MINIMIZING THE IMPACT OF ESCALATOR FAILURES IN METRO TACUBAYA SUBWAY STATION ON USER´S MOBILITY

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ABSTRACT

TACUBAYA subway station interconnects subway Lines 1,7, and 9 of Mexico City subway system. In TACUBAYA station there are a total of 24 escalators, 6 are downstream and 18 are upstream. Subway station service starts at 5 a.m. and finishes at 12 p.m. from Monday to Friday. On Saturday operates from 6 a.m. to 12 p.m., and on Sundays from 7 a.m. to 12 p.m. In last years, escalators have presented failures that have critically affected the passenger´s mobility due to tens meters of deep. The aim of this paper is to develop an agent-based simulation model to minimize the impact of escalator failures on user´s mobility making some escalators bidirectional allowing the flow of passengers to be continuous. First, a conceptual model of TACUBAYA subway station is developed. Second, it is implemented in computer using AnyLogic™ software. Then, some simulation scenarios are designed to evaluate the impact of escalator´s failures on the mobility of passengers.

Keywords: escalator failures, urban mobility, subway, subway stairs, Mexico City.

1. INTRODUCTION

TACUBAYA subway station interconnects subway Lines 1,7, and 9 of Mexico City subway system (see Fig. 1). Line 1 PANTITLAN-OBSERVATORIO comprises 20 stations, and the annual ridership was more than 267 million in 2015. This subway line has a length of more than 16 km. underground and just one km. at ground level. While, Line 7 EL ROSARIO-BARRANCA DEL MUERTO operates with 14 stations. The annual ridership of Line 7 in 2015 was almost 101 million. Line 7 has a length of 18 km. underground and 0.6 km. at ground level. Meantime, Line 9 TACUBAYA-PANTITLAN is currently operated with 12 stations, and recorded an annual rideship of almost 120 million in 2015. Line 9 has a length near to 10 km. underground and 5 km. elevated. TACUBAYA subway station is located in the Miguel Hidalgo Borough of Mexico City. It is considered as one of the busiest subway stations. From January to March 2016, this stations recorded fifty-two thousand ridership.

Figure 1: Geographical location of TACUBAYA subway station

TACUBAYA station was built on many levels to accommodate the three subway lines. There are a total of 24 escalators, 6 are downstream and 18 are upstream, that communicate all levels. The confortable escaltor´s speed is 0.5meters /second. From Monday to Friday Subway station service starts at 5 a.m. and finishes at 12 p.m. On Saturday operates from 6 a.m. to 12 p.m. and on Sundays from 7 a.m. to 12 p.m. TACUBAYA station has two busy periods, one at the morning and the other one at the evening. In last years, escalators have presented failures that have critically affected passenger´s mobility due to tens meters of deep (see Fig. 2). The aim of this paper is to develop an agent-based simulation model to minimize the impact of escalator failures on user´s mobility making some escalators bidirectional allowing the flow of passengers to be continuous.

This paper is prepared as follows: a conceptual model of TACUBAYA subway station is developed considering the flow of passengers in Section 2. An agent-based simulation model is implemented using AnyLogic™ software and validated via a sensitivity analysis in Section 3. The evaluation of the impact of escalator´s failures on the mobility of passengers and its optimization is presented in Section 4. Conclusions are outlined in Section 5.

Figure 2: Passengers on escalators in TACUBAYA subway station when one escalator failures

2. THE CONCEPTUAL MODEL

We develop the conceptual model of the processes involved when a user stay in TACUBAYA subway station and decide to transboard from Line 7 and 9 to Line 1. For instance, if passengers get off Line 1-OBSERVATORIO direction, they decide to take between escalators and stairs. Then, passengers decide to take Lines 7 or 9. Contrary, they exit the system. In the case that passengers go to Line 7 or 9, they take again escalators or stairs (see Fig. 3). The flow chart of passenger´s activities in TACUBAYA subway station when they get off Line 7 and Line 9 are showed in Fig. 4 and Fig. 5, respectively.

