

The Microsimulation of Pedestrians in the New São Joaquim Station at the São Paulo Subway

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Abstract: The present paper focuses on the development and analysis of the pedestrian flow at São Joaquim station from Metrô de São Paulo (line 1 – blue), which will receive the integration of the new line 6 – Orange. The study consists of the analysis of the pedestrian flow in the existing station and the construction of a model of pedestrian microsimulation, with the use of a specific software of pedestrian microsimulation, so that it is possible to simulate and verify the operation of the new station to be built. The aim of the development of microsimulation is to show that the use of tools such as this is very important in the initial phases of the project to avoid problems that, in some cases, are already known in the operation of stations and terminals, besides to the financial benefit of adjustments before calculated in the sizing of the equipment, such as quantity of locks, ladders, escalators, lifts, width of corridors, etc. The simulation helps predict the behavior of the users and the operation situation of the station equipment, anticipating the operation situation and the places that need attention in the design phase and the operation phase.

Key words: microsimulation of pedestrians, subway station design, subway station project

1. Introduction

Many problems in subway stations are only perceived when these stations begin their operations. For the project development is necessary to meet standards and calculations to guarantee the level of service for the user. But, occurrences are hard to notice in a design phase, as one of the most acute of the flow of people at the station.

The São Joaquim Station (Line 1 – blue), in downtown, was designed to receive the number of users of the mid 70's. Nowadays, a new line (Line 6 – orange) is under study, and the station is terminal of the line that will start in Brasília quarter. The integration between lines and the regions that will be linked makes this station the subject of this study because a high flow of people will be incorporated to it.

Origin-destination data were used to design and scale the station, to guarantee a safe and comfortable project.

For this analysis, a pedestrian microsimulation software was used, for the study of the flow of passengers in the station. From the simulation, it was possible to suggest solutions, still in the design phase, to get the best design for the season aiming for an improvement in the flow of the passengers.

2. Microsimulation and Service Level

The simulation is even more used for the analysis of areas with intense pedestrian activity, to generate safe, comfortable and friendly spaces and has replaced the theoretical models, for the integration with models of macrosimulation to get pedestrian demand analysis.

The quality of the service requires quantitative measures to characterize operational conditions within a traffic flow and the level of service is a measure that influences parameters that involve speed and time of travel, freedom of manoeuvre, interruptions of traffic, and comfort and convenience [1, 2]. Service levels are

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divided into six categories and analyse the availability of square meters per person (Table 1) [3].

To analyse the service level is necessary to check the availability of area in a certain space. Crowds do not flow as fluids spreading throughout an area [4]. The

TfL [5], describes and illustrates (Fig. 1) the service levels compared with the quality of space to provide adequate levels of comfort without “oversizing” the seasons, making them economically unviable.

Table 1 Level of service — Square meter available per person [3].

Service level	A	B	C	D	E	F
Walkways	> 3,25	3,25 a 2,32	2,32 a 1,39	1,39 a 0,93	0,93 a 0,46	< 0,49
Stairs	>1,85	1,85 a 1,39	1,39 a 0,93	0,93 a 0,65	0,65 a 0,37	< 0,37
Row areas	> 1,21	1,21 a 0,93	0,93 a 0,65	0,65 a 0,28	0,28 a 0,19	< 0,19

