Report on *"Evaluation of taxi services provision on airport terminals curbside for picking up passengers"*

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Executive Summary: Airport terminals curbsides are the critical interfaces between standing vehicles, moving vehicles and pedestrians, acting as the capacity buffer between the road delivery system and the airport terminal building. Their design and capacity are essential to the successful performance of any airport infrastructure and, therefore, impact the quality of passenger experience.

The current solution at Portela Airport for taxi service provision on the passengers arrival curbside consists on a set of two parallel lanes next to the door of the airport terminal, with four spots (two in each lane) for taxis to stop and pick up passengers. Its design turns the service of taxis in the same lane strongly linked, leading to the occurrence of blocking effects among taxis, which also reduces the utility of expanding the number of stop areas.

A new solution for taxi service provision was recently proposed by Globalvia. The new service configuration consists of a “spine” parking design for 8 taxis at arrivals, and another one at departures with an identical geometry but for private cars. In both cases, the proposed solution consists of a strip parallel to traffic routes, with parking positions arranged at 45 degrees with respect to the road, aligned parallel to each other. Thus, the vehicles coming from the adjacent track, either being taxis (at airport arrivals) or private vehicles (at airport departures), after stopping, follow a route that is dedicated exclusively to them, creating a traffic flow independent of others, thus minimizing the points of conflict between vehicles.

The aim of this work is to study and analyze the viability of the new proposal, comparing its capacity and performance with the solution currently implemented at Portela Airport.

1 Introduction

Airports are important infrastructures of modern life and play a major role in the transportation of passengers for tourism and business. Airport terminals curbsides are the critical interfaces between standing vehicles, moving vehicles and pedestrians, and act as the capacity buffer between the road delivery system and the airport terminal building. A correct design and dimensioning of airport terminals curbsides is a major step for achieving positive passenger experiences since long pedestrian paths, lack of information or long waiting time for transportation may cause passengers discomfort and bewilderment. Positive passenger experiences of airport use are crucial for improving their satisfaction and leveraging demand at airports.

One important transportation feature for the quality of the service provided by an airport is the taxi service provision at the airport's terminal curbside for picking up passengers. The common used solution for taxi service provision on the passengers arrival curbside, currently implemented at Portela Airport, consists on a set of two parallel lanes next to the door of the airport terminal, with four spot areas that promote the passengers pick up, as shown in Figure 1, followed by taxis queueing and waiting for the departure of the taxis stopped in the spot areas. This solution allows for a nearly independent functioning of the two groups of (two) taxis at the spot areas, one group in each of the two lanes. However, the service of taxis in the same lane is strongly linked, with a blocking effect occurring in two directions: (a) the presence of a taxi in the front row in a given lane prevents the taxi on the back row in the same lane from departing even if it has completed the picking up of a passenger group, and (b) the presence of a taxi in the back row in a given lane prevents the taxi at the top of the queue in the same lane from moving to the spot area in the front row of the same lane when this spot area is free.

The nearly independent functioning of the two groups of (two) taxis at the spot areas, one group in each of the two lanes, is reinforced by the fact that the supply of taxis at Portela Airport curbside is highly abundant during the operational period during which the airport is open, especially at peak-hours, as stressed in Costa (2009). Therefore, for modeling purposes, we may admit that the taxi queues at the two lanes have infinite taxis available for entering the stand and providing the service. After arriving to the stand, a taxi takes/depart a group of passengers from the queue if any, and waits for the arrival of passengers otherwise.

With the air traffic increase observed in the past few decades, we observe the formation of large queues of customers waiting for taxi in peak traffic hours. An illustration of this fact is presented in Figure 2, taken from Costa (2009), where we can see a progressive accumulation of passengers at Portela Airport waiting for taxi service over the second half-hour of a one-hour period. The formation of long queues is caused by the taxi demand exceeding the taxi departure capacity at the taxi service provision during peak traffic hours. The taxi service provision

