Performance and Design of Taxi Services at Airport Passenger Terminals

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Abstract

The main objective of this dissertation is to analyze, through the consideration of a case-study - Portela Airport - the current operational and regulatory design options in systems of taxi service provision at airport passenger buildings, and propose, based on its performance levels, alternative schemes and possible interventions that can improve the existing services.

On the regulatory side, the methodology chosen to pursue these objectives was based on the systematic analysis of the involved stakeholders, their institutional roles and power-sharing mechanisms. On the operational side, an extensive data collection effort was performed and used to calibrate a simulation model which represents system behavior. Both of these analyses were then subject to a scenario-building process, in order to test different stimulus for both perspectives.

As main conclusions, it must be stated that the current taxi service system at Terminal 1 is not able to adequately cope with peak-hour solicitations and offer good quality of service to passengers at these times. Queues are a fundamental part of the problem and their behavior must not be diluted in average-based analysis that do not expose the frailties of the system at peak-hours, some of them intensified by seemingly small exogenous factors such as police coordination or taxi maneuvering needs. They may also be a key part of the solution, as slight physical rearrangement of queues or service areas can lead to greatly improved service as regards queue length, delays and reliability. ANA and Lisbon Municipality should thus behave proactively to face this problem.

Key Words: Taxi Services, Queuing Systems, Airports, Regulation, Simulation, Simul8

1. Thesis Objectives and Structure

Airports are nowadays multimodal, multi-service platforms, with intense non-aeronautical activities that cover several different industrial, economical and social areas. Taxi services are a fundamental piece of the transportation diversity an airport requires, in order to become attractive and efficient. This transportation service gains special relevance when coupled to existing high-demand nodes like hospitals, monuments, shopping areas, hotels, or airports. Its “service profile” is highly compatible to the traditionally higher willingness to pay of passengers with trip urgency and high comfort needs or economic power, such as hospital patients, shoppers, businessmen or tourists (La Croix, 1991) (Curry, 1977). Recent surveys in Europe show that about 50% of the urban mobility customers prefer the taxi to travel to the Airport, making it an almost specialized airport feeder service (Cardon, 2007).
The main objective of this dissertation is to analyze, through the consideration of a case-study - Portela Airport - the current operational and regulatory design options in systems of taxi service provision, namely at airport passenger buildings, and propose, based on its performance levels, new and alternative schemes and possible interventions that can improve the existing services.

This issue is often subject to average-based intuitive thinking and political pressure when building or re-designing of the system, many times leading to inefficiencies, excessive waiting times and/or low-quality of service. The way taxi services are organized at the airport taxi stands also impacts the quality of service and thresholds for efficiency gains at the terminals themselves. Availability, reliability and lower waiting times at the taxi stand are important to arriving passengers who wish to quickly get to their destination after a long trip. Effects of variability in arrival and service patterns at peak-hours are a key issue in this context, frequently ignored, increasing unreliability and delays. (Odoni, 2007)

In recent years, Portuguese society has been intensely discussing the construction of a new Airport for the city of Lisbon, which is to be located at Alcochete. This major project, still in its early stages of development, opens a window of opportunity to contribute towards the discussion on the design options of the future taxi service there and provides an excellent candidate for a case study – the soon-to-be-replaced, Portela Airport. This opportunity, coupled with the almost absence of acknowledged studies on airport taxi service performance and design in scientific literature, also provides this theme with a substantial level of relevance.

One of the main difficulties of this endeavor is related to the complexity of the relations between the several elements that compose the system. This multidisciplinary nature, coupled with the inherent complexity of an airport infrastructure, can make the problem boundaries become blurry and spread the focus of the effort, intensifying it towards unsustainable levels. Careful focus on the critical elements of this issue and objective-oriented time management can help minimize this risk. The other main difficulty is related to a common bane of all researchers – data availability. Little to no recent information can be found on taxi service indicators on airport passenger terminals and taxi companies either do not usually keep a record of their service performance, or are very rigid about releasing it. Early identification of reliable and critical information sources and preparation of a structured data collection plan can function as mitigation measures regarding this risk.