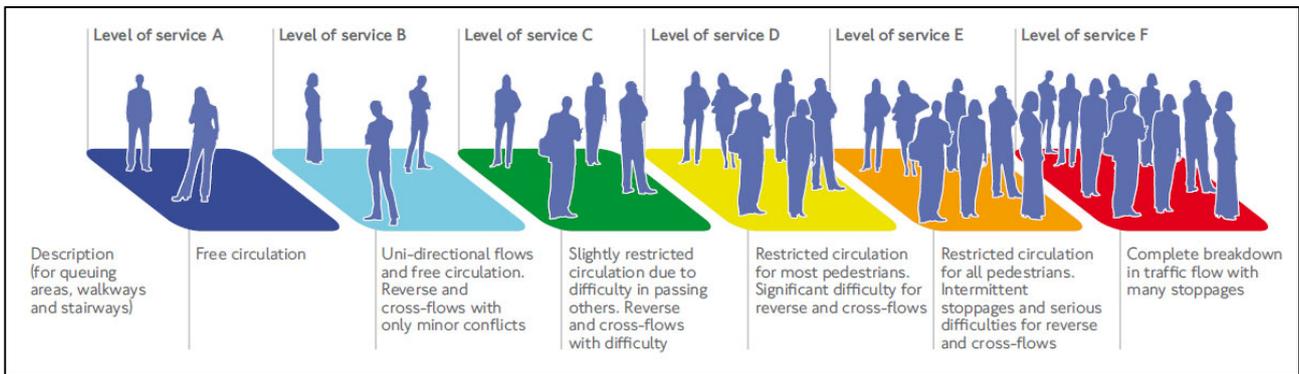


Fig. 1 Representation of service levels [5].

3. The São Joaquim Station

The São Joaquim station is near the center of Sao Paulo, remain a significant point of attraction of users due to the proximity to universities and hospitals. The station receives approximately 46,000 people daily.

The station of Line 1 counts with two accesses, east and west, and after crossing the line of locks, on the mezzanine, several escalators and stairs make the connection, directly with the platforms.

The station on line 6 will count on six levels. The box office is the first level after entering the station, as it passes through the blockade line, users will distribute between the vertical circulation equipment to access the lower levels and reach the mezzanine, which has the function of distributing the users on the platforms and that tends to be the “funnel” that will control the speed and the number of users that follow direction transfer. The level of transfer between lines will be the one with the highest circulation of users and has a tunnel of 94 m connecting the two stations.

4. Data Collection and Analysis

The validation focused on the points of great impact in the flow of the users, such as the escalators and ladders, the number of locks, kiosks, position and direction of the queues in the box office, among others. After validation, a score was affected in set points to simulate the base scenario of the morning peak hour. The main goal of the count was to validate the distribution of the users by the way (Jabaquara and Tucuruvi) and also the actual use of stairs in the station.

Criteria used for the sizing of the new station:

- a) Scaled for the year horizon of 2020, simulation base year;
- b) Intervals between trains predicted 150 seconds;
- c) Accesses with a minimum width of 2.00 meters, divided into modules of 0.60 meters with a capacity of 1,800 people/hour per module;
- d) The number of blockages must meet the demand for loading and unloading and the escape route, plus

10%, to contemplate any faults or maintenance of the equipment;

e) Ladders of a minimum width of 2.00 meters and divided in modules of 0.60 meters with the capacity of 2,400 people/hour per module;

f) Escalators with the capacity of 6,500 passengers/hour;

g) Lock with capacity of 1,200 passengers/hour in and 1,500 passengers/hour out;

h) Mezzanines sized to accumulate up to 20% of passengers in each interval between trains with a maximum capacity of 2.5 passengers/m².

Because it is an integration station, different demand studies were needed on both lines. According to the Metrô de São Paulo, approximately 166,000 people is expected at the station on line 1, daily, an increase of approximately 360% relative to the current volume and during the morning peak time the forecast is that the station receives around 38,000 people between boarding and landing.

Table 2 expresses the demand forecast for the morning peak for the line 1 and Table 3 expresses the demand forecast for the line 6, both for the year 2020.

Table 1 The estimated demand of the São Joaquim station on line 1 for the year 2020 [6].

Line 1 Station	Morning peak time						Daily
	Tucuruvi - Jabaquara			Jabaquara – Tucuruvi			
	Boarding	Landing	Total	Boarding	Landing	Total	
São Joaquim	8,809	10,122	18,930	7,401	11,563	18,964	166,170

Table 2 The estimated demand of the São Joaquim station on line 6 for the year 2020 [6].

Line 6 Station	Morning peak time						Daily
	Brasília – São Joaquim			São Joaquim – Brasília			
	Boarding	Landing	Total	Boarding	Landing	Total	
São Joaquim	0	15,967	15,967	11,652	0	11,652	121,110

Another important feature, so that the simulation reflects the situation of the station, is the distribution of users by access. Table 4 and Fig. 2 shows the results of field lookup in the station accesses. It is possible to verify that access A (65.1%) receives a fairly higher number of users than access B (34.9%).