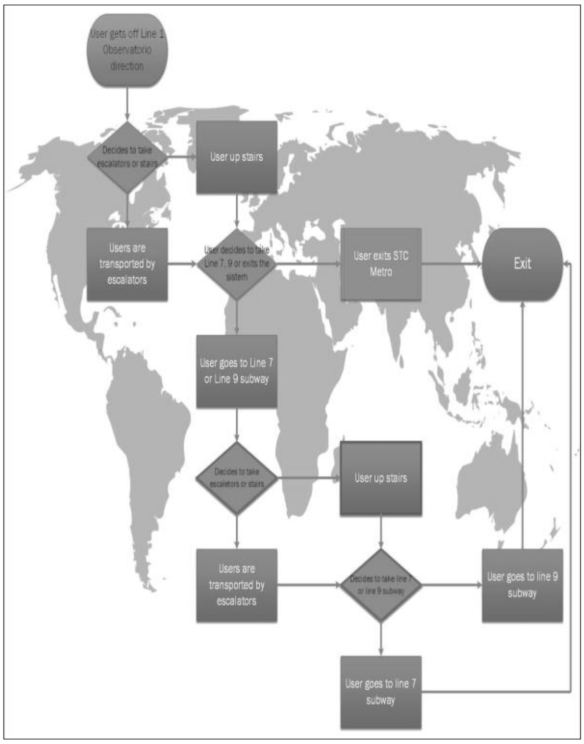


Figure 3: Flow chart of passenger´s activities in TACUBAYA subway station, Line 1 direction

Figure 4: Flow chart of passenger´s activities in TACUBAYA subway station, Line 7 direction

Figure 5: Flow chart of passenger´s activities in TACUBAYA subway station, Line 9 direction

3. THE SIMULATION MODEL OF TACUBAYA SUBWAY STATION

We develop the simulation model of pedestrian activities in the TACUBAYA subway station using discrete-event simulation (DES) approach and agent-based modeling and simulation (ABMS) approach. The simulation model was implemented using AnyLogic^{TM} Personal Learning Edition. In this study, we use two Anylogic libraries: Pedestrian (see Fig. 6) and Rail (see Fig. 7). It is important to note that in models created with Pedestrian Library, pedestrians move in continuous space, reacting on different kinds of obstacles (walls, different kinds of areas) and other pedestrians (Anylogic 2016).