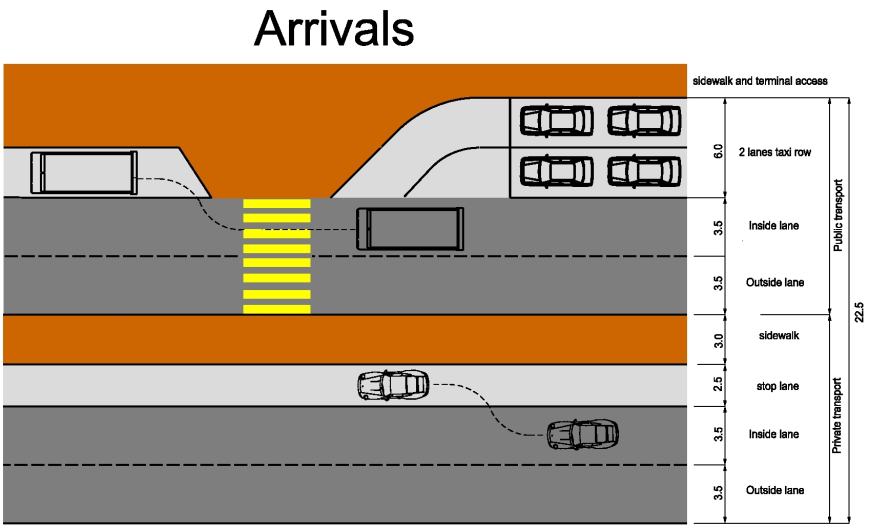

Figure 1: Portela Airport current scenario.

has not kept pace with the increase in taxi demand over recent years, and such demand-service capacity mismatch results in significant undesirable customer delays. As a consequence, in order to mitigate these delays, more efficient taxi service provision designs, to be implemented at least in peak traffic hours, are welcome.

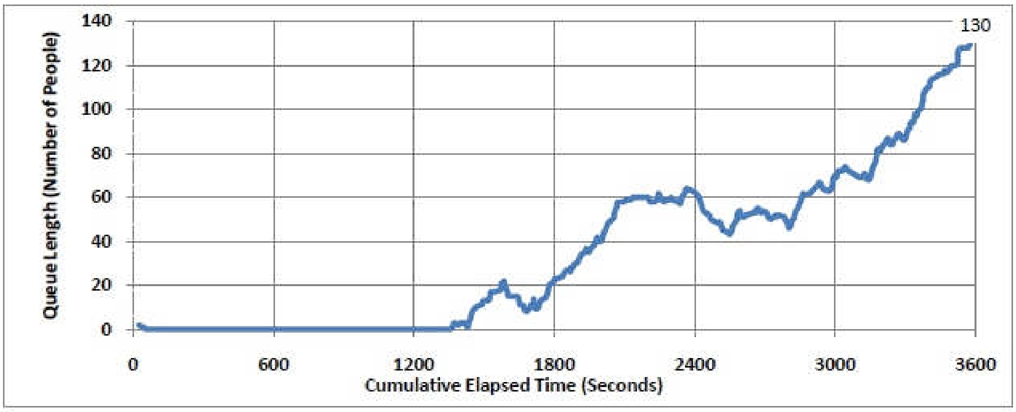

Figure 2: Queue length evolution at Portela Airport current scenario.

Proceeding in this direction, Globalvia proposed a new design for taxi service provision. The proposed solution, illustrated in Figure 3, consists of a “spine” design for taxis at arrivals (and another one at departures with an identical geometry but for private cars) with a strip parallel to traffic routes from which taxis approach the stopping area, with parking positions arranged at 45 degrees with respect to the road, aligned parallel to each other. Thus, the vehicles coming from the adjacent track, either being taxis (at airport arrivals) or private vehicles (at airport departures), after stopping, follow a route that is dedicated exclusively to them, creating a traffic flow independent of others, thus minimizing the points of conflict between vehicles. However, the parallel design of the spots for taxi stops has the drawback that the customers are no longer waiting "in front" of the taxistand. In fact, customers will be informed of the number of the taxi stop they should go to for boarding a taxi, and will experience an additional walking time from the queue to that taxi stop.

