Passenger´s flow for a Train's Coach and Dwelling Time Using Fuzzy Logic

Case Study: Panama Metro Line 1

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***Abstract*—The passengers´ traffic and station dwelling time estimation are significant parameters for mass transit planning. Nevertheless, classical methodologies are not easy to apply in certain practical situations. This work presents a new approach that combines the origin destination matrices method with the application of fuzzy logic using as a case study the Panama´s metro line 1. In particular, this paper presents an extension and practical application of the previous papers, using three fundamental levels of passenger´s flow in the membership function for a train's coach and finally the application of the proposed algorithm in order to predict more realistic effects.**

Keywords—Panama Metro; Panama Metro line 1; fuzzy logic; passenger´s flow; origin-destination matrix; artificial intelligence Techniques; fuzzy and hybrid techniques; dwelling time; stopping time; membership function levels; train´s coach

I. Introduction

The estimation of station dwelling time is critical for an acceptable railway timetable planning [3] since the line capacity in metro and high-frequency suburban railways is as much determined by station stop times as by factors such as line speed or train acceleration. Additionally, the dwelling times at platform tracks can be systematically extended due to hinder by other trains and the performance of railway personnel [4]. It has been shown that this dwelling time is function of rolling stock, through passengers and passengers' flow on the station platform. Harris and Anderson [5] proposed and demonstrated a formulation for dwelling time estimation. This paper is structured as follows: First, it describes the Panama metro line 1 and then presents the estimation of passenger distribution on the train by O-D matrices. Second, it shows the estimation of the elements of the O-D matrix followed by the dwelling time estimation. Later the Fuzzy inference engine and the proposed algorithm are presented. Finally, the paper concludes with the results for simulated data, conclusions and suggestions for future research.

II. Railway Line of Panama Metro Line 1

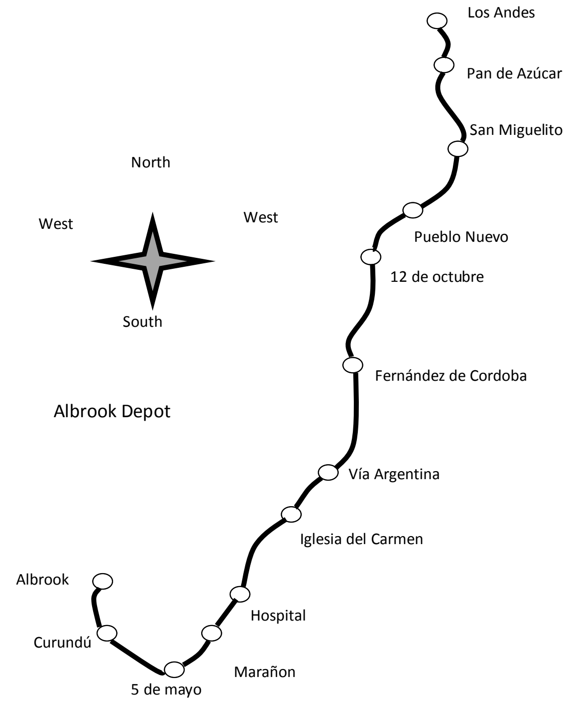

Fig. 1. Panama metro line 1.

The length of the station's platform on the Panama metro line 1 is 110 meters and the platform´s minimum width 3 meters. The train depot is located next to Albrook station. In

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particular, we analyzed the morning scenario during peak-hours (i.e. 6:00-8:00) for analyses when the discomfort effects could be greatest for the passengers. Each train has 3 electric multiple units with a total capacity of 800 passengers/train. The line extension is about 13,7 km and the timetable in terms of headways for the first operation´s year is 3 minutes (i.e 20 trains/hour) between 6:00 am – 8:00 am and other potential scenarios is 5 minutes (i.e. 12 trains/hour) in off-peak hours. (See figure 1)

III. Estimating the distribution of passengers on the train by OD matrices

The matrix method of area trips O-D (Origin-Destination) is one of the most used methods to design the movement of passengers [11, 17]. This method can be used to model passenger travel between different stations. For example, a random sample of the demands of traveling, which purpose is to estimate passenger flow between pairs of stations considering all those that are part of the transport system and then making a *trip time matrix* with all the possible combinations of pairs of stations [15]. Another study aims at estimating metropolitan railway passenger flow using OD matrix data in order to analyze passenger flow everyday [16]. However, the OD matrix data does not give any information about how passengers are distributed along the set of train cars. A similar situation occurs in Nanda et al. [20], who present a method to determine the elements of O-D matrix when the information on trip generation (input) and trip attraction (output) for each zone are not precise.

