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► **To cite this version:**

Mouloud Khelf, Salim Boukebbab, Neila Bhourri. The Effect of Tram Management on Road Traffic Fluidity and its Influence on Drivers Behaviors at a Critical Junction in Algeria. *Transport Problems = Problemy Transportu*, 2023, 18 (2), pp.31-42. 10.20858/tp.2023.18.2.03 . hal-04273335

HAL Id: hal-04273335

<https://hal.science/hal-04273335>

Submitted on 7 Nov 2023

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Keywords: tram management; drivers' behaviors; junction; travelers; traffic congestion

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THE EFFECT OF THE TRAM MANAGEMENT ON THE ROAD TRAFFIC FLUIDITY AND ITS INFLUENCE ON DRIVERS' BEHAVIORS AT A CRITICAL JUNCTION IN ALGERIA

Summary. This research paper aims to study the effect of tram management on traffic fluidity and its impact on car drivers' behaviors in junctions crossed by the tram. The methodology used in this research is based on a mathematical model and an investigation of car drivers. The first step sets to analyze the data of annual travelers' attendance: to assess the number of trams offered and needed in operation to respond adequately to the factual demand. The second step, then, proceeds to prove how the previous results of the trams' fleet influence traffic jam. That is, to identify how the number of trams used in operation blocks other motorists and reduces traffic flow capacity in junctions. Finally, the purpose of the questionnaire is to figure out the car drivers' opinion about the causes of traffic congestion in junctions and to know how this phenomenon affects their behaviors. The outcome demonstrates that tram management is ineffective because there is a considerable gap between the annual offered tram fleet and the actual one needed according to the real statistical data. The high number of trams utilized is the leading cause of traffic congestion. Furthermore, it disturbs the control of traffic lights at the common intersections. Unfortunately, this outcome is the main reason for the drivers' poor behavior noting that 75.20% of car drivers are always stressed. These issues have intensified traffic jam in several junctions along the tram line. The article recommends some solutions to improve tram management and to improve traffic fluidity to avoid the substandard behavior of car drivers in junctions.

1. INTRODUCTION

In spite of the considerable evolution of road infrastructure that has been made around the world, traffic jam is still a difficult issue to resolve [1, 2]. The main implemented solution in several countries is that of investing in sustainable public transport [3, 4]. Those modes of transportation must respond to the population demand, so that, they can attract them to be used as the first transportation means to travel by [5, 6].

The tram is one of these modern transportation modes and this goes to the different advantages it affords [7, 8]. Especially, that it helps in reducing the traffic flow and minimizing road accidents on its line [9]; What allowed many countries across the world, to construct and develop this kind of railways [10]. The Algerian government as well has, forcefully, financed the construction of trams' networks. many cities benefited from a tram line, including Constantine city [11].

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However, the tram has become a source of enormous traffic jams in junctions. Its passage in the rush hour (every 3 minutes) in both directions, has negatively affected road traffic [11, 12]. At junctions like other trams in many countries, the Algerian tram has the priority compared to other motorists [13, 14], it stops reducing the cars fluidity at its passage [15, 16], this can be a source of irritation for the majority among them.

Certainly, the establishment of traffic lights to control the crossroads is very important, because it organizes the traffic and decreases the delay for drivers [17, 18]. However, if the synchronization of lights does not respond effectively to the real situation, they will increase traffic jams [15, 19].

Several papers before, have studied the impact of road accidents on congestion and the drivers' behaviors on accidents [20-23], but the impact of traffic jam on the risks of accidents is less discussed [24, 25]. The behavior of drivers is one of the causes of accidents and congestion at the same time [26, 27]. Multiple precedent studies that have been held, have shown that changing the queue on a road is a dangerous maneuver [28, 29], which often causes accidents and aggravates the case of traffic jams, especially in urban areas [30-32].

In this work, we will analyze the causes of congestion in a complicated junction in the city and know how congestion can influence the drivers' behaviors. For this, we will evaluate the tram management to know its influence on traffic congestion at intersections. In addition to studying the situation of the road traffic capacity in the common junction, by utilizing the results of the tram's number applying in operation. Finally, the opinion of drivers who use this itinerary will be analyzed to know from their perception, the causes of traffic jams and to detect its effect on their behaviors.