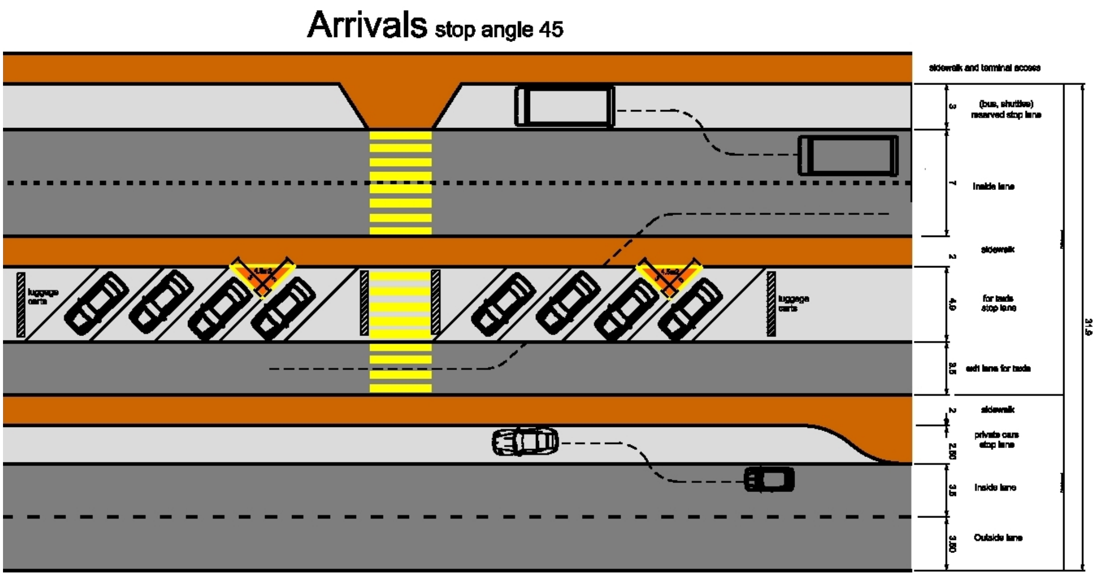

Figure 3: New proposal scheme by Globalvia.

In this report we will compare the solution proposed by Globalvia with the solution currently implemented at Portela Airport, for the taxistand at arrivals, addressing several measures of quality of service, in order to analyze the viability of the solution proposed by Globalvia.

2 Modeling description

At a taxistand service provision, passengers arrive single or in groups to the taxistand and demand for a taxi either in a single form or in groups (not necessarily coincident with arrival groups). As the number of taxis that may being providing service simultaneously is limited, the service provision offered by taxis may be insufficient to cope with the demand for taxi services, leading to the formation of a queue of passengers waiting for taxi service. The size of the passenger arrival groups naturally impacts the enlargement of the passenger queue. Nevertheless, the passengers groups formed to effectively pick up a taxi together are the ones that determine the required number of taxis needed to handle the passengers of the queue, and are the ones that ought to be considered. Thus, in the following, by "passenger group" we will mean a group of passengers that board a taxi together.

In the following we denote the current solution implemented at Portela Airport as **Scenario 1** and the "spine" solution proposed by Globalvia as **Scenario 2**. Due to their nature, we model each one of these two scenarios by means of appropriate queueing systems. For that purpose, we view each group of passengers that board together a taxi as a single customer entity. In doing so, we are considering that customers arrive in a single form to the taxistand queue and start being served by a taxi at one of the taxi stops in order of arrival, modeling the system by an appropriate $GI/G/s$ queue. Here $GI/G/s$ is Kendall's notation for queues, with GI standing for General Independent interarrival times, G to General (independent) service times, and s to the number of servers.

2.1 Performance measures in a single channel $GI/G/s$ queue

A $GI/G/s$ queue is a queueing system with a single service facility with s identical servers and unlimited waiting room. Customers arrive in a single form according to a renewal process with a given interarrival time distribution having mean λ^{-1} and the individual customer service times requirements are assumed to be independent and identically distributed (iid) random variables having a general distribution (denoted by G) with mean μ^{-1}, independent of the customer interarrival times. If an arriving customer finds a free server, it immediately enters service, otherwise it waits in queue. When a server becomes free, it picks the next customer to process from the head of queue.

The traffic intensity, defined as $\rho = \frac{\lambda}{s\mu}$, is a natural measure of the load on the system per server and it is well known that the queue length process is ergodic (if and only) if $\rho < 1$, in which case ρ equals the long-run fraction of time each server is busy – provided arriving customers are randomly assigned to free servers when more than one server is free. The performance of a $GI/G/s$ queueing system is, in general, evaluated trough the computation of important system characteristics such as the (steady-state) number of customers in the system at an arbitrary time, N, the (steady-state) number of customers waiting for service at an arbitrary time (i.e., the queue length), Q, and the (steady-state) customer waiting time in queue (time elapsed since the arrival of a customer until it enters service), W_q.

In general, when $\rho \leq 0.8$, a $GI/G/s$ system behaves in a good manner and has a very small steady-state (mean) number of customers in queue and (mean) customer waiting time in queue. These random quantities start increasing rapidly when the traffic intensity ρ exceeds 0.9, achieving an undesirable magnitude when the queue gets critically loaded (ρ close to 1) and exploding for $\rho > 1$. It is also known that, for $\rho < 1$, the queue length is typically larger when there is more variability in the interarrival and/or the service time distributions.

Despite the substancial queueing theory literature on $GI/G/s$ systems, their analysis is a classical hard task. Accordingly, these systems are usually considered to be mathematically untreatable and are frequently treated by simulation. However, since simulations are often computationally costly and time demanding, in the last decades much effort has been spent not only on creating faster queueing systems simulators but also on finding simple closed-form formulae approximations for important system characteristics of $GI/G/s$ systems.