The main stakeholders of this effort are firstly the taxi sector as a whole, in the sense that greater efficiency, and lower queuing lengths and waiting times for passengers and taxis increases demand and number of trips - consequently revenues - and decreases operational costs. Airport management companies also benefit from better and more efficient taxi services at their terminal’s curbside, for increased connectivity and less queuing problems (space efficiency) – consequently less complaints. Passengers are also confronted with less waiting times, more service flexibility and eventually money-saving effects, deriving from the potential implementation of different taxi service types such as the shared-taxi, for example. Finally, there are positive externalities for society in general caused by possible decreases in congestion and modal share increases for taxi versus private cars, due to higher occupation rates and greater service efficiency and availability for airport passengers.
This dissertation is based on a structure of four chapters. **Chapter One** provides the general framework for the development of the thesis, starting by identifying its objectives, opportunity and relevance. It also builds a knowledge basis for the subsequent analysis, through background research and literature review, framing it in the regulatory, institutional and operational context of the sector. By gathering all relevant information on previous studies, theoretical bibliography and emerging trends, a strong knowledge background is created and the analysis becomes richer in content. **Chapter Two** is dedicated to the problem definition and the justification of the proposed methodology for the analysis. A Data Collection Plan is built and the field work procedures are described along with all assumptions and simplifications. **Chapter Three** relates to the description of the Case Study – Portela. It defines the specific institutional, regulatory and operational setting, analysis on the collected data, model characterization and assumptions, presentation of results, scenario building and consequent discussion (SIMUL8 Software will be used as a simulation tool). It is a central chapter in this dissertation as it allows the overview of the system mechanics and defines scenarios for performance testing. **Chapter Four** summarizes the major findings of the experiment, analyses its implications, discusses possible limitations of the study and proposes interventions for improvement of the system.

## 2. Problem definition and methodology

### 2.1. Regulatory and Institutional Framework

Taxi service at airports is subject to strong influences from many stakeholders with specific interests, some with conflicting objectives, such as taxi operators and airport authorities. As with many other transportation systems, the balance between equity, efficiency and sustainability should be the main objective of regulation and transport policy. At airport taxi stands, this balance is not trivial to achieve, especially because the involved agents may have conflicting interests and local context seems to decisively influence the best course of action for each situation. A more in-depth, case-specific analysis on the main stakeholders, regulation and institutional mechanisms is required to know which problems emerge, to what extent this aspect of the system can be improved and by which changes and interventions we can improve it. The methodology for this regulatory and institutional analysis was centered on the following steps:

1. Analysis of the general market characteristics and regulatory environment, namely the types of existing or possible contractual arrangements and access to profession.
2. Identification of the main stakeholders and their specific interests and bargaining power.
3. Identification of the hierarchical relationships between the involved institutional agents and the sharing of responsibility and power among institutions.

### 2.2. Operational Framework

The airport taxi stand operational setting can be analyzed through quality and performance indicators of the queuing system, such as average waiting time for passengers or maximum queue length (Valadares Tavares, et al., 1996). These can be measured or estimated through a series of methods, which usually require field data collection, used to calibrate simulation models to mimic reality. These are used to test different scenarios and system configurations, in search for better
solutions. The main identified steps that constitute the methodology concerning the operational context are:

1. Identification of the problem of queuing at Airport Taxi Stands;
2. Literature review and general queuing theory research;
3. Identification of a suitable and real case-study;
4. Preliminary in situ observations of system behavior;
5. Elaboration of a Data Collection Plan;
6. Test data collection procedures;
7. Collect relevant data;
8. Compile and analyze the collected data;
9. Build basic queuing simulation model;
10. Test and validate the basic simulation model based on the collected data;
11. Perform scenario building and testing;
12. Results analysis and conclusions.

One of the most important steps of this methodology was the definition of a Data Collection Plan, in order to organize the time, resources and methods to be used in the data collection procedures. The Taxi Stand at the Arrivals Hall was chosen as the basis for this planning phase. Some portions of this Plan were developed iteratively, as different methods for collecting data and conceptual considerations were being tested in the field.