For the development of the simulation model, more detailed data were needed to reflect the integration of the lines in the São Joaquim station and the number of

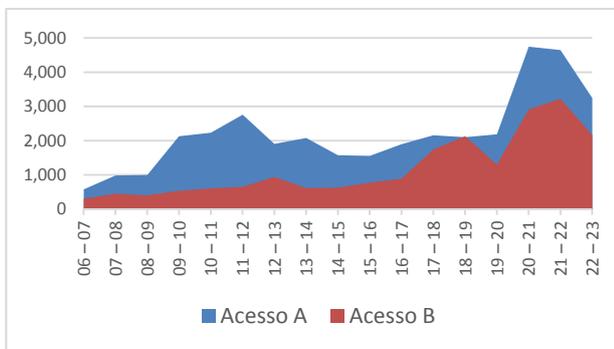


Fig. 2 Entrances by access to the station.

Table 3 Count in the accesses of the station.

Time	Aces. A (East)	Aces. B (west)
06-07	576	306
07-08	983	450
08-09	998	405
09-10	2,133	538
10-11	2,235	605
11-12	2,760	655
12-13	1,906	944
13-14	2,078	616
14-15	1,577	630
15-16	1,558	775
16-17	1,897	892
17-18	2,157	1,745
18-19	2,105	2,130
19-20	2,185	1,302
20-21	4,748	2,916
21-22	4,649	3,228
22-23	3,247	2,166
Total	37,792	20,303

neighboring boarded and landed in the two stations, as shown in Table 5 and Table 6.

Analyzing this data, it turns out that 57% of the integration user stream accesses line 1, while 43% accesses line 6; 47% of the total of users landed on line 1 will not integrate and only 3.5% of the landed on line 6

will not do the integration; 30% of the total users during the peak hour of the morning will come from the external inputs and outputs and 70% will come from the integration between the lines. Fig. 3 illustrates the distribution of the flow at the station.

Table 4 Loading station São Joaquim line 1 at the peak of the morning — the year 2020 [6].

Line 1	Boarding			Landing			Daily
	Locals	Line 6	Total	Locals	Line 6	Total	
São Joaquim	801	15,409	16,210	10,131	11,555	21,686	166,170

Table 5 Loading station São Joaquim line 6 at the peak of the morning — the year 2020 [6].

Line 6	Boarding			Landing			Daily
	Locals	Line 1	Total	Locals	Line 1	Total	
São Joaquim	98	11,555	11,653	558	15,409	15,967	121,110