Due to economic and practical reasons this model does not include passenger distribution along the various train cars. Consequently, if it is necessary to estimate passenger distribution, it is necessary to generate another level of OD sub-matrices for each train car, in every station *I*. This new OD matrix can be constructed by subdividing the original OD matrix. (See figure 2).

$$
\begin{bmatrix}
0 & \cdots & \cdots & M_{1121} & \cdots & M_{112m} & M_{1131} & \cdots & M_{113m} & \cdots & \cdots & \cdots & M_{11n1} & \cdots & M_{11nm} & O_{11} & \vdots \\
\vdots & 0 & \cdots & \cdots & & \cdots & \cdots & & \cdots & & \cdots & & \cdots & & \cdots & \cdots & O_{T1} \\
\vdots & \vdots & 0 & M_{1m21} & \cdots & M_{1m2m} & M_{1m31} & \cdots & M_{1m3m} & & & & M_{1nm1} & \cdots & M_{1mnm} & O_{1m} & \vdots \\
M_{2111} & \cdots & M_{211m} & 0 & & & M_{2131} & & M_{213m} & & & & M_{21n1} & \cdots & M_{21nm} & O_{21} & \vdots \\
 & \cdots & & & 0 & & & & & & \cdots & & \cdots & & \cdots & \cdots & O_{T2} \\
M_{2m11} & \cdots & M_{2m1m} & & & 0 & M_{2m31} & & M_{2m3m} & & & & M_{2mn1} & \cdots & M_{2mnm} & O_{2m} & \vdots \\
M_{3111} & \cdots & M_{311m} & M_{3121} & & M_{312m} & 0 & & & & & & M_{31n1} & \cdots & M_{31nm} & O_{31} & \vdots \\
\vdots & & & & & & & 0 & & & \cdots & & \cdots & & \cdots & \cdots & OT_{3} \\
M_{3m11} & \cdots & M_{3m1m} & M_{3m21} & & M3m2m & & & 0 & & & & M_{3mn1} & \cdots & M_{3mm} & O_{3m} & \vdots \\
\vdots & & \vdots & & & & & & & 0 & & & & & & \cdots & \vdots \\
\vdots & \cdots & \vdots & & \cdots & & & \cdots & & & 0 & & & \cdots & & \cdots & \vdots \\
\vdots & & \vdots & & & & & & & & & 0 & & & & \cdots & \vdots \\
M_{n111} & \cdots & M_{n11m} & M_{n121} & \cdots & M_{n12m} & M_{n131} & & M_{n13m} & & & & 0 & & & O_{n1} & \vdots \\
\cdots & & \cdots & \cdots & & & & & & & \cdots & & \cdots & 0 & \cdots & \cdots & O_{Tn} \\
M_{nm11} & \cdots & Mnm1m & M_{nm21} & \cdots & M_{nm2m} & M_{nm31} & & M_{nm3m} & & \cdots & & \cdots & & 0 & O_{nm} & \vdots \\
D_{11} & \cdots & D_{1m} & D_{21} & \cdots & D_{2m} & D_{31} & \cdots & D3m & & \cdots & & D_{n1} & \cdots & D_{nm} & & \vdots \\
 & D_{T1} & & & D_{T2} & & & D_{T3} & & \cdots & \cdots & \cdots & & D_{Tn} & & & \vdots
\end{bmatrix}
$$

Fig. 2. The new OD matrix.

Where $D_T \in \Re^{1xn}$ is the alighting vector and $O_T \in \Re^{nx1}$ corresponds to the boarding vector of passenger for *n* stations. Here, each element of alighting D_{TJ} and boarding O_{TI} vectors can be subdivided into *m* passenger cars, becoming two new vectors $D \in \Re^{1xn_s}$ and $O \in \Re^{n_s x1}$ where:

$$
\begin{aligned}
D &= \begin{bmatrix} D_{11} & D_{12} & \ldots & D_{1m} & D_{21} & D_{22} & \ldots & D_{2m} & \ldots & D_{n1} & D_{n2} & \ldots & D_{nm} \end{bmatrix} \\
O &= \begin{bmatrix} O_{11} & O_{12} & \ldots & O_{1m} & O_{21} & O_{22} & \ldots & O_{2m} & \ldots & O_{n1} & O_{n2} & \ldots & O_{nm} \end{bmatrix}
\end{aligned} \quad (1)
$$

$$n_s = nm$$

n= number of stations.