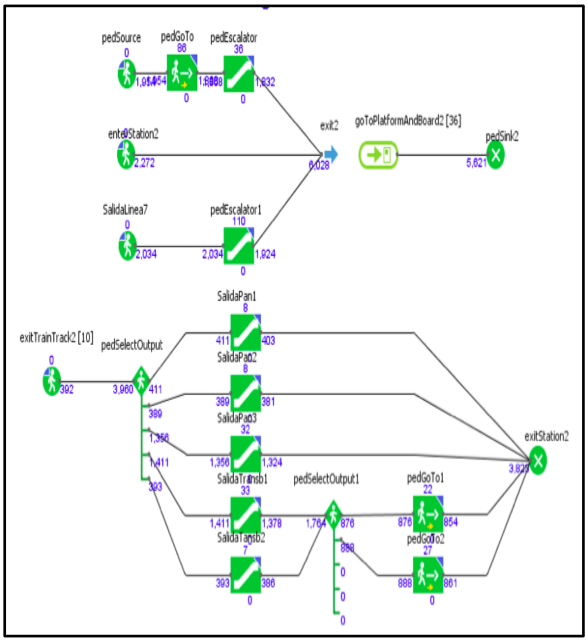


Figure 6: Pedestrian library blocks-TACUBAYA subway station

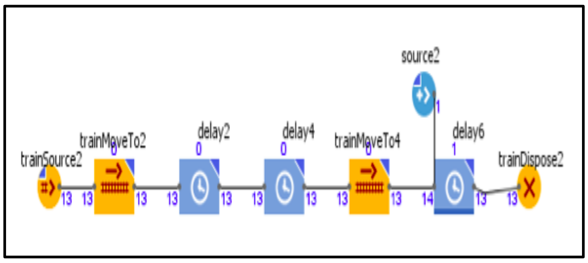
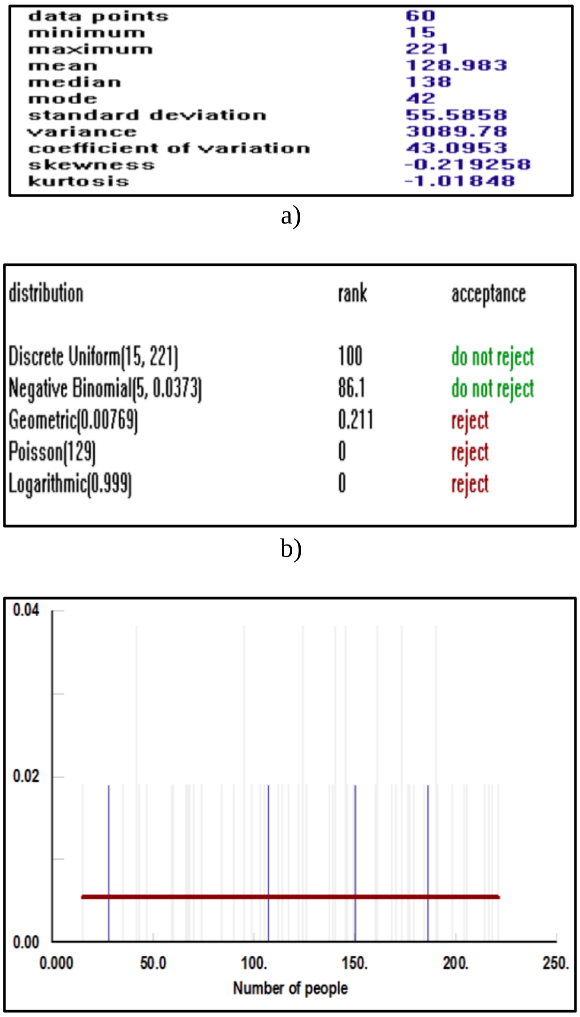


Figure 7: Rail library blocks- TACUBAYA subway station

3.1. Input data analysis

During two weeks, we did some technical visits in TACUBAYA station to collect data about the number of passengers in escalators during one busy hour on Thursday. Then, we used Stat::Fit® version 3.0.1.0 Standard, developed by Geer Mountain Software (Benneyan 1998) to auto fit the appropriate probability distributions. As is observed in Fig. 7, passengers in escalators from Line 7 and Line 9 fit very well to a Discrete Uniform and a Negative Binomial distributions. In this direction, the simulation model was calibrated using the Negative Binomial distribution.



data points	60
minimum	15
maximum	221
mean	128.983
median	138
mode	42
standard deviation	55.5858
variance	3089.78
coefficient of variation	43.0953
skewness	-0.219258
kurtosis	-1.01848

a)

distribution	rank	acceptance
Discrete Uniform(15, 221)	100	do not reject
Negative Binomial(5, 0.0373)	86.1	do not reject
Geometric(0.00769)	0.211	reject
Poisson(129)	0	reject
Logarithmic(0.999)	0	reject

b)

c)

Figure 7. Passengers in escalators from Line 7 and Line 9, a) descriptive statistics, b) Auto fit of distributions and c) graphic of discrete uniform distribution

3.2. Simulation model verification

The verification of simulation model is the process of determination of whether the computer implementation of the conceptual model is correct. (Banks 1998). For the purposes of this study, the Anylogic™ code was checked by other persons considered expertise using Anylogic™ software. Additionally, both the input data and the output data were verified to be reasonable and the trace tool included in Anylogic™ was free of warnings.

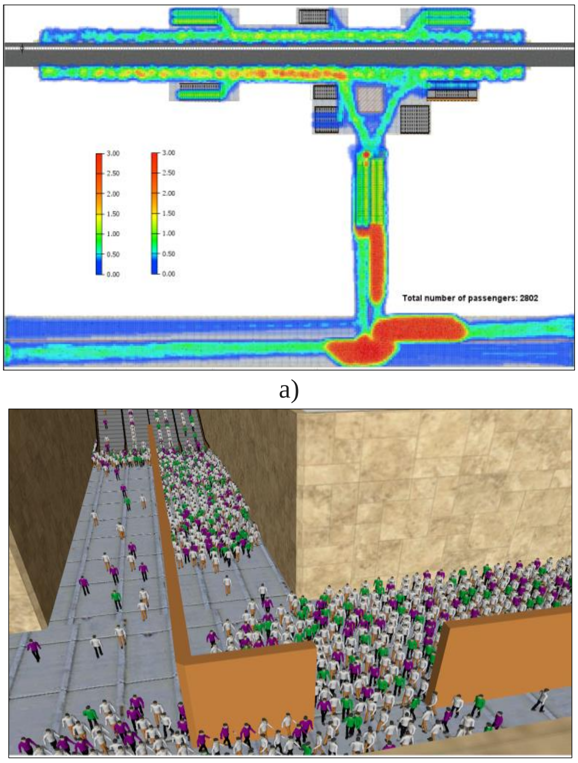
3.3. Simulation model validation

The validation of simulation model is the process of determination of whether the conceptual model can be substituted for the real system for the purposes of experimentation (Banks 1998). To validate the simulation model we design a sensitivity analysis considering changes in the escalator speed. We propose two extreme values, one low and the other one high, and observe with "what happened" scenarios with the flow of passengers (see Table 1).