Several approximations have been proposed in the literature for particular cases of $GI/G/s$ systems, most of them depending on the interarrival and service time distributions only through their first two moments (cf., e.g., Whitt (1993), Abate *et al.* (1995), Tijms (1986)). These approximations are usually expressed through relatively simple formulas that can can be easily applied to approximate such important measures as the (steady-state) mean number of customers in queue and mean customer waiting time in queue.

As $N = Q + B$, with B denoting the number of busy servers at an arbitrary time, it follows that $E(N) = E(Q) + E(B) = E(Q) + s\rho$. In addition, from Little's law, it is known that $E(Q) = \lambda E(W_q)$. Therefore, given λ, μ and s, it suffices to obtain an approximation for the mean waiting time in queue, $E(W_q)$, in order to obtain the corresponding approximations of

$E(Q)$ and $E(N)$. In this line of work, we used the Allen-Cunneen approximation of $E(W_q)$ (cf. Whitt (1993), p. 123)

$$E(W_q) = E(W_q^{GI/G/s}) = \left(\frac{\tau_a^2 + \tau_s^2}{2}\right) E(W_q^{M/M/s}) \tag{1}$$

which is based on the exact results for the steady-state mean waiting time in queue in a $M/M/s$ queueing system, $E(W_q^{M/M/s})$, and on the coefficients of variation of interarrival and service times distributions, τ_a and τ_s, respectively. Here, $M/M/s$ system stands for the particular case of a $GI/G/s$ queueing system with interarrival and service times having exponential distributions.

Due to the memoryless property of the arrival Poisson process in $M/M/s$ queues, the process $\{X(t), t \geq 0\}$, where $X(t)$ denotes the number of customers in system at time t, is mathematically simple to treat as it is a (birth-and-death) continuous-time Markov chain with state space $\mathbb{N}_0$, birth rates $\{\lambda_n = \lambda, n \in \mathbb{N}_0\}$ and death rates $\{\mu_n = \min(s,n)\,\mu, n \in \mathbb{N}_0\}$. Closed form expressions for the most important measures of quality of service of this system are well established for a long time. In fact, under the stability condition $\rho = \frac{\lambda}{s\mu} < 1$, the steady-state probability function of the number of customers in a $M/M/s$ queue, N, is given by

$$p_n = P(N^{M/M/s} = n) = \begin{cases} \dfrac{(s\rho)^n}{n!}\, p_0, & \text{for } n = 0, 1, \ldots, s-1 \\ \dfrac{(s\rho)^n}{s!s^{n-s}}\, p_0, & \text{for } n \geq s \end{cases}$$

with

$$p_0 = \left[\sum_{k=0}^{s-1} \frac{(s\rho)^k}{k!} + \frac{(s\rho)^s}{s!(1-\rho)}\right]^{-1}.$$

As a consequence, the steady-state mean queue size is

$$E(Q^{M/M/s}) = \sum_{n=s}^{\infty} (n-s)p_n = \frac{\rho\,(s\rho)^s\,p_0}{s!(1-\rho)^2} \tag{2}$$

and the steady-state mean number of customers in system is

$$E(N^{M/M/s}) = \sum_{n=0}^{\infty} np_n = E(Q^{M/M/s}) + s\rho.$$

In addition, the steady-state delay probability, i.e., the probability that a customer has to wait in queue, $P(W_q^{M/M/s} > 0)$, which in these systems coincides with the probability that all servers are busy, $P(N^{M/M/s} \geq s)$, is given by

$$P(W_q^{M/M/s} > 0) = P(N^{M/M/s} \geq s) = \sum_{n=s}^{\infty} p_n = \frac{(s\rho)^s \, p_0}{s!(1-\rho)},$$

and is usually known as Erlang's delay formula or Erlang-C formula.

Finally, conditioning on the number of customers a customer finds in the system upon arrival, the steady-state survival function of the waiting time in queue (at time x) is

$$\begin{aligned} P(W_q^{M/M/s} > x) &= \sum_{n=s}^{\infty} p_n \sum_{k=0}^{n-s} e^{-s\mu x} \frac{(s\mu x)^k}{k!} \\ &= \frac{(s\rho)^s \, p_0}{s!(1-\rho)} \; e^{-s\mu(1-\rho)x}, \quad \text{for } x \geq 0 \end{aligned}$$

so that the steady-state mean waiting time in queue is

$$E(W_q^{M/M/s}) = \int_0^{\infty} P(W_q^{M/M/s} > x) \, \mathrm{d}x = \frac{(s\rho)^s \, p_0}{s! \, s\mu \, (1-\rho)^2}$$

in agreement with (2) and Little's formula $E(Q^{M/M/s}) = \lambda E(W_q^{M/M/s})$.