m=number of coaches per train. For this practical application, each train has 3 electric multiple units during the first operation´s year of the Panama metro line 1, m=[1, 2,3]

Also, the trip classic matrix $T \in \Re^{nxn}$ is subdivided, resulting in a new matrix that analyses the movement of passengers between the stations considering passenger cars $M \in \Re^{n_s x n_s}$,

Where, each element of the alighting and boarding vectors and trip matrix must satisfy:

$$D_{TJ} = \sum_{k=1}^{m} D_{Jk} \quad (2)$$

The alighting element D_{TJ} is the summation of alighting flows of *m* traveller's cars at station *J*

$$O_{TI} = \sum_{k=1}^{m} O_{Ik} \quad (3)$$

The boarding element O_{TI} is the summation of alighting flows of *m* traveller's cars at station *I*. The relationship between the matrix elements in original and new OD matrix follows,

$$T_{IJ} = \sum_{i=1}^{m} \sum_{j=1}^{m} M_{IiJj} \quad (4)$$

Subject to

$$D_{Ij} = \sum_{i=1}^{n_s} M_{IiJi}, \forall_j = 1 \ldots n_s \quad (5)$$

$$O_{Ji} = \sum_{j=1}^{n_s} M_{IiJj}, \forall_i = 1 \ldots n_s \quad (6)$$

IV. Estimation of the elements of O-D matrix

One way to estimate the travel's matrix element is by assuming that the system is governed by the principle of maximum entropy. In the context of both physical systems and communication systems the uncertainty is known as the entropy. Note that in general the entropy, because it is expressed in terms of probabilities, depends on the observer. One person may have different knowledge of the system from another, and therefore would calculate a different numerical value for entropy. The Principle of Maximum Entropy is based on the premise that when estimating the probability distribution, you should select that distribution which leaves you the largest remaining uncertainty (i.e., the maximum entropy) consistent with your constraints. That way you have not introduced any additional assumptions or biases into your calculations.

However, this estimation could be improved by incorporating information, even if it is inaccurate. The interaction and behavior dynamics of different groups of passengers could be included by applying artificial intelligence-based techniques, more specifically, Fuzzy Logic.

To apply this model of distribution based on the following assumptions:

a) T_{IJ}, O_{TI} and D_{TJ} have little uncertainty within a planning horizon. Each element of vector O_{Ji} or D_{Ij} can be represented as a function of the boarding vector O_{TI} or alighting vector D_{TJ} respectively and a power function with exponents C_{DIj} or C_{OJi}. Equations (7) and (8) approximate human reasoning for boarding and alighting distributions in cars, [7][18]

$$D_{Ij} = \frac{2^{C_{DIj}}}{\sum_{k=1}^{m} 2^{C_{DIk}}} D_{TJ} \tag{7}$$

$$O_{Ji} = \frac{2^{C_{OJi}}}{\sum_{k=1}^{m} 2^{C_{OJk}}} O_{TI} \tag{8}$$

b) Each element of M_{IiJj} trip matrix can be represented as T_{IJ} function and a power function with exponent C_{MIiJj}.

$$M_{IiJj} = \frac{2^{C_{MIiJj}}}{\sum_{r=1}^{m}\sum_{s=1}^{m} 2^{C_{MIrJs}}} T_{IJ} \tag{9}$$

c) C_{DIj}, C_{OJi} y C_{MIiJj} come from a fuzzy inference engine based on the experience of an expert or railway´s planner.

It is important to highlight here, that the exponents C_{DIj} and C_{OJi} are related to the passengers preference for boarding or alighting for any train's coach at specific station. If these exponents are zero, the estimation becomes the maximum entropy estimation, while if you have a positive or negative number corresponds to a train's coach with low or high demand respectively.

On the other hand, the exponent C_{MIiJj} sets the relative level of importance of the flow of passengers between train's coach *i* at I station to train's coach *j* at J station. Here, the maximum entropy estimate also corresponds to a value of zero and a negative or positive number corresponds to a low flow or high demand respectively.