3. Case Study – Portela Airport – Terminal 1

Portela Airport is the biggest and most important airport in Portugal, serving the nation’s capital, Lisbon. In 2000, a survey concluded that about 42% of passengers were tourists and 28% traveled due to business motives (FCG-Parsons, 2002), while another source, in 2006, states that 56% of the passengers of this airport had traditionally middle-high income professions (ANA, 2006). Also, in 2008, Portela processed about 13.6 million passengers, 1.5% more than in 2007, following a steady but slow growth trend, since 2003 (ANA, 2008). The percentage of taxi users at Terminal 1 was 38%, in 2000 (FCG-Parsons, 2002), later estimated at 30% in a 2006 study, by ANA.

3.1. Regulatory and Institutional Analysis

Airport taxi stands are often seen by taxi companies and owners/drivers as profitable service locations. In Lisbon, and despite the proximity of the airport to the city center, this seems to be no exception. Distance and time, although always considered as crucial income factors for drivers at the airport, are often accompanied by the luggage factor and tips, which tourists are known to give, traditionally more often than regular city locals.

The abovementioned percentages, coupled with the fact that air passenger flows at Portela have not diminished for a long time, means that Demand is not only relatively high and constant, mainly at peak times, but also that the customer characteristics themselves are adequate for the transportation segment under analysis. On the supply side, taxis are highly abundant at the airport, gathering at the
taxi parking facility, about fifty meters from the terminal and queuing along the access road, on a segregated lane, sometimes for several hours, according to some taxi drivers. External competition is also present, mainly in the form of buses, pre-booked car services and rent-a-car companies.

There is an open system-like arrangement at Lisbon airport for taxis wanting to solicit service at Terminal 1’s stands. This system has only two main basic restrictions, besides the mandatory IMTT professional licensing of companies and drivers: taxis that want to service the airport must be Lisbon-registered, licensed vehicles and the maximum number of taxis serving any taxi stand is limited to the corresponding parking regime and spaces available. Regarding the institutional framework (Figure 1), regulator and vehicle licensing roles are with Municipality of Lisbon and the driver/company licensing is the role of the IMTT. The main planning entity is also the Lisbon Municipality, in collaboration with ANA. The conceding entity is Lisbon Municipality and the operators are taxi companies and drivers.

![Figure 1 – Institutional framework regarding Portela’s taxi service system](image1)

### 3.2. Operational Analysis

The taxis form a queue originating from a nearby parking lot, along a segregated lane of the access road (Figure 3). There is a strong police presence at the curbside, not only to monitor illegal parking of private cars, but also to coordinate and help discipline the queuing and service of taxis. There is a passenger queue which extends between two of the Terminal exits. Observations at peak-hours have confirmed occasional formation of secondary queues, originating from the two closest terminal exits, and several queues going beyond the defined space for the taxi passenger waiting area.

![Figure 2 – Taxi Service Organization at the Arrivals of Terminal 1](image2)
It has been observed *in situ* that the system closer to the passenger queue is composed of two parallel taxi rows or lanes (inner Row A and outer Row B – see Figure 3) and service is usually restricted to the four front parking positions. Server 4 does not seem to show equal behavior - in terms of service times - to the other servers and is sometimes empty due to a conjunction of service-time-increasing conflicts present in Figure 3. FIFO discipline is supposedly present both at the passenger queues and taxi queues. Due to the splitting of the single original segregated lane into two service lanes/rows, taxis are ordered to bypass other taxis parked at the inner Row A by a police element.

Figure 3 – System configuration at the Arrivals Taxi Stand and Server 4 conflicts

The field data collection was essential for understanding of the system behaviors and quantification of its functioning. The collected data at Portela was based upon the need to have more information on three key aspects: arrivals of passengers, namely the inter-arrival times and group composition (Figure 4); service of taxis, namely service times (Figure 5), including “empty time” between availability; and passenger queue evolution, namely the queue length and the waiting time, through an indirect method presented in (Newell, 1982), based on inter-arrival and service times (Figure 6).

Figure 4 – Histogram for Inter-Arrival Times for Groups and Group Size
The simulation model is a very important part of this study, in the sense that it allows the manipulation of the system characteristics, such as arrival/service rates, number of servers, queues, queue discipline, routing of passengers, time-dependent behaviors, etc. For the construction of this model, SIMUL8 software was chosen, and system configuration is shown on Figure 7.