The study area will be in Constantine city, Algeria; More exactly in Che Guevara junction, this last is a complicated junction located on the operating line [12]. It has been chosen because of the high demand of traffic and its strategic location that leads to some important areas (Fig. 1).

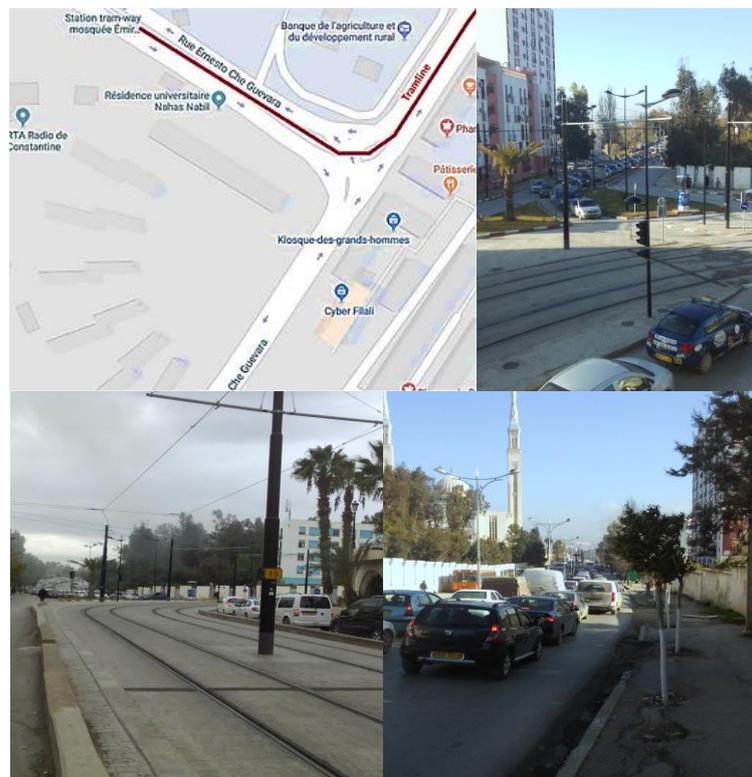


Fig. 1. Map and photos of Che Guevara junction, Constantine city, Algeria

2. METHODOLOGY

The methodology followed in this study is divided into 3 sections:

2.1. Trams' management analysis

In the first part, from the tram operation data, we have made a comparison between the number of trams required to respond to the real users' attendance and the proposed number of trams offers of the year 2018. This allowed us to evaluate the tram's control and to detect its impact on traffic jams.

The tram brand is a Citadis 402 range, from Alstom. It is able to take in charge 302 users by tram [7, 11]. The interval of time between trams is 3 minutes during rush hours (7:00 to 9:00 am and from 2:00 p.m to 6:00 p.m), and 5 minutes at other hours during weekdays [11, 33, 12]. The length of Constantine tram network is currently 8 km, pending the opening of the next extension, which is being tested [7, 33]. The table 1 present the offered number of tram in 2018 according to the interval of time in weekdays, Fridays and Saturdays.

Tab. 1

The suggested number of trams used in operation.

	Weekdays	Fridays	Saturdays
The performance (tram/days)	504	368	252

In an exceptional month of the year 2018, the number of trams used in operation is 592 trams per day for 30 days (between 16 May-14 June 2018). The theoretical number of travelers per month is calculated in the equation (1).

$$P_o = T_o * M_c \quad , \quad (1)$$

- P_o is the theoretical number of travelers per month.
- T_o is the theoretical number of trams offered per month.
- M_c is the trams' mass capacity (302 travelers per tram).

Noting that the theoretical number of trams offered per month is calculated in the equation (2).

$$T_o = (T_w + T_f + T_s) \quad , \quad (2)$$

- T_w is the theoretical number of trams offered in weekdays per month.
- T_f is the theoretical number of trams offered in Fridays per month.
- T_s is the theoretical number of trams offered on Saturdays.