In addition, to compute the steady-state survival function of the waiting time in a $GI/G/s$ queue (at time x) we have used the exponential approximation

$$P(W_q^{GI/G/s} > x) \approx \alpha e^{-\eta x}, \qquad x > 0 \tag{3}$$

were α and η should verify the small tail asymptotics

$$\lim_{x \to \infty} e^{\eta x} P(W_q^{GI/G/s} > x) = \alpha$$

known to be remarkably accurate when x is not to small (cf. Whitt (1993)).

For simplicity, the computation of these parameters was done based on the following Whitt

(1993) and Abate *et al.* (1995) approximations

$$\eta \approx \frac{2s\mu(1-\rho)}{\tau_a^2+\tau_s^2} \qquad \text{and} \qquad \alpha \approx \eta\, E(W_q^{GI/G/s}). \tag{4}$$

We will use the approximations proposed in this subsection for $GI/G/s$ performance measures because of their simplicity and good properties, such as the monotonicity with respect to the traffic intensity that is characteristic of these systems. However, we should stress that no approximations for $GI/G/s$ performance measures work well for the all range of interarrival and service time distributions (cf. Gupta (2010)).

2.2 Modeling Scenario 1

A detailed illustration of Scenario 1 is presented in Figure 4, taken from Costa (2009). Note that there are two parallel taxi lanes but, however, there are only four spots for taxi stops, the two at the front in each of the two lanes. These spots are clearly identified in the figure, numbered from 1 to 4.

The characterization of the passenger group size and service times distributions was done based on the Portela Airport study-case provided in Costa (2009). According to this study, customers (which should here be understood as a group of passengers that pick up a taxi together) arrive to the taxistand rank according to a Poisson process with the (exponentially distributed) customer interarrival times having mean λ_G^{-1} seconds, where $\lambda_G \approx 0.078$. Moreover, the distribution of the individual customer service times (the time a taxi requires to take a group of passengers along with their luggage), S_T, is log-normal distributed with mean $m_T = 66.8\,\text{s}$ and coefficient of variation $\tau_T = 0.497$ (derived in Costa (2009) for taxi spot 1, which constitutes the spot with the smallest taxi loading times). The probability density function of the fitted lognormal taxi loading times distribution is displayed in Figure 5.

Customers initiate service by order of arrival, walking by default primarily to the front row taxi spots 1 (inner lane) and 2 (outer lane) and only then to the back row taxi spots 3 (inner lane) and 4 (outer lane). As, in this model, customer wait in front of the taxi spots, customer walking distances times from queue to the taxi sopts were set to zero.

Note that the design of the spots for taxi stops does not allows taxis to provide their service

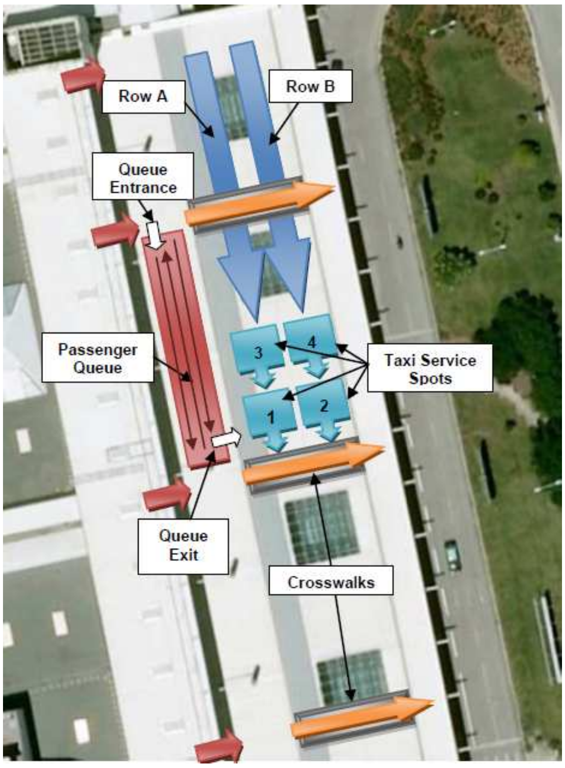

Figure 4: Detailed illustration of Scenario 1.