V. DWELLING TIME ESTIMATION

Accurately estimating station dwelling time is critical for an acceptable railway timetable planning [25] and the line capacity in metro and high-frequency suburban railways is as much determined by station stop times as by factors such as line speed or train acceleration. Additionally, the dwelling times at platform tracks can be systematically extended due to hinder by other trains and performance of railway personnel [19]. It has been shown that this dwelling time is function of rolling stock, through passengers and passengers' flow on station platform.

The through passengers in car *k* at station *l* is defined by,

$$M_{Tlk} = \sum_{j=l+1}^{n}\sum_{I=1}^{l-1}\sum_{i=1}^{m} M_{Iijk} \tag{10}$$

Harris and Anderson [8] proposed and demonstrated a formulation for dwelling time estimation. Even though, such formulation demands good statistical data in order to obtain an appropriate model, it is possible to approximate the time for opening and closing doors in train's coach *k* at station *l* as follows,

$$t_{oclk} = t_{ocm} + \left(1.5\left[1+0.9\frac{M_{Tlk}}{V_c}\right]\frac{D_{lk}^{a}}{n_d}\right) + \left(1.3\left[1+0.8\frac{M_{Tlk}}{V_c}\right]\frac{O_{lk}^{b}}{n_d}\right) + 0.027\frac{D_{lk}O_{lk}}{n_d^2} \tag{11}$$

and, consequently, the dwelling time is defined as:

$$t_{dl} = \max(t_{ocl1}, t_{ocl2}, \ldots\ldots, t_{oclm}) \tag{12}$$

where:

a = 0.7; b = 0.7

t_{ocm}=15 seconds (minimum stopping time)

Vc = Capacity of the hall (assuming 200 passengers by car´s train)

t_{dl} = Time to stop at the station *l*

n_d = number of doors

$D_{lk=}$ alighting passengers from train's coach *k* and station *l*

$O_{lk=}$ boarding passengers at train's coach *k* and station *l*

The values of the coefficient *a* and *b* have been kept equal to those in the original equation [2][8].

As consequence, a train´s station dwelling time is determined by the combination of the passenger boarding/ alighting process, the door control systems processes, actions taken by the train driver and infrastructure design. In this sense, the station dwelling time can be conceived as consecutive sequences of a set of actions like: door-unblocking, door opening, boarding /alighting passenger time, door closing for at each one coach´s train and departure time.

Due to variable passenger flow distributions boarding and alighting the train´s coach *k* at station *l* over the platform and the last closing door determines the passenger service time. After the last door has been closed, the dwell process continues with the train dispatching sub-process [25].

VI. Fuzzy inference engine

The exponents C_{DIj}, C_{OJi} y C_{MIiJj} can be designed using the help of fuzzy logic. In this particular case it seems reasonable to use triangular membership functions (Figure 3). These exponents can be estimated by considering:

1. Stairs, elevators and other facilities are closer to some cars on the platform *design during the* boarding process. Therefore, these cars present a greater flow of passengers. On the other hand, groups of more experienced passengers usually wait at more distant places on the platform knowing the exact location of the doors of the arriving train during peak hours [9,34]. For example, there are some passengers mingling but a higher percentage of passengers are waiting at the doors then at other places along the platform. Further, the proportion of passengers not boarding is significantly lower at the car near the platform. London Underground´s explanation is that this suggests that people who intended to move are also likely to move to a more comfortable area of the platform [26]. A similar approach is presented by Helbing et al., [34], where they consider the emerging passenger flows decisively depend on pedestrian capacity and the geometry of pedestrian facilities. In this sense this authors [34] consider that optimization procedure depend of the arrangement and shape of walkways, entrances, exits, stairs, elevators, rooms and corridors.

2. Many passengers know the location of stairs, elevators and other facilities on the platform of the destination station, i.e. the geometrical shape of passenger facilities inside the railway stations has an important impact. As a result, the cars that are closer to these facilities have a greater flow of passengers. People will naturally aim for the shortest route available to the exits. This is to be expected chiefly during the peak hour period, when everybody is busily running to their predetermined end of a planned journey.

3. The level of car occupancy depends on the purpose of travel (work, studies, leisure, shopping, tourism, etc), gender and age [12]. It is important to remember that the train has limited space or capacity and the passenger's perception about a crowded train produce an effect of reducing the expectation of the boarding passenger to travel in the train. [35]

4. Furthermore, Zhang et al., in their calculation for individuals active tendencies, which include the personal characteristics, gender and age of individual passengers, defined three types of passengers: active, standard and conservative [35].