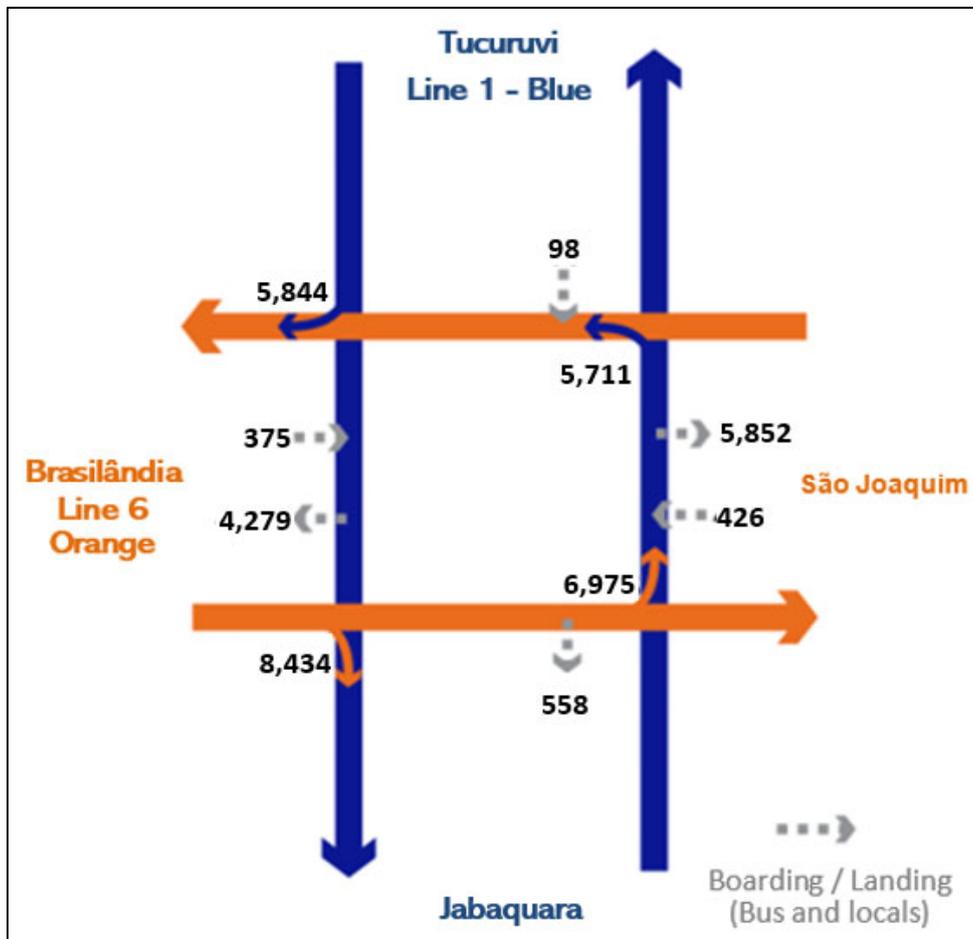


Fig. 3 Demand Schematics – São Joaquim station [6].

The demand shows the time loads of the station during peak hours, however, as the simulation refers

only to the morning peak hour, it was necessary a better analysis within this peak, that is, it was necessary to

analyze the peak within the peak. The count showed that at the peak hour of the morning, the largest crowd is between 7:15 and 8:15 (simulated time in the model).

The parameters (assumptions) of the model were drawn up based on this data (Table 7).

Table 6 Assumptions adopted in the model.

Interval between trains (Headway)	Line 1	150 Seconds
	Line 6	120 Seconds
Capacity available on trains	Tucuruvi	60%
	Jabaquara	60%
	Brasilândia	100%
	São Joaquim	0
Lock capacity (by equipment)	entrance	17 People/minute
	exit	25 People/minute
Number of Locks	entrance (Line 1)	4 Equipment
	exit (Line 1)	8 Equipment
	entrance (Line 6)	2 Equipment
	exit (Line 6)	2 Equipment
Open Door Time	30 seconds	
Preference for landing	5 seconds	
Average escalator capacity	100 People/Metro/min	

5. Microsimulation Analysis

From the simulation, it was possible to notice some points of conflict of flows and accumulation of pedestrians in the station, these that can have a great impact on the operation of the station. For a better understanding of the model, the entities were color-distinguished (Fig. 4).

Fig. 5a shows the user conflict on line 1 platforms. Users who land and want to access line 6 need to go through a large accumulation of users who climb the escalator to the mezzanine, as those who want to board on the first cars need to transpose a large gathering of people. The Fig. 5b shows that the areas, in front of the escalators, present levels of service E and F during the peak. Apparently, this is due to the width of the platform and the positioning of escalators, which generate the accumulation of users and the conflict of flows.

Because it is a terminal station, the station in line 6 has no flux conflict, as it will operate only with loading or unloading. The boarding of the users happened without problem during the simulation, the platform being emptied after each train. The landing demonstrated great demand during the simulation (Fig. 5a and b). One important part, in this case, is the ability to empty the platform during headway. Despite the accumulation of users due to high demand, the simulation showed that the circulation equipment is enough.

It is possible to note, by the colors of the entities, that the majority disembarks as destination Line 1. As for the level of service, it is possible to note that the escalator area has a higher density, (E and F), which is normal in stations with a central shaft.

East exit Line 1	West exit Line 1	Boarding Line 1 Jabaquara	Boarding Line 1 Tucuruvi	Boarding Line 6	Exit Line 6
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Fig. 3 Entity colors by destination.