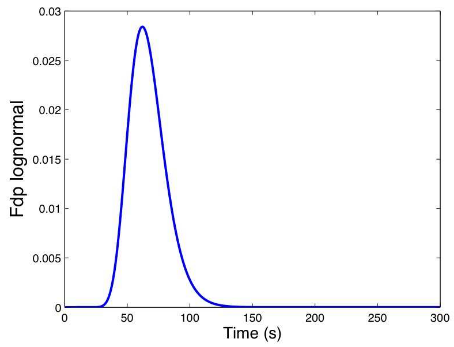

Figure 5: Probability density function of the fitted lognormal taxi loading times distribution.

in an independent manner as they experience customer and taxi flows conflicts. In particular, the substitution of a taxi by another taxi in the same spot is conditioned, in addition to the departure of the taxi previously occupying the spot, by the departure of the taxi previously occupying the other spot on the same lane. Moreover, taxis in the outer lane are more difficult to reach that taxis in the inner lane.

In order to avoid a queuing system model with heterogeneous servers (for which no mathematical formulation are available), we have considered an optimistic framework to modeling Scenario 1, with the resulting model, denoted as **Model 1**, consisting of an $M/G/2$ queueing model for which we consider that: i) the two lanes work in an independent manner both as fast as the inner lane; and ii) the two front taxis in each lane are grouped into a single cluster taxi server for which we model the simultaneous service of two customers (groups of passengers boarding a taxi together). Therefore, the arrival rate to this queue was readjusted to be $\lambda = \lambda_G/2$ and for each one of the *two new servers*, the synchronized service time, S_1, was set to be the maximum of a pair of independent individual taxi service times, i.e.,

$$S_1 = \max\{S^{\#}, S^*\}, \text{ with } S^{\#} \stackrel{d}{=} S^* \stackrel{d}{=} S_T \text{ and } S^{\#} \perp S^*.$$

Resorting to simulation, we have obtained values for the empirical mean and coefficient of variation of the adjusted S_1 taxi service time of $m_1 = 75.46\,\mathrm{s}$ and $\tau_1 = 0.183$, respectively.

We note that, by using the described $M/G/2$ system for Model 1, we are able to present analytical approximations capable of yielding a lower bound for modeling Scenario 1's performance measures, as we are considering, in fact, an optimistic situation for the operation of the taxi service provision under this scenario.

2.3 Modeling Scenario 2

In Scenario 2, corresponding to the solution proposed by Globalvia and illustrated in Figure 3, there are 8 spots for taxi stops arranged in parallel at 45 degrees from the road. This design along a route exclusive for taxis eliminates the blocking effect conflicts between different taxis observed in Scenario 1. Such a design allows the 8 taxis to work in parallel, providing their service in an independent manner, reason why the system behavior will now be modeled by an

$M/G/8$ queueing system. We denote by **Model 2** the model modeling Scenario 2.

In order to establish a comparison with Scenario 1, we consider in Model 2 that customers (groups of passengers boarding a taxi together) arrive to the taxistand according to a Poisson process with rate $\lambda_G \approx 0.078/\text{s}$. The service times associated to a passenger group boarding a taxi and the taxi leaving the service spot reduces again to S_T, which we consider as before to have a lognormal distribution with mean $m_T = 66.8\,\text{s}$ and coefficient of variation $\tau_T = 0.497$. However, the parallel design of the spots for taxi stops has the drawback that the customers are no longer waiting "in front" of the taxistand. In fact, customers will be informed of the number of the taxi spot they should go to for boarding a taxi, and will experience an additional walking time from the queue to that taxi spot. This walking time is considered (in general) in this study to be a random variable S_W with mean $m_W = 30\,\text{s}$ and coefficient of variation $\tau_W = 1/6$, independent of S_T. As a consequence, the efective service time in Model 2, S_2, becomes the convolution of the random variables S_W and S_T (the walking time to a taxi and a taxi service time). That is,

$$S_2 = S_W + S_T, \quad \text{with } S_W \perp S_T$$

which leads to S_2 having mean $m_2 = 96.8\,\text{s}$ and coefficient of variation $\tau_2 = 0.347$.

3 Numerical Results and Comparisons

Based on the analytic approximations for performance measures of $GI/G/s$ queuing systems presented in Section 2, we provide in this section the numerical evaluation and comparison of the performance of Model 1 and Model 2 (the models proposed in the previous section for modeling the current taxi service provision implemented at Portela Airport and the new design proposed by Globalvia, respectively) under different quality of service criteria.

In the figures presented in the section, we denote Model 1, associated to Scenario 1, by S1 or S1-4T, where the "4T" refers to the fact that in this scenario there are 4 spots for taxis to stop. Likewise, we denote Model 2, associated to Scenario 2, by S2-8T. In addition, we consider an analogous of Scenario 2 having 6 (instead of 8) spots for taxis to stop, and denote the associated $M/G/6$ model (having the same parameters as the $M/G/8$ model proposed for Scenario 2) by

S2-6T.