5. In this sense, Schmöcker [26] present an explanation for more congestion in some days where the demand will be higher than estimated in the OD matrix. The OD matrix surveys are always carried out on typical autumn day therefore ignoring additional demand that might occur during peak seasons and before and after public holidays. D´Acierno et al. [31] mentioned that in the event of breakdowns, since faulty trains cannot usually be overtaken and their removal could pose extreme difficulties especially in metropolitan systems with two separate tunnels, re-establishing the regular service could involve inconveniently long travel times. Also, D`Acierno et al. [31] analyses emergency management effects for different levels on degraded rail services in order to define the best strategy to adopt to minimize user discomfort. They overlook that fact that in failure contexts some trains might not have enough space to accommodate all those boarding.

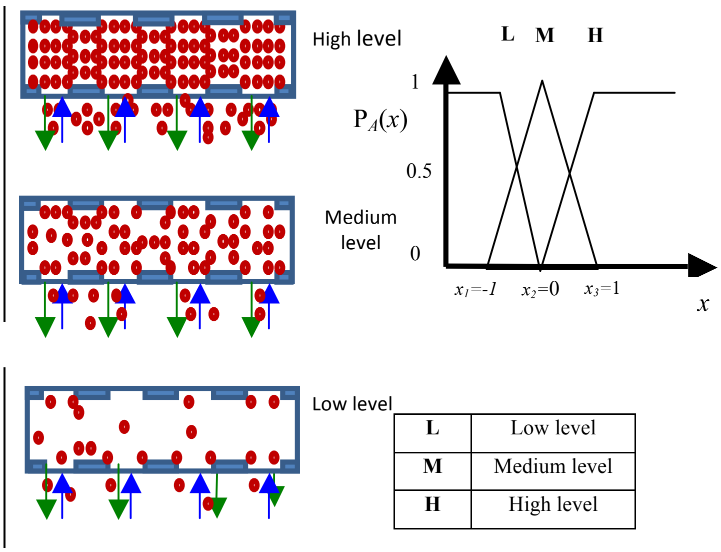
6. Passengers move in groups with either motivations for alighting or boarding, and passengers with similar motivations affect each other. The ratio of group sizes affects the boarding and alighting times. A larger sized boarding group leads to negative effect on alighting time and allows for more boarding opportunities before the end of alighting and vice versa. Ratio of group sizes are constantly changing as the number of passengers decreases with time [35]

7. In addition, children move more irregularly than described above since they must learn optimal strategies of motion first, which are used more or less automatically later [34].

8. Passengers show a certain joining behavior. For example, families, colleagues, neighbors, friends, university students or tourist parties often travel in groups.

The membership function levels of the alighting and boarding rates in each of doors car train are shown in figure 4. These are triangular membership function levels. There are three basic levels of passenger's flow [18]. Here, the high level approximates a great passenger's congestion; on the other hand the low level represents a weak passenger's flow. Delgado et al., [36] mentioned that it makes no sense to use sophisticated shapes for membership functions, taking into account that the linguistic appraisements are just approximate assessments, given by the experts and accepted by the decision makers because obtaining more accurate values is impossible or unnecessary. In fact, we consider triangular or trapezoidal membership functions good enough to capture vagueness of linguistics assessments. Other important aspect is that Kikuchi et al., [37] prove that the size of the range has not significant effect on the final adjusted values, but it has to be large enough to find a feasible set of solutions. Let the universe of discourse X be the subset of real numbers R, $X=\{x_1,x_2,x_3,\ldots,x_n\}$. A fuzzy set $A=\{(x,P_A(x))x\in X\}$ in X is a set of ordered pairs, where $P_A(x)$ is the membership function and it is $X\rightarrow[0,1]$ and the greater $P_A(x)$ is, the greater the truth of the statement that element x belongs to set A. Now, we parameterize a triangular fuzzy number A by a set (x_1,x_2,x_3) and the membership function is defined by

$$\mathrm{PA}(x)=\begin{cases}\dfrac{x-x_1}{x_2-x_1} & x_1\le x\le x_2\\ \dfrac{x_3-x}{x_3-x_2} & x_2\le x\le x_3\\ o & \text{in other case}\end{cases}\quad(13)$$



L	Low level
M	Medium level
H	High level

Fig, 3.Membership function three basic levels for a train´s coach.