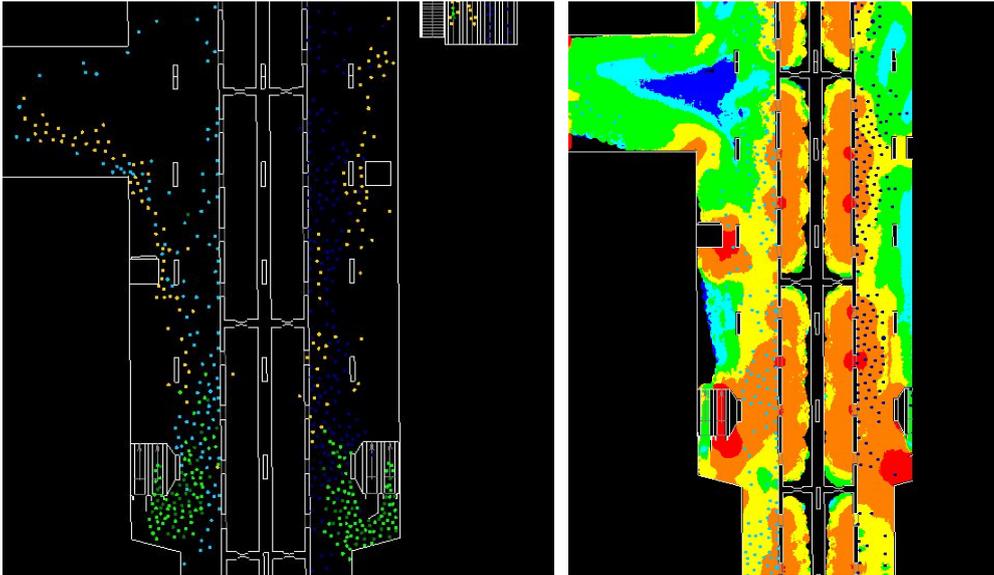


Fig. 4 Flow (a) and Density (b) in Platform of Line 1.

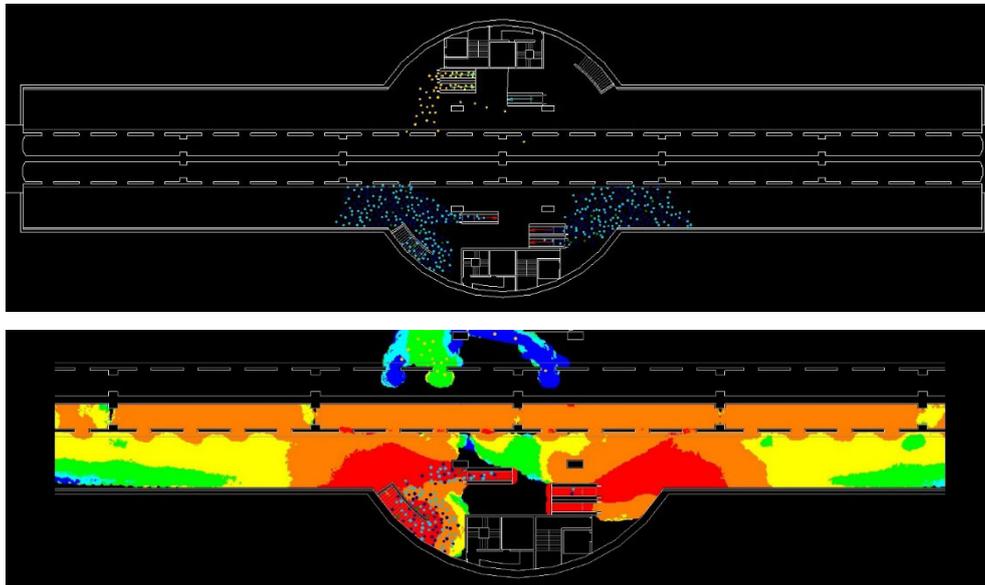


Fig. 5 Flow (a) and density (b) in platform of line 6.

The level with the worst performance is the transfer level, where, from the 7:40, the escalators, which lead the users of line 6 to line 1, will not meet the demand, thus a buildup began to be formed, as shown in Fig. 7. The buildup caused by the transfer creates an area that offers, also to a great discomfort, a risk to safety, in situations like this, some problem in the tunnel can generate turmoil, which can cause accidents.