Table 1: Input variables for designing the sensitivity analysis

Input variables		
	Low	High
Escalator speed	0.1 m/s	1 m/s

In the first case, when the escalator speed is very low, 0.1 m/s, we observe two conflicting areas on escalators, where the passenger´s density is very high reaching 3 passengers per square meter (see Fig. 8). Contrary, when the escalator speed is high, 1 m/s, we observe the escalator with a low passenger´s density, almost 1 passenger per square meter (see Fig. 9), but we observe a conflicting area on the subway platform. Under extreme conditions of escalators speed, the dynamic of the simulation model is similar to the dynamic of the real system.



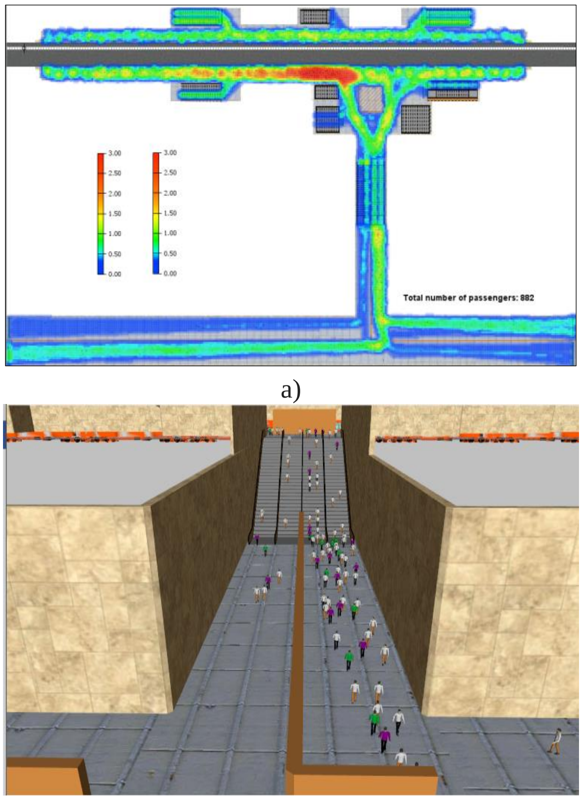
a)

b)

Figure 8: Escalators speed at low value, a) pedestrian density (pedestrian/m^2), b) pedestrian dynamics

3.4. Design of simulation experiments

We conduct a 2^3 factorial design (Montgomery, 2005) of simulation experiments. We take into account three factors (see Table 2 and Table 3): escalator´s speed, passenger´s speed, and passenger´s flow, with two different values, one minimum and one maximum. The simulation run time is during one hour. In Fig. 10, the main effect of factors on the number of passengers that up escalators are showed. From Fig. 11 to Fig. 18 the pedestrian density (pedestrian/m^2) is shown related to each simulation experiment.



a)

b)

Figure 9: Escalators speed at high value a) pedestrian density (pedestrian/m^2), b) pedestrian dynamics

Table 2: Factors for design of simulation experiments

Input variables and parameters			
Parameter	Input variable	Low value	High value
A	Escalator´s speed	0.1 m/s	1 m/s
B	Passenger´s speed	0.1 m/s	1 m/s
C	Passenger´s flow	400	4000

Table 3: Design of simulation experiments

Input parameters			
A	B	C	Number of passengers that up escalators
-1	-1	-1	765
-1	+1	-1	775
-1	-1	+1	4661
-1	+1	+1	4800
+1	-1	-1	777
+1	+1	-1	792
+1	-1	+1	4739
+1	+1	+1	7827

