:*** A *Colônica de Formigas* (ACO) é um método de otimização que pode ser utilizado para agrupar dados. *Hyperbox clustering with Ant Colony Optimization* (HACO) é um método de agrupamento que utiliza ACO tentar posicionar hipercaixas no espaço de forma a agrupar a maior quantidade de dados possível, e ainda gera uma forma simples de classificar novos dados.

   ACO é baseado no comportamento de formigas reais, que otimizam o caminho percorrido entre o alimento e o formigueiro. Hipercaixas definem de forma muito simples uma região em um espaço n-dimensional, combinadas para definir regiões de topologia complexa, e utilizadas como um classificador de forma trivial.

   HACO busca encontrar uma partição de dados, efetivamente definindo grupos. Primeiro, aplica ACO para tentar posicionar hipercaixas de forma que estas contenham a maior quantidade possível de dados. A seguir, se não há conhecimento prévio da quantidade de classes, considera-se que as hipercaixas que se sobrepõem representam uma mesma classe de dados, e [grupos de] hipercaixas distintas representam classes diferentes. Caso o número de classes seja conhecido, HACO aplica o algoritmo *Nearest-neighbor* (NN) para definir a quantidade correta de grupos. Uma consequência de se usar hipercaixas é que o resultado do agrupamento define também um classificador: se um novo dado está dentro de uma hipercaixa, sua classe será a mesma da definida por esta hipercaixa.

   Os resultados experimentais de HACO fora, comparados a três algoritmos que têm o mesmo fim: testado em NN, *Fuzzy C-Means* (FCM), e o próprio ACO (com uma abordagem diferente para agrupamento). O primeiro teste foi em conjuntos de dados sintéticos, e serviu como prova de conceito, oferecendo diversas informações sobre o comportamento do método em função de certas configurações. Um segundo experimento foi realizado com dados reais de pacientes para agrupá-los em "saudáveis" e "não saudáveis", e HACO obteve o melhor resultado dentre os algoritmos testados. A análise da estrutura do classificador gerado possibilita descobrir informações relativas às características das classes, indicando um "perfil de risco" para os pacientes.

   Foi apresentado o método HACO para agrupar dados, utilizando a meta-heurística ACO e hipercaixas, que possibilita a extração de informações inerentes a estrutura dos dados. HACO foi validado com experimentos, e demonstrou grande potencial. Os resultados são muito influenciados pela configuração dos parâmetros, que será investigada.

6. ***Análise crítica:*** ~~Este é o melhor artigo de todos os tempos.~~ O artigo apresenta uma forma inovadora de agrupar dados, de forma não-supervisionada (embora possa aproveitar informações se houver). O resultado pode ainda ser utilizado como classificador de novos dados, e - o mais interessante - analisado para descobrir informações sobre as classes. Além disso, explora as vantagens de cada elemento que compõe o método, obtendo melhores resultados e diminuindo o custo computacional. A aplicação em um caso real, cujos resultados podem ser utilizados para auxiliar o diagnóstico de pacientes, dá mais destaque ao trabalho.

   O problema de agrupamento de dados é muito pertinente e, em tempos de excesso de dados, a possibilidade de análise intuitiva da estrutura e descoberta de conhecimento é bastante interessante. Além disso, a solução proposta é de uso geral, oferecendo mais possibilidades de uso.

   Os experimentos realizados foram coerentes e suficientes para demonstrar o que foi afirmado. Entretanto, o método só foi comparado a outros algoritmos simples, seria interessante uma comparação com algoritmos mais avançados, bem como específicos para aplicação. A comparação também foi em uma única aplicação específica, seria mlehor que houvesse mais testes com outros dados para conclusões melhor embasadas. Além disso, é preciso uma análise mais profunda quanto às configurações de HACO, que influenciam muito o resultado.

# Annex I

# Documentação Original UnB-CIC (parcial)

```
% -*- mode: LaTeX; coding: utf-8; -*-
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%% File    : unb-cic.cls (LaTeX2e class file)
%% Authors : Flávio Maico Vaz da Costa
%%               (based on previous versions by José Carlos L. Ralha)
%% Version : 0.96
%% Updates : 0.5  [??/11/2004] - Initial release. don't remember the day.
%%         : 0.75 [04/04/2005] - Fixed font problems, UnB logo
%%                               resolution, keywords and palavras-chave
%%                               hyphenation and generation problems,
%%                               and a few other problems.
%%         : 0.8  [08/01/2006] - Corrigido o problema causado por
%%                               bancas com quatro membros. O quarto
%%                               membro agora é OPCIONAL.
%%                               Foi criado um novo comando chamado
%%                               bibliografia. Esse comando tem dois
%%                               argumentos onde o primeiro especifica
%%                               o nome do arquivo de referencias
%%                               bibliograficas e o segundo argumento
%%                               especifica o formato. Como efeito
%%                               colateral, as referências aparecem no
%%                               sumário.
%%         : 0.9 [02/03/2008]  - Reformulação total, com nova estrutura
%%                               de opções, comandos e ambientes, adequação
%%                               do logo da UnB às normas da universidade,
%%                               inúmeras melhorias tipográficas,
```

```
%%                              aprimoramento da integração com hyperref,
%%                              melhor tratamento de erros nos comandos,
%%                              documentação e limpeza do código da classe.
%%          : 0.91 [10/05/2008] - Suporte ao XeLaTeX, aprimorado suporte para
%%                              glossaries.sty, novos comandos \capa, \CDU
%%                              e \subtitle, ajustes de margem para opções
%%                              hyperref/impressao.
%%          : 0.92 [26/05/2008] - Melhora do ambiente {definition}, suporte
%%                              a hypcap, novos comandos \fontelogo e
%%                              \slashedzero, suporte [10pt, 11pt, 12pt].
%%                              Corrigido bug de seções de apêndice quando
%%                              usando \hypersetup{bookmarksnumbered=true}.
%%          : 0.93 [09/06/2008] - Correção na contagem de páginas, valores
%%                              load e config para opção hyperref, comandos
%%                              \ifhyperref e \SetTableFigures, melhor
%%                              formatação do quadrado CIP.
%%          : 0.94 [17/04/2014] - Inclusão da opção mpca.
%%          : 0.95 [06/06/2014] - Remoção da opção "mpca", inclusão das opções
%%                              "doutorado", "ppginf", e "ppca" para identificar
%%                              o programa de pós-graduação. Troca do teste
%%                              @mestrado por @posgraduacao.
%%          : 0.96 [24/06/2014] - Ajuste do nome do curso/nome do programa.
%%
```