The real number of trams needed per month is calculated from equation (3).

$$T_r = \frac{D_r}{M_c} \quad , \quad (3)$$

- T_r is the real number of trams needed per month.
- D_r is the real number of travelers per month.

The number of tram attendance rate per month is calculated from equation (4).

$$A_r = \frac{T_r}{T_o} \quad , \quad (4)$$

- A_r is the number of tram attendance rate per month.

2.2. The evaluation of the road traffic situation

In the second part, according to the results of the tram's operation analyzed previously, the objective is to evaluate the traffic flow at the intersection. We have focused on the impact of the tram exploitation on the traffic flow situation. This section will show clearly the estimation of the blocked cars, due to the passage of trams at the shared signalized crossroads. A comparison between the traffic flow blocked, because of the suggested and real trams' frequency had been analyzed, to show their impacts on the traffic fluidity.

The time headway h in the calculation of the traffic flow is 2 seconds [34]. The required time t for the tram to leave the Che Guevara junction is 40 seconds [12]. The estimated blocked traffic flow according to the theoretical and real number of trams is calculated from the equation (5).

$$Q_b = \frac{T_f * t}{h} \quad , \quad (5)$$

- Q_b is the estimated blocked traffic flow.
- T_f is T_o in the case of the estimated blocked traffic flow Q_{bo} according to the theoretical number of trams per month.
- T_f is T_r in the case of the estimated blocked traffic flow Q_{br} according to the real number of trams needed per month.

The estimated gained rate of traffic fluidity Q_{bg} in Che Guevara junction is calculated from the equation (6).

$$Q_{bg} = \frac{Q_{bo} - Q_{br}}{Q_{bo}} * 100 \quad . \quad (6)$$

2.3. A survey with cars' drivers

In this last step of the study, 250 drivers who pass through the junction of Che Guevara, were interviewed for having their opinions on traffic congestion in April 2019. This, to confirm from their opinions the existence of the traffic congestion in the junction of Che Guevara, to know the main causes and how can this impact their behaviors, for instance, doing dangerous maneuvers and violence toward other drivers.

3. ANALYSIS AND DISCUSSION

3.1. Trams' management evaluation

Comparison of the annual suggested and real travelers' frequency

The collected data of the annual frequency of the tram travelers are acquired from the Enterprise Metro Algiers (EMA). Overall, the figures below, show that the tram does not respond optimally to the travelers' demand, because it is not operated at the real time. Fig. 2 shows that the suggested users demand is 4 to 5 times greater than the real users' attendance, this proves that the tram operation is not suitably managed in real-time.

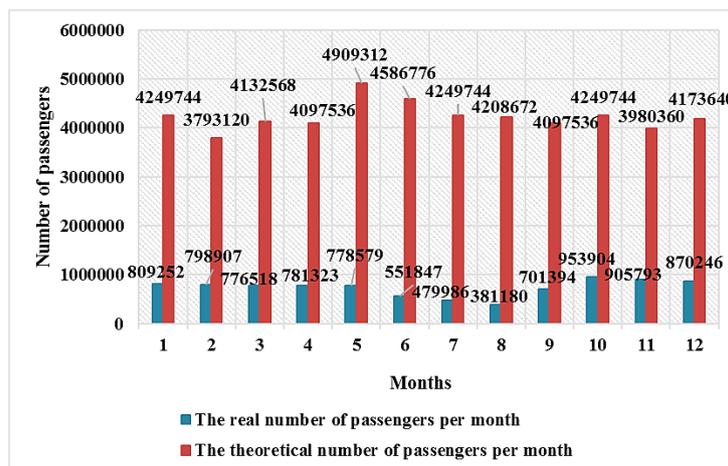


Fig. 2. Comparison of the annual suggested and the real travelers' demand

Estimation of the suggested and the real number of trams

Fig. 3 represents a comparison between the suggested number of trams used in operation and the real number needed to satisfy the real traveler attendance during the year 2018. Noting, the actual

number of trams that could meet the travelers' demand does not exceed 3500 trams per month. The rate of trams needed to respond to the real users' demand is just between 9.06% and 22.76% of the offered suggested trams.