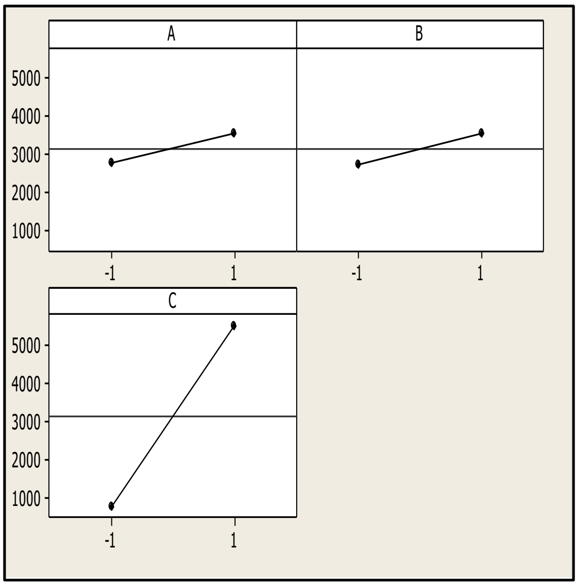


Figure 10: Main effect of factors on passengers that up escalators

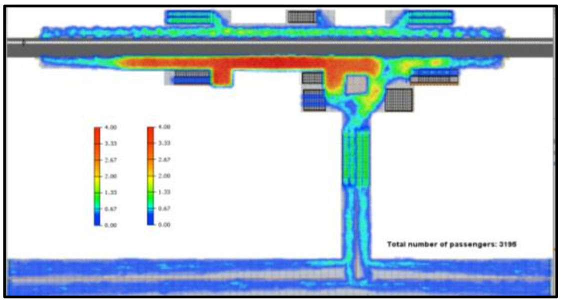


Figure 11: Pedestrian density (pedestrian/m^2), simulation experiment 1

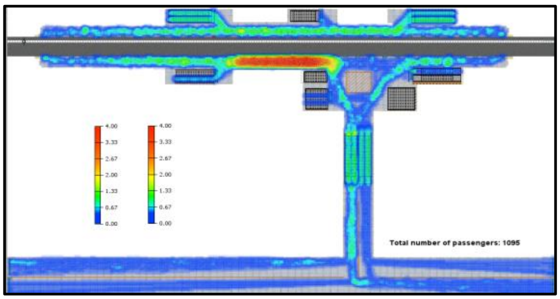


Figure 12: Pedestrian density (pedestrian/m^2), simulation experiment 2

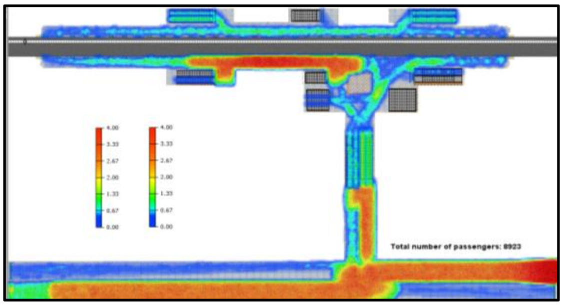


Figure 13: Pedestrian density (pedestrian/m^2), simulation experiment 3

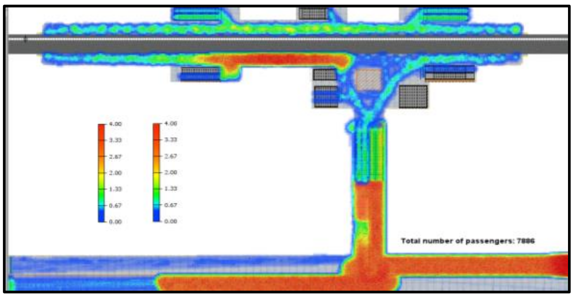


Figure 14: Pedestrian density (pedestrian/m^2), simulation experiment 4

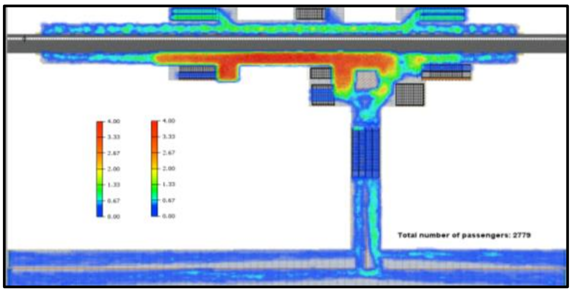


Figure 15: Pedestrian density (pedestrian/m^2), simulation experiment 5

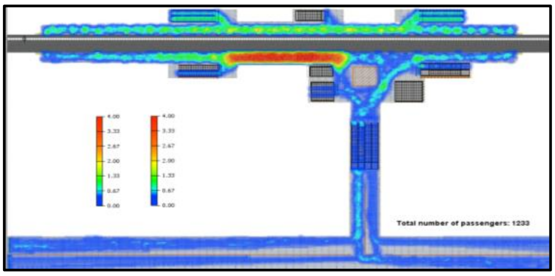


Figure 16: Pedestrian density (pedestrian/m^2), simulation experiment 6

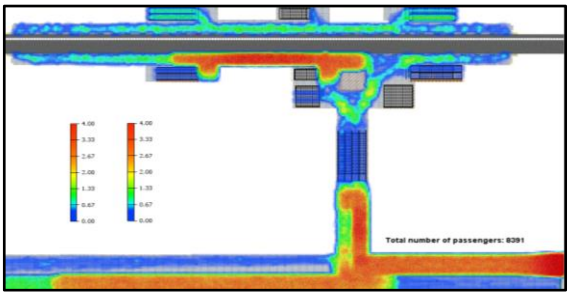


Figure 17: Pedestrian density (pedestrian/m^2), simulation experiment 7

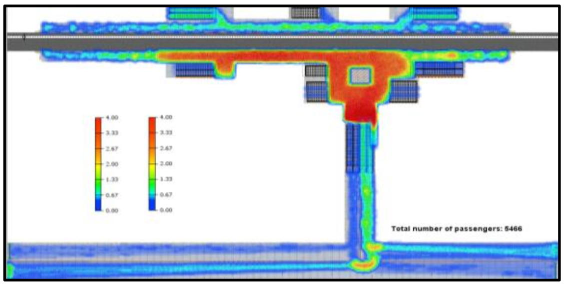


Figure 18: Pedestrian density (pedestrian/m^2), simulation experiment 8