We start by comparing the performance of the models in terms of the (steady-state) mean waiting time in queue and mean queue size. In this respect, Figure 6 exhibits the expected waiting time in queue, $E(W)$, and the mean number of passenger groups in queue, $E(Q)$, as a function of the passenger group arrival rate, λ_G.

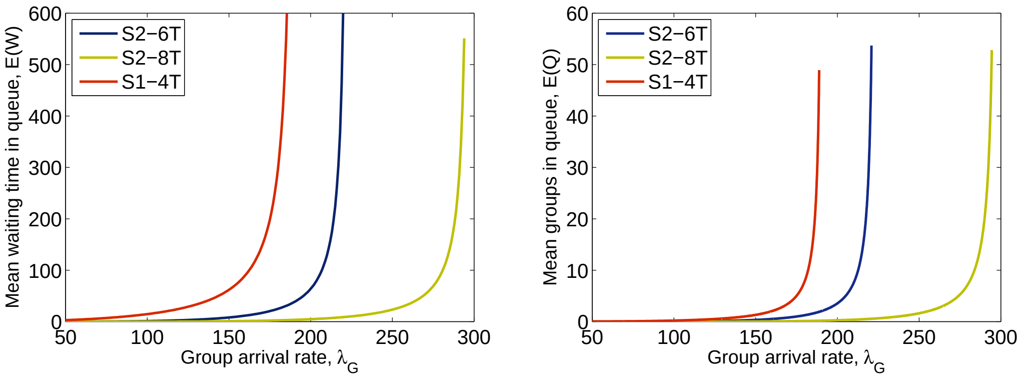

Figure 6: Steady-state mean passenger waiting time in queue and mean number of passenger groups in queue as a function of the passenger group arrival rate.

As expected, we observe that the mean passenger waiting times in queue and the mean number of passenger groups in queue increase with the arrival rate. In addition, the results show that the Model 1, associated to the solution currently implemented at Portela Airport, behaves fairly well for passenger group arrival rates smaller than 150/h but does not work well for group arrival rates as small as 190/h, which are arrival rates nowadays observed at peak-traffic-hours at Portela Airport. In contrast, the new 8 taxis spine solution proposed by Globalvia works well for group arrival rates as large as 280/h (considering mean walking times to taxis of 30 s).

To analyze the sensitivity of the spine solution with respect to the number of taxis working in parallel, we have considered additionally a similar spine scenario with 6 taxis (instead of 8) offering service in parallel (considering again mean walking times to taxis of 30 s). It is also clear from Figure 6 that the 6 taxis spine model works better than the actual model implemented at Portela Airport, and will be able to support conveniently the actual peak-traffic-hours at Portela Airport.

In Figure 7 the performances of Model 1 and Model 2 are compared in terms of waiting times in queue, considering a passenger group arrival rate of $\lambda_G = 190/\text{h}$. In particular, the figure presents the behavior of the models concerning the survival function of the steady-state passenger waiting time in queue, i.e., the probability that a passenger group remains in queue more than a certain quantity of time t, $P(W > t)$.

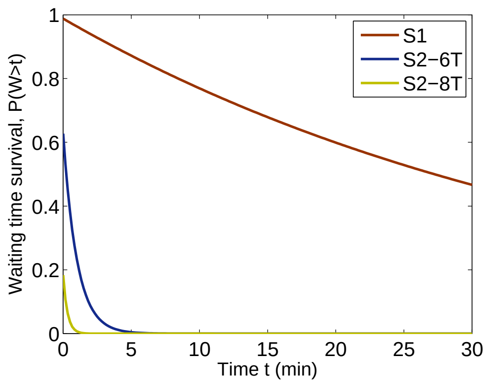

Figure 7: Survival functions of steady-state passenger waiting times in queue.

As mentioned before, and as confirmed by Figure 7, a passenger group arrival rate of $\lambda_G = 190/\text{h}$ corresponds to a rate at which Model 1 is critically loaded (ρ is close to 1) which translates into high waiting time in queue survival probabilities persisting for very large values of time. By contrast, the 6 taxis or 8 taxis spine solutions have no problems whatsoever to deal with a passenger group arrival rate of $\lambda_G = 190/\text{h}$. In fact we see that in both of these solution there is a very small probability of passengers waiting in queue more than 5 minutes.

To evaluate the sensitivity of spine solutions with respect to the walking times to taxis, S_W, we have computed the steady-state mean waiting time in queue for several 8 taxis spine solutions with different walking times to taxis, namely with walking times with means $m_W = 15\,\text{s}, 20\,\text{s}, 25\,\text{s}, 30\,\text{s}, 35\,\text{s}, 40\,\text{s}$, all of then with coefficient of variation $\tau_W = 1/6$. As illustrated in Figure 8, 8 taxis spine solutions are very sensitive to variations on the mean walking time to taxis. Thus, as expected, in order to improve the performance of this type of solution, a strong effort to reduced to a minimum the passenger walking time to taxis should be made during the planning of the terminal curbside.