Figure 5 – Histograms for Service Times

Figure 6 – Arrival Curve and Exit Curve based on the collected data

Figure 7 – Final System Configuration for the current situation at Portela’s Arrivals Taxi Stand
After building the main basic model structure, the relevant parameters for system and object behavior and processing had to be introduced, in order to calibrate the model to resemble reality. For this, the collected field data was statistically analyzed. The main following assumptions were made:

- The simulation duration was set to 3600 seconds (representing 1 hour of peak-hour behavior);
- For the definition of the inter-arrival times distribution, the observed values were used. The statistical analysis of this dataset resulted in a good fit to the Exponential distribution ($\lambda=0.07263$).
- Regarding service times, all four different server service time observation sets were used and the aggregated results were fitted into a single Lognormal distribution ($\mu=4.1983; \sigma=0.46905$).
- The model does not consider Reneging, Jockeying or Balkling.

<table>
<thead>
<tr>
<th>Queue Length (persons)</th>
<th>In-Queue Waiting Time (seconds)</th>
<th>Queue Length (persons)</th>
<th>In-Queue Waiting Time (seconds)</th>
<th>Queue Length (persons)</th>
<th>In-Queue Waiting Time (seconds)</th>
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<tbody>
<tr>
<td>Low 95% range</td>
<td>Average Result</td>
<td>High 95% range</td>
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<td>1211</td>
<td>125</td>
<td>873</td>
<td>130</td>
<td>907</td>
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</table>

Figure 8 – Final result comparison between the Empirical Process and the Simulation Model of the current system

The results shown on Figure 8 refer to the common indicators than can be extracted from SIMUL8 and from the Empirical Process. Despite some expected discrepancies, main indicators/evolution point to similar results and field behavior appears to be adequately represented by the SIMUL8 Model.

### 3.3. Scenario Building and Evaluation

Three policy actions were tested on the regulatory and institutional context, with the following evaluation, based on a SWOT methodology (Figure 9, Figure 10 and Figure 11):

**Strengths**
- Increased Spatial and Energy Efficiency
- Less Congestion Externalities
- Less Environmental Externalities
- Decrease in passenger queuing

**Weaknesses**
- Lack of experience and knowledge of Portuguese passengers
- Taxi Drivers resistance to reduction of Demand for individual taxis
- Investment and operational costs of the GPS/GIS-based management system.

**Opportunities**
- Introduction of the Collective Taxi on a Competitive environment with intense demand for taxi services
- Existence of the Departures Stand for possible implementation of the service

**Threats**
- Lack of passenger interest due to social habits
- Lack of operational interest for transportation operators
- Strikes and boycotts from taxi drivers and associations

**Strengths**
- Safer, cleaner and more comfortable taxis
- Friendly, knowledgeable and professionally trained drivers
- Increase in Airport Operator’s responsibility and intervention power

**Weaknesses**
- Significant decrease in competition levels
- Increased administrative costs in monitoring and regulatory enforcement
- Possible increase of taxi fares

Figure 9 – SWOT analysis for Policy Action I – Introduction of Taxi Sharing
### Opportunities
- Increase in service quality while ensuring more driver accountability
- Investment in a new and modern taxi service fleet and driver skills
- Integration of Taxi Services into the Airport’s concessions
- Increased independence and strengthening of the airport-city development model

### Threats
- Political issues related to the introduction of service access restrictions where none existed
- Service availability issues, if correct number of permits is not adequately determined
- Protests from passengers due to higher taxi fares

#### Figure 10 - SWOT analysis for Policy Action II – Introduction of a Special Airport Fleet and Concession changes

### Strengths
- Creation of a new service type, increasing diversity and options for airport passengers
- Take advantage of the high willingness to pay of high value-of-time passengers to segment the market

### Weaknesses
- Impact on regular Departures Stand users, who might be forced to join the longer queues at the Arrivals Stand.
- Creation of a second layer of service, inside the Terminal, increasing administrative costs.

#### Opportunities
- The Departures Stand already exists and is, from a regulatory perspective, an authorized area for taxi services
- Incentive taxi drivers to modernize their vehicles and improve their professional skills by possibly introducing special service or vehicle requirements

#### Threats
- Political issues related to the perception of driver and passenger discrimination.
- Increase in taxi driver tensions and possibility of aggressive competition, due to higher profitability of the Departures Stand.