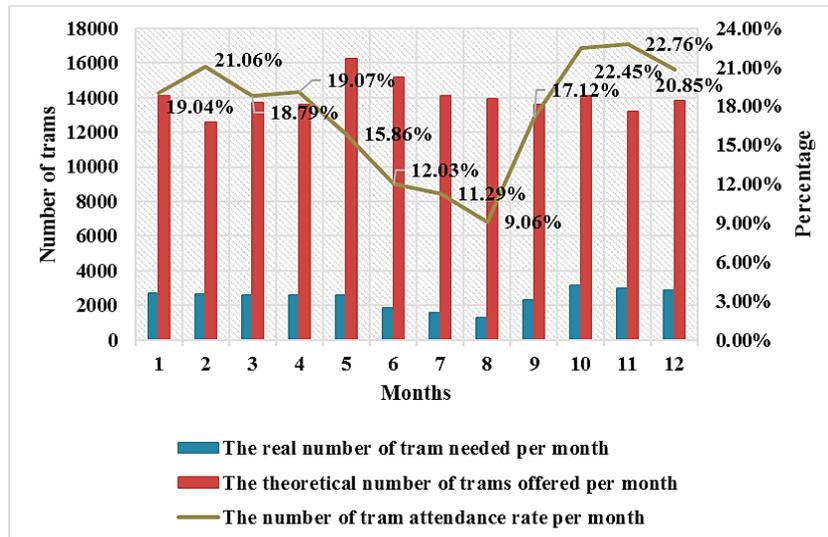


Fig. 3. Estimation of the real number of trams needed and the suggested number offered

3.2. Evaluation of the traffic flow at the intersection

Fig. 4 illustrates the estimated blocked traffic flow due to the passage of the suggested and real number needed of trams in Che Guevara junction. This estimation of the blocked traffic flow is calculated for drivers' cars who cross the tram line to go to their itineraries.

The result of this part shows that the traffic flow could have been better if the number of trams has responded, optimally, to the tram travelers' attendance. Because the intersection could have gained between 77.24% to 90.94% of fluidity, compared to the applied proposed number of the trams; Which contributes efficiently to reducing congestion in Che Guevara intersection and all the other junctions located on the lane of tram. This situation is existing until now, it is necessary to reduce the number of trams, to be more efficient to reduce traffic jams.

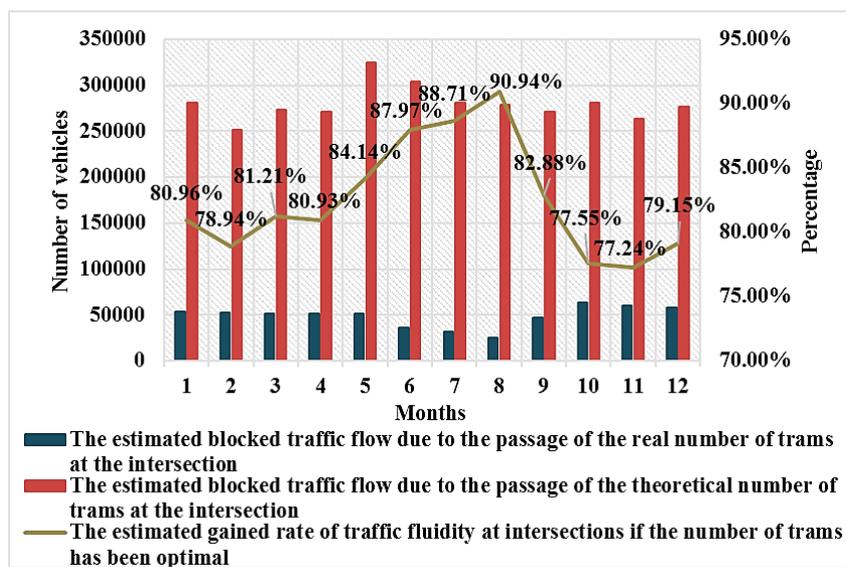


Fig. 4. Estimation of the blocked traffic flow due to the passage of the tram in Che Guevara junction