As is observed from Fig. 19, the passenger´s flow effect on number of passengers that up escalators is larger than either the escalator´s speed or the passenger´s speed.

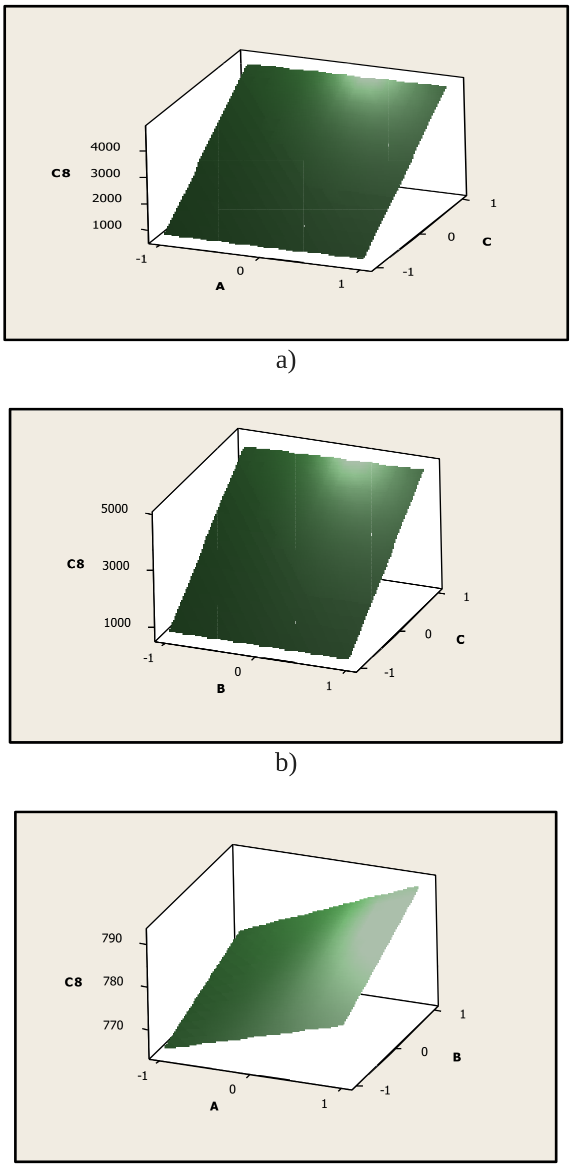


Figure 19: Main effect of factors on passengers that up escalators

4. MINIMIZING THE IMPACT OF ESCALATOR FAILURES ON USER´S MOBILITY

We design some simulation scenarios to evaluate the impact of escalator´s failures on the mobility of passengers. We take into account the escalator´s speed and passenger´s speed equal to 0.5 m/s and the passengers from Line 7 and Line 9 equal to 2000. When escalator failures (see Fig. 20), there are three zones of conflict. One just in front of the escalator that does not work. One solution for this situation is to change from unidirectional to bidirectional an additional escalator (see Fig. 21). As result, the pedestrian density on the escalator zone remains between 2 and 2.5 pedestrian/m^2, without traffic of pedestrians. The optimum situation is when all escalators work well and additionally one escalator works in a bidirectional way(see Fig. 22). In this case, pedestrian density remains less than 2 pedestrian/m^2.