The density map (Fig. 8) shows that the line 1 direction works with F service level in almost all its length, reaching a peak of 9 people/m². Already in line

6, the tunnel presented service level D at peak. Redefining the width of the tunnels would not necessarily help to solve the problem since the bottleneck, in this case, are the escalators. With the analysis of the layouts, it was not possible to define whether it would be reasonable to add more escalators, which would probably help to move the users faster, but in this case, probably the problem would be carried to the platform of line 1, what would be an even greater risk.

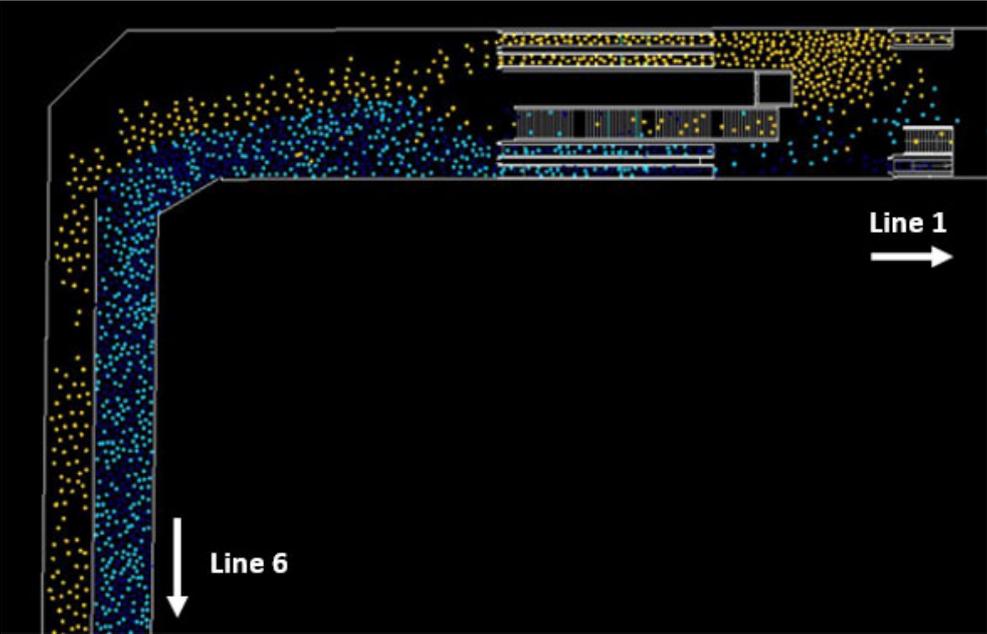


Fig. 6 Flow in transfer tunnel between stations.