VII. PROPOSED ALGORITHM

a) Estimate the exponents C_{DIj}, C_{OJi} y C_{MIiJj} based on the inaccurate available information available using three membership function levels for a train's coach.

b) Estimate attraction vectors and generation, D_{Ij} and O_{Ji}, for the stations using the exponential equations (14a) y (14b)

$$D_{Ij}=\frac{2^{C_{DIj}}}{\sum_{k=1}^{m}2^{C_{DIk}}}D_{TJ}\qquad(14a)$$

$$O_{Ji}=\frac{2^{C_{OJi}}}{\sum_{k=1}^{m}2^{C_{OJk}}}O_{TI}\qquad(14b)$$

c) Estimate the trip matrix $\boldsymbol{M_{IiJj}}$, using,

$$M_{IiJj}=\frac{2^{C_{MIiJj}}}{\sum_{r=1}^{m}\sum_{s=1}^{m}2^{C_{MIrJs}}}T_{IJ}\qquad(15)$$

d) Proceed to check if $O_{Ji}=\sum_{j=1}^{n_s}M_{IiJj}\forall_i=1\ldots n_s$. Consequently, if $\left|\sum_{j=1}^{n_s}M_{IiJj}-O_{Ji}\right|<\varepsilon$ is true for a given level, it is accepted. Meanwhile, if not, the values of the matrix elements are corrected with

$$M_{IiJj}\Leftarrow\frac{O_iM_{IiJj}}{\sum_{j=1}^{n_s}M_{IiJj}}\qquad(16)$$

e) Proceed to check if $D_{Ij}=\sum_{i=1}^{n_s}M_{IiJi}\forall_j=1\ldots n_s$. Consequently, if $\left|\sum_{i=1}^{n_s}M_{IiJj}-D_{Ij}\right|<\varepsilon$ is fulfilled, it is accepted. Meanwhile, if not, the values of the matrix elements are corrected with

$$M_{IiJj}\Leftarrow\frac{D_jM_{IiJj}}{\sum_{i=1}^{n_s}M_{IiJj}}\qquad(17)$$

f) Proceed to check whether $T_{IJ}=\sum_{i=1+m_B(I)}^{m_E(I)}\sum_{j=1+m_B(J)}^{m_E(J)}M_{IiJj}$, for all i, j, I, J. Consequently, if $\left|\sum_{i=1+m_B(I)}^{m_E(I)}\sum_{j=1+m_B(J)}^{m_E(J)}M_{ijm}-T_{IJ}\right|<\varepsilon_m$ satisfied, it is accepted. The error is a value defined by the designer. In the case of this research work present here, the authors used the value of 2 %. Meanwhile, if not, the values of the matrix elements are corrected with

$$M_{IiJj}\Leftarrow\frac{T_{IJ}M_{IiJj}}{\sum_{i=1+m_B(I)}^{m_E(I)}\sum_{j=1+m_B(J)}^{m_E(J)}M_{IiJj}}\qquad(18)$$

g) Return to step d, if the tolerances are not satisfied.

h) Finally,

$$M_{Tlk}=\sum_{j=l+1}^{n}\sum_{I=1}^{l-1}\sum_{i=1}^{m}M_{Iijk}\qquad(19)$$

$$t_{oclk}=t_{ocm}+\left(1.5\left[1+0.9\frac{M_{Tlk}}{V_c}\right]\frac{D^a_{lk}}{n_d}\right)W+\left(1.3\left[1+0.8\frac{M_{Tlk}}{V_c}\right]\frac{O^b_{lk}}{n_d}\right)W+0.027\frac{D_{lk}O_{lk}}{n_d^2}\quad(20)$$

$$t_{dl}=\max(t_{ocl1},t_{ocl2},\ldots\ldots,t_{oclm})\qquad(21)$$

VIII. CASE STUDY: PANAMA METRO LINE 1.

In a previous paper the proposed algorithm was validated using a simulated case [18]. This is was useful in order to illustrate the theory of the proposed algorithm with a membership function of three basic levels for a train's coach. In the previous work, the station dwelling time obtained using the proposed algorithm had an acceptable error of 6,25% compared to the original trip matrix without the proposed algorithm [18]. The proposed methodology is applied to a Panama metro line 1. While the case study might be of interest in itself, the main objective is to illustrate that the algorithm can also be used for practical applications. Now, let´s consider a track between the "San Miguelito" station and "Iglesia del Carmen" station because is the track with more congestion during the morning peak hours period in the Direction ("Los Andes"- Albrook) according the studies of passenger´s flow demand about Panama Metro line [23] and Berbey et al., [39]. This railway line has a three-car train. Under these conditions the estimated dwelling time by the Panama metro line planning authorities is about 20 and 25 seconds.