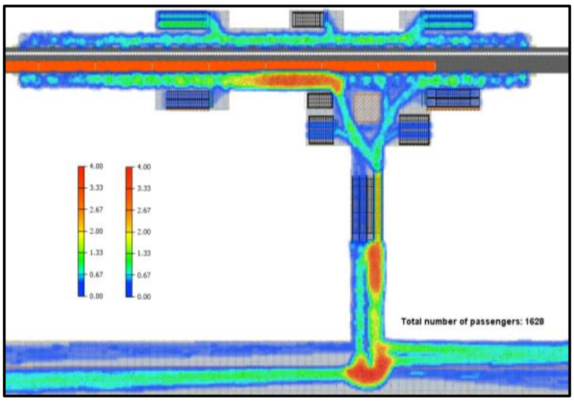


Figure 20: Pedestrian density (pedestrian/m^2) when a escalator failures

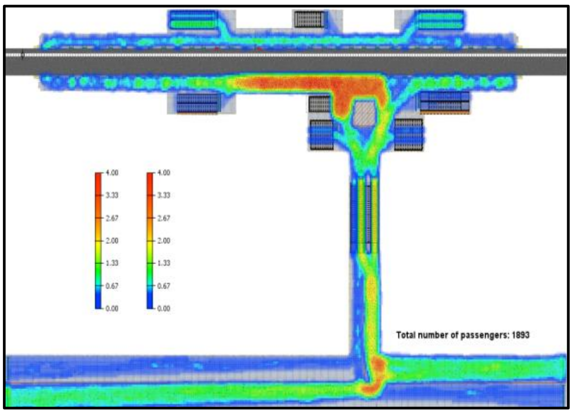


Figure 21: Pedestrian density (pedestrian/m^2) with an additional bidirectional escalator

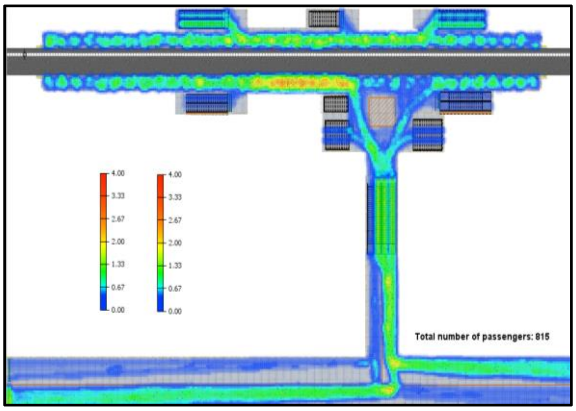


Figure 22: Pedestrian density (pedestrian/m^2) with two escalators working well and an additional bidirectional escalator

5. CONCLUSIONS

We developed the conceptual model of the processes involved when a user stays in TACUBAYA subway station and decides to transboard from Line 7 and 9 to Line 1 using discrete-event simulation (DES) approach and agent-based modeling and simulation (ABMS) approach. The simulation model was implemented using AnyLogic^{TM} Personal Learning Edition. During two weeks, we collected data about the number of passengers in escalators during one busy hour on Thursday, then we fitted it to probability distributions to calibrate the simulation model. To validate the simulation model we designed a sensitivity analysis considering changes in the escalator speed. We conducted a 2^3 factorial design taking into account three factors escalator´s speed, passenger´s speed, and passenger´s flow. The passenger´s flow effect on number of passengers that up escalators was larger than either the escalator´s speed or the passenger´s speed. Finally, we evaluated the impact of escalator´s failures on the mobility of passengers. When escalator failures there are three zones of conflict. One solution for this situation is to change from unidirectional to bidirectional one escalator. However, the optimum situation is when all escalators works well and additionally one escalator works in a bidirectional way.

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