3.3. The survey analysis

The characteristics of respondents

The first part of the sample represents the respondents' characteristics, it is composed of 68% of men and 32% of women. 83.60% of motorists are between 18-36 and 37-55 years old. The first reason for 66.40% of drivers to take this itinerary is for work. Moreover, 66.40% of them use this route every day and 15.20% between 3-4 times per week. This proves that the selected drivers know this way well.

Tab. 2

The characteristics of respondents [35]

		Number of drivers	Percent
Gender	Female	80	32.00%
	Male	170	68.00%
	Sum	250	100%
Age	18-36 years	75	30.00%
	37-55 years	134	53.60%
	56-75 years	41	16.40%
	Sum	250	100%
Activity	Student	10	4.00%
	Worker	216	86.40%
	Retired	17	6.80%
	Jobless	7	2.80%
	Sum	250	100%
The itinerary usage reason	School/University	6	2.40%
	Job	166	66.40%
	Shopping	40	16.00%
	Other uses	38	15.20%
	Sum	250	100%
Intersections usage frequency	Every day	166	66.40%
	3-4 uses per week	38	15.20%
	1-2 uses per week	13	5.20%
	Time to time	33	13.20%
	Sum	250	100%

The traffic congestion problem

Table 3, presents the problem of the traffic congestion and its causes in intersections, 87.60% of respondents, see eye to eye that traffic jams in signalized crossroads has, always, caused them delays and no one had denied. According to the data of this table, it is apparent that 45.20% of drivers find that the minimum of the necessary time to cross the intersection between 7:30 a.m and 06:00 p.m is 16 minutes, 32.40% say 11- 15 minutes and 22.40% of drivers find it between 5-10 minutes.

The main cause of this problem in Che Guevara junction is the tram operation, 63.60% of car drivers claim that Constantine tram is weakly exploited because its passage is not regular in Che Guevara junction, this is one of the traffic congestion causes.

Furthermore, the synchronization of the traffic lights is also a cause of this issue, because the signal timing is not consistent with the operation of the tram. The passage of this last causes a distribution in the traffic lights.

Traffic Congestion problems and causes at the intersection [35]

		Number of drivers	Percent
The delay caused by traffic congestion	Always	219	87.60%
	Sometimes	31	12.40%
	Never	0	0.00%
	Sum	250	100%
The necessary time to cross the intersection. (minutes)	5- 10	56	22.40%
	11- 15	81	32.40%
	16-20	67	26.80%
	21-25	22	8.80%
	26-30	24	9.60%
	Sum	250	100%
The tram operation causes congestion at intersections	Always	159	63.60%
	Sometimes	51	20.40%
	Never	40	16.00%
	Sum	250	100%
The synchronization of the traffic lights causes of congestion	Always	179	71.60%
	Sometimes	42	16.80%
	Never	29	11.60%
	Sum	250	100%

Impact of traffic congestion on drivers’ behavior

This section represents the results of the impact of traffic congestion on drivers’ behaviors. It is divided into three parts:

- The stress due to the traffic congestion

Fig. 5 demonstrates that 75.20% of drivers are always stressed due to the congestion at the intersection. This result is so high because stress is a type of annoyance that impacts negatively the behavior of drivers, which complicates the state of road traffic at the intersection. That conduct us to discover the severe consequence of this problem on their behaviors.