#### Figure 11 - SWOT analysis for Policy Action III - Market segmentation and other changes to the Departures Taxi Stand

Four operational scenarios were tested: **Scenario I** - Extra Service Lane, 2 extra servers; **Scenario II.A** - One service lane, 3 servers; **Scenario II.B** - One service lane, 4 servers and **Scenario III** - 2 queues, Special Service Type, yielding the following results (Figure 12; Figure 13):

#### Figure 12 – Results for the main Queue Size indicators

#### Figure 13 – Results for the main Queuing Time indicators
4. Main Conclusions and Intervention Proposals

The main conclusions of this thesis are listed below:

- The current system at Terminal 1 is not able to adequately cope with peak-hour solicitations and offer good quality of service to passengers at these times. Observations have confirmed rapidly growing queues of deplaning passengers that often expand beyond the delimited space for queuing, making people excessively wait for a supposedly faster transportation service.

- As this study points out, several secondary operational factors, sometimes exogenous to the queue itself, can also greatly influence the performance of the system, as can be seen at Portela, and possibly in all airports, in general. Server 2x2 disposition, Police presence and coordination at the taxi stand, crosswalks, distance and line of sight issues, bypassing maneuvers, secondary queues, driver conflicts, etc. can significantly increase service times for the whole system.

- Queues are not only a very important part of the problem; they may be the key part of the solution. As shown in this study, relatively simple and small physical rearrangement of queues can lead to greatly improved service as regards queue length, waiting times and reliability.

- The way of analyzing and designing the operation of the airport taxi service cannot be based on the limited observation of the supply and demand quantities per hour or on average. Queues are a fundamental part of the problem and their actual behavior must not be diluted in aggregate numerical counts that do not expose the frailties of the system at peak-hours, which is exactly when passengers experience the worse service quality.

- On a more regulatory and institutional perspective, one can effectively conclude that each case is a case, with regards to airport taxi stands. This leads to the conclusion that there is no general optimal solution for taxi systems at airports, and each should be analyzed in detail in order to evaluate current/expected quality of service and possible alternative system structures.

Main proposed interventions focus on the following aspects:

- The taxi system at Portela should be closely monitored for service quality and compliance with price, service and vehicle regulations. For this, the author proposes the creation of a new monitoring entity, integrated into the company structure of ANA, with the co-management or active participation of taxi companies/associations.

- Among the initiatives that this newly formed entity could promote are the mandatory installation of automatic receipt machines and/or a GPS-based system in taxis, a detailed information panel on the several pricing schemes, close to the passenger queue. Also assume police’s coordination role and perform random periodic inspections to ensure greater transparency and service quality.

- The creation of differentiated service types should be considered, namely shared-taxis and business-class taxi services, possibly taking advantage of the characteristics of the Departures Taxi Stand as a suitable area for implementation.

- A change in the concessionaire role should be studied for feasibility and efficiency, especially at the future Lisbon Airport, in the Alcochete area. Following a airport-city logic of development, the NAL’s taxi stand should become a concession of ANA. The possibility of the IMTT assuming the
regulator role when the NAL is in operation should also be considered, taking into account the smaller influence, power and resource pool of the Montijo/Benavente Municipality.

The operational design of the taxi system at Portela should be changed, in order to achieve better level of service, both at the queue for passengers and taxis, relating to queue length and waiting times. The most cost-efficient of the studied alternatives seems to point to the change in the queue configuration, to allow more room for the boarding phase and to the service area, with one single service lane, a free lateral lane and four parking service spots (Scenario II.B).

The taxi service system at the NAL (or the intervention at Portela) should be planned and designed according to a methodology that explicitly considers peak-hour variability, and does not focus on average behaviors. ANA, Lisbon Municipality and other such authorities in other regions should have a proactive attitude regarding the planning phase of airport taxi stands, namely implement methodologies for ensuring adequate evaluation of peak-hour impacts on the system.

The next steps in research for this topic should focus on three main vectors: an inherent need to further quantify the benefits of the different regulatory and operational designs; study the value of flexibility in these kinds of systems, as a main driver for efficiency, based upon real options analysis, for example; and perform a more systematic view on the several existing types of contractual arrangements and market conditions on other airports.

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