Commonly, the best information available about the elements of the last O-D matrix is imprecise. In this case, a general O-D matrix considering only passenger flow between stations and some general idea about the flow between cars considering passenger behavior (Please see figure 4)

	Destination	....			....			1172			491			1524			1250			10088			5382			..
Origin	station	LA			PA			SM			PN			12-oct			FC			VA			IC			
6650	LA	0	0	0	…	…	…	L	M	L	M	H	L	L	H	M	L	M	L	L	M	L	L	M	L	..
946	PA	…	…	…	0	0	0	L	M	L	L	H	M	L	H	M	L	M	L	L	M	L	L	M	L	..
4792	SM	…	…	…	…	…	…	0	0	0	L	H	M	L	H	M	L	M	L	L	M	L	L	M	L	..
283	PN	…	…	…	…	…	…	…	…	…	0	0	0	L	H	M	L	M	L	L	M	L	L	M	L	..
920	12oc	…	…	…	…	…	…	…	…	…	…	…	…	0	0	0	L	M	L	L	M	L	L	M	L	..
455	FC	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	0	0	0	L	M	L	L	M	L	..
2459	VA	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	0	0	0	L	M	L	..
	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	..

Fig. 4. Imprecise partial Panama metro line 1 O-D matrix by car`s train.

As a result, the proposed algorithm estimates an approximated dwelling time matrix by train´s coach *k* (1,2,3) and station *l* during the morning peak hour period applying a fuzzy logic inference motor. Now, it is possible to see the dwelling time for the "San Miguelito" station(SM) is determined by a car 1 with 22 seconds, while the dwelling time for Pueblo Nuevo station (Pn) is determined by car 3 with 17 seconds. It the same case for the "12 de octubre" (12-oct) and "Fernandez de Cordoba" (FC) stations with 19 seconds (car 1) and 26 seconds (car 3) respectively. For the "Via Argentina" (VA) and "Iglesia de Carmen" (IC) stations, the car 1 determined the dwelling time for both with 29 and 22 seconds respectively. (See figure 5)

Stations		LA	PA	SM	Pn	12-oct	FC	VA	IC	…
Car´s tain	1	…	…	22	16	19	18	29	22	…
	2	…	…	15	16	16	23	19	17	…
	3	…	…	16	17	17	26	21	18	…

Fig. 5. The resulting dwelling time O-D matrix using the proposed algorithm.

These preliminary results obtained about the dwelling times for the Panama metro line´s stations are appropriate in comparison with the dwelling times for metro transportation systems mentioned in the railway literature [40][8], where the dwelling times for stops at intermediate stations correspond to 15 to 30 seconds and stops and changes of direction in terminal stations operate within the range of 30 to 60 seconds

It is important indicate that the upper triangle of the estimated Panama metro line 1 OD matrix by the proposed method showed that the 68,97% of the total trips occurs in the "Los Andes"-Albrook direction. It is a good reasonable result in comparison with the studies of the Metro authorities of the Government of Panama [SMP, 2010] because according the estimation of authorities of the Government of Panama, the total number of passengers is 34491 and they are distributed in 23594 (Direction "Los Andes" - Albrook) and 10897 (Direction Albrook- "Los Andes") during the period of peak hours morning [23]. This means that the 70% of the passengers travel in the "Los Andes"-Albrook direction during the peak hour morning (6:00-8:00 a.m).

IX. CONCLUSIONS

These results have shown the potential and effectiveness of this new methodology in the case study of a Panama metro line 1. This new proposed algorithm has been developed using the help of fuzzy logic to predict the dwelling times of passengers' trips, alighting and boarding time passenger cars in explicit stations. As a guideline for future research, it is interesting to improve the fuzzy inference engine, and proved other more artificial intelligence techniques. Also, this methodology can be combined with techniques of image processing and it should be possible the incorporation of other sources of information in the proposed algorithm.

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