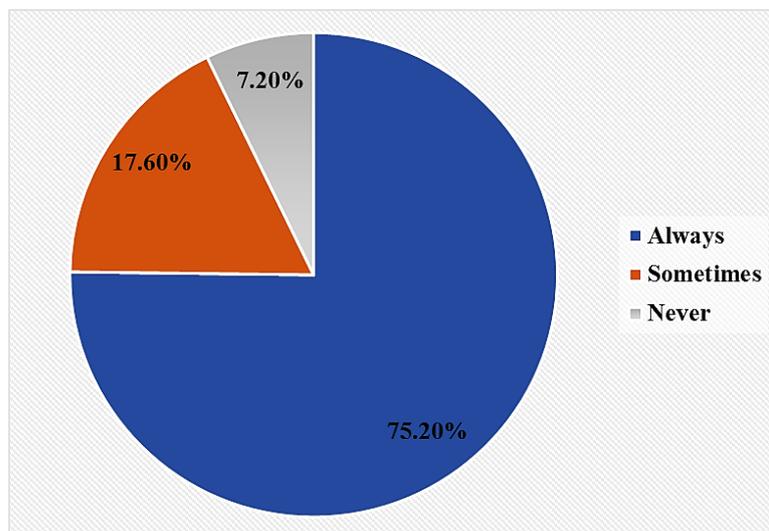


Fig. 5. The stress due to the traffic congestion

- Violence due to the stress

Fig. 6 illustrates the violence due to the stress caused by traffic congestion, 44.80% of drivers are sometimes to always violent. A lot of drivers commit verbal abuse, honk, tailgating cars and cut off other drivers.

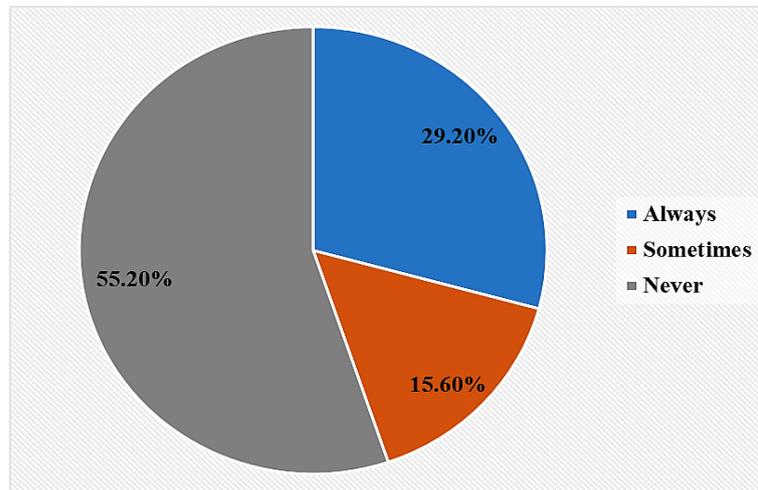


Fig. 6. Violence due to the stress

- Dangerous maneuvers due to the stress

Fig. 7 represents dangerous maneuvers due to the stress. This last causes drivers' dangerous maneuvers, because 49.60% of them do maneuvers changing lane because of the stress and impatience and they take the risk to cross the intersection before the tram's arrival. Also, they use the car horn to incite other drivers to do more speed for crossing the lights when they turn red.

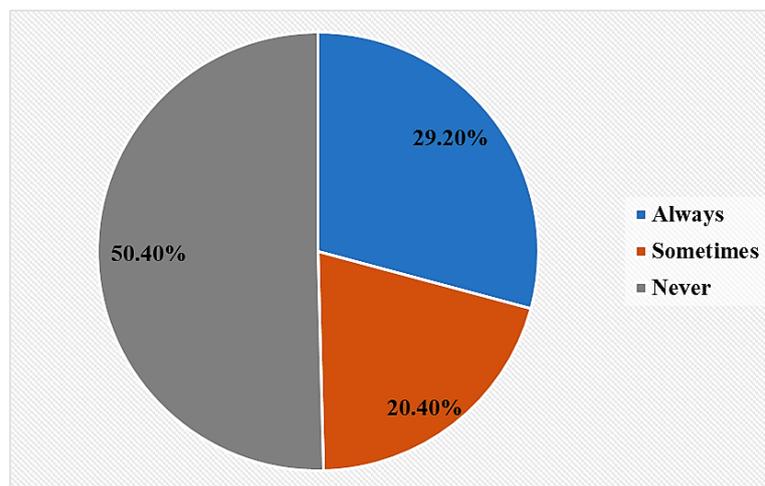


Fig. 7. Dangerous maneuvers due to the stress (non-respect of the red light and changing lane behavior)