Finally, in Figure 9, we explore the sensitivity of the minimum number of taxis that are

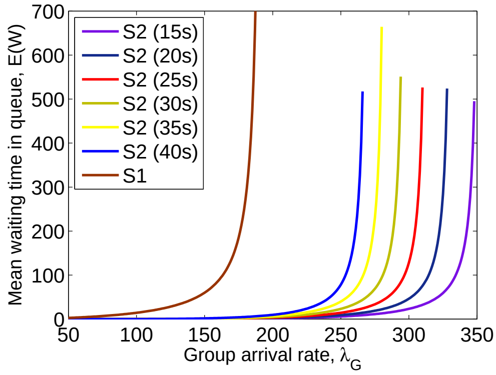

Figure 8: Seady-state mean passenger waiting time in queue for different mean walking times to taxis, presented inside brackets, as a function of the passenger group arrival rate.

needed in spine systems with respect to an upper bound on the steady-state mean passenger waiting time in queue, for passenger group arrival rates of 200/h, 300/h, 400/h, and 500/h. As

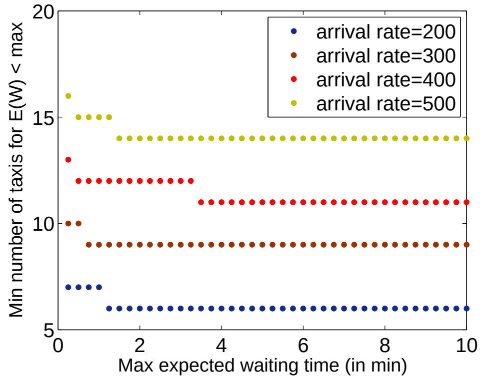

Figure 9: Minimum number of taxis in spine systems in face of an upper bound on the steady-state mean passenger waiting time in queue

expected and illustrated in Figure 9, the minimum number of taxis needed to obtain a steady-state mean passenger waiting time in queue smaller than a given value decreases as that value increases and is very sensitive to the passenger group arrival rate. We can observe, for example, that for a passenger group arrival rate of 200/h, a 6 taxis spine solution is enough to provide a steady-state mean passenger waiting time in queue smaller than 2 minutes.

4 Conclusions and recommendations

We have analyzed the current 4-taxis service provision solution implemented at Portela Airport and the 8-taxis spine solution proposed by Globalvia, modeling them by means of two different $GI/G/s$ queueing models for which no explicit analytic results are available. As a result, we have resorted to approximation formulas proposed in the literature for performance measures of $GI/G/s$ queues, involving simple analytic expressions, based on $M/M/s$ queues and on the first two moments of the interarrival and service times distributions.

From the results obtained, we could conclude that the proposed 8-taxis spine solution (or even the analogous 6-taxis spine solution) has a much better performance than the current solution implemented at Portela Airport. In fact, the proposed 8-taxis spine solution is fitted to eliminate the insufficiencies of the current solution implemented at Portela Airport, which is not able to adequately cope with peak-hour taxi service solicitations and offer good quality of service to passengers at these times.

We have observed that the 8-taxis spine solution is very sensitive to variations on the mean walking times to taxis. As a result, and in order to minimize walking times to taxis, a strong effort should be made to reduce the distance passengers need to walk to taxis to a minimum. Moreover, for a more accurate evaluation of the improvement of the proposed 8-taxis spine solution over the current 4-taxis service provision solution, the following two actions should be carried on:

- Collect appropriate airport taxi service data at Portela Airport to tune up the models.
- Validate the analytical approximations used using simulation (e.g. SIMULINK).

The data collection process at Portela Airport should include information relative to individual passengers, passenger groups, and taxis. For individual passengers, arrival times to queue at peak traffic hour should be recorded. As regards passenger groups, the data collection should involve the recording of the walking times to taxis and the group sizes. Finally, for taxis, the load up times (luggage + passengers) should be recorded. As concerns the use of simulation, it should be mainly directed to the consideration of very specific sets of parameters associated, e.g., with the traffic presently observed at Portela Airport or future scenarios of interest.

In future projects, like the construction of the new International Lisbon Airport, the curbside design and the taxi access should be planed at a very early stage of the construction process to improve the airport taxi service provision. This planning should be made in a very comprehensive way, resorting to a strong use of analytical models and simulation to evaluate the performance of the proposed solutions.

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