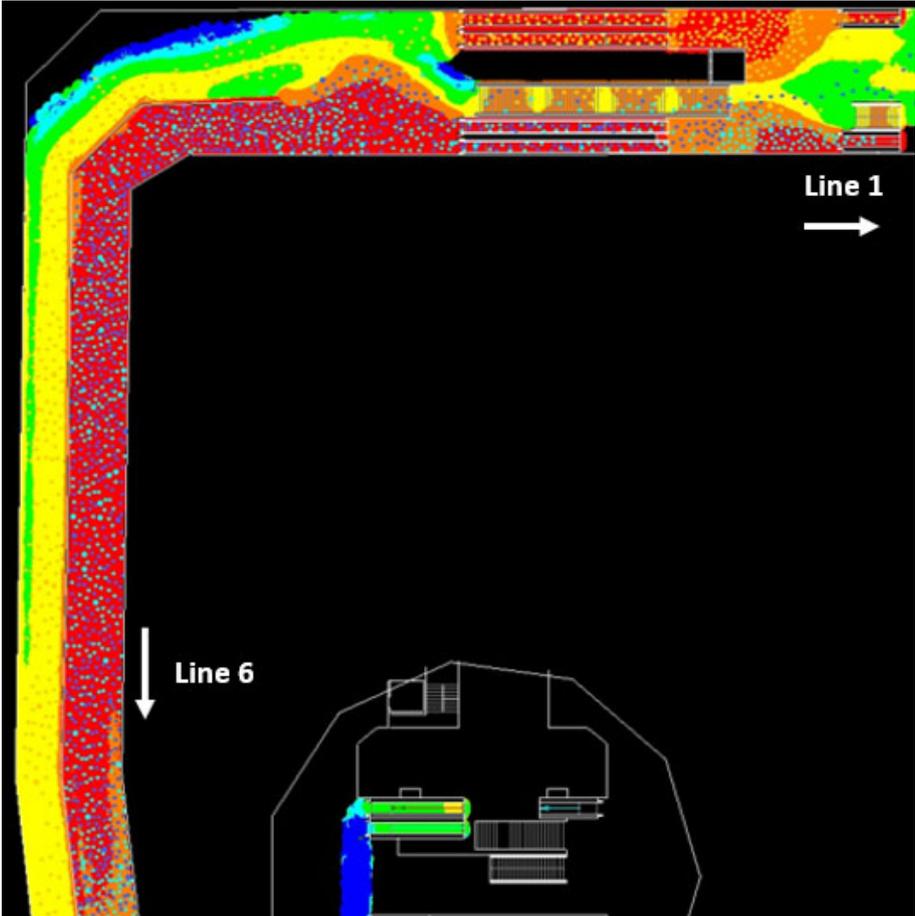


Fig. 8 Density in the transfer tunnel between stations.

Fig. 9 shows the growth in peak accumulation, as well as the maximum number of users at the worst time. The buildup reached its peak at 7:56, with a maximum row of 1,144 people. During the start of the peak, the

transfer corridor, to line 1, presented an average rate of 440 people/minute, before the start of the accumulation in the tunnel.

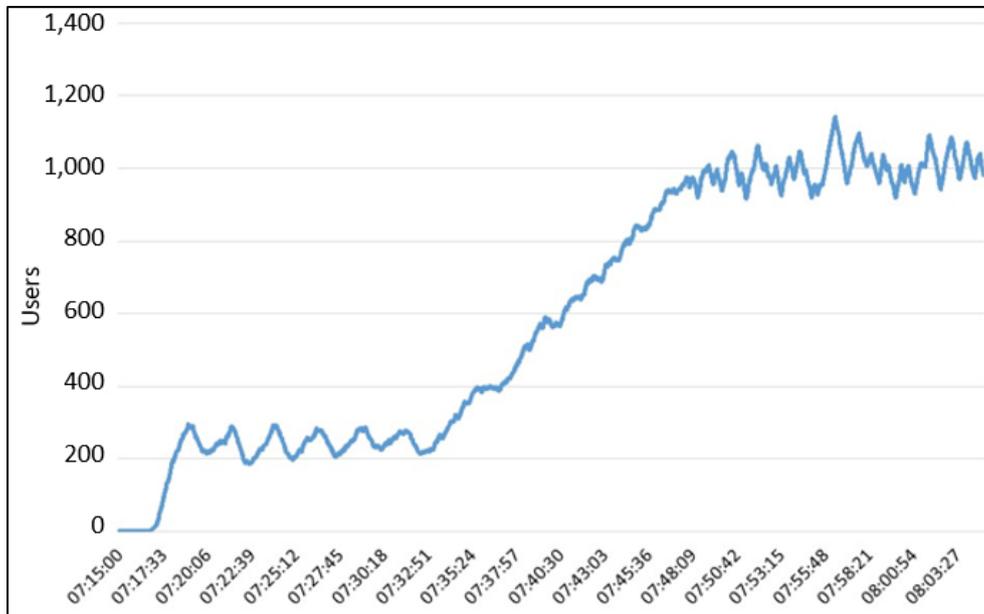


Fig. 9 Gathering of users in the transfer tunnel.

6. Conclusion

For decades the microsimulation technology has been used in several countries for the development of studies that assists the planning and operation of transportation modals. In Brazil, in most cases, microsimulation is used to rather solving detected problems than preventing them.

The main purpose of the work was to warn of pedestrian problems that can be created in the project phase and passed to the phases of operation. The work demonstrated that through the microsimulation process were detected bottlenecks and problems in the pedestrian flow in the future São Joaquim station.

With this model there was a large gathering of users and service levels not recommended in the transfer tunnel between the stations, which practically caused a collapse in the model and caused the station to work at service levels far below of the recommended,

threatening the comfort and especially the safety of the users.

It is possible to declare, through the study developed, that using tools such as pedestrian microsimulation is very important for the detection of problems still in the project phase, with the objective of preventing social and financial losses.

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