Otherwise, sometimes trams pass into the intersection when the light is green for motorists who traverse the line of the tram, this is too dangerous (Fig. 8). This mismanagement of the multimodal traffic system influences negatively the drivers' behaviors at the intersection. From almost three years to now, this problem is still existing, it is high time to resolve it and to ameliorate the traffic control at intersections that include tramlines. Finally, Fig. 9 shows that 90% of drivers are not satisfied with the current multimodal traffic management, they find it bad because of all causes cited previously.



Fig. 8. The disturbance in the traffic lights synchronization (the green light when the tram passes for those who cross the tramline) [35]



Fig. 9. The users' satisfaction of the current multimodal traffic management at intersections

4. DISCUSSION & CONCLUSION

The particularity of this article is to identify the real cause of congestion at intersections that contain a lane of the tram, besides, to know its repercussion on the drivers' behaviors. In this study, especially, in Che Guevara junction, it is impossible to modify the geometry or build an expansion of the roads, because of several constraints. Hence, it is necessary to, optimally, adjust the existing infrastructure.

Unlike the other articles, the value of this paper is that both tram exploitation and its effect on the traffic flow situation are analyzed and evaluated at one time. Also, its importance is to know the opinions of road users about congestion at this intersection and how it affects their behaviors.

In this study, a detailed analysis of the real and suggested travelers' demand has been made, in addition to the comparison between a calculated proposed and real number of trams, to know whether Constantine tram is performing well.

From this article, it has been shown that the real demand of travelers is significantly less than the proposed one, the number of trams applying in operation throughout the year 2018, greatly exceeds the number which can respond to the real attendance. This bad performance causes a high traffic flow blocked at the intersection because of the considerable number of trams that cross the intersections.

Otherwise, the high frequency of trams is not the only source of traffic jams, but, also the non-consistency of traffic lights with the tram operation system is one of these main causes, because of the existence of some disturbances in the signal timing when the rail vehicle passes through the intersection. The last part of the results has shown that 87.6% of drivers are always stuck in congestion

at this intersection. The non-optimal multimodal traffic control has a negative impact on the drivers' behaviors because it makes them stressed. Almost 50% would opt to take a dangerous decision to change the lane or cross the intersection when the tram is near the intersection.

All this can be an extra origin of congestion and complicates more the problem, especially because of a probable accident. Therefore, traffic jams can be a source of accidents because of drivers' behaviors especially stress.

5. RECOMMENDATIONS

Multiple recommendations should be implemented in order to lessen the impact of the tram fleet used in operation on the other motorists and to increase traffic fluidity. This allows avoiding the adverse behavior of drivers at intersections.

The establishment of an efficient timetable is necessary to ensure a better management of the tram fleet and to guarantee a sustainable mobility. This solution cannot be realized without an equilibrium between the tram supply (capacity or number of trams offered) and travelers' demand. Furthermore, an extensive study of the tram exploitation during the previous years is imperative to find the optimal interval of time, especially at rush hours. Therefore, the increase of the time interval between trams for an optimal management of the fleet will not influence work appointments of travelers as it will be done according to the data in real time to guarantee the regularity of trams especially at rush hours.

Furthermore, the optimization of its operation is an important factor to have more fluidity for motorists. That is, when the tram interval time increase, the motorists will have more time to cross the junctions and therefore this solution allows reducing the delay for motorists in junctions.

The optimal management of the multimodal traffic system is among the chief solutions to decrease traffic jam in junctions. The optimization of the traffic light system according to the tram control system will reduce traffic jams and limit its negative impact on drivers' behavior. In addition, it will contribute to avoiding drivers' stress. This will, subsequently, reduce taking risks either by changing the lanes or by crossing the tramline in a dangerous position.

This article can be a reference to other papers that are studying traffic jam problems, the tram operation, and the driver's behavior in critical junctions.

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