Proposals for Intervention in Bus Lines with Reduced Commercial Speed

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1 Introduction

The commercial speed is one of the main factors affecting the performance and quality of public transport services, directly influencing travel times for passengers and operators costs. Best commercial speeds bring benefits for operators, customers and the community by facilitating mobility.

The public transport, despite its environmental efficiency potential in the transport of people compared to private vehicles, is perceived as slow and unreliable. This is even more obvious when the public transport shares the infrastructure with private transport. Obtaining higher and more stable commercial speed should be one of the objectives of transport operators making their service more attractive, and at the same time, redirecting users of private transport, reducing the high energy consumption and pollution that is associated to it.

This paper aims to assess and quantify the influence of different factors affecting the commercial speed of road public transport. These include distance between stops, traffic conditions and traffic volumes, second lane parking and loading/unloading operations on the roadway. It also intends to develop measures to be applied in order to obtain higher commercial speeds. To these objectives a case study was selected to perform a micro simulation and apply changes.

2 Background

In terms of energy, the car (specific consumption 40.51 gep/pkm) is less efficient than the bus (5.29 gep/pkm of specific consumption), so all the improvements that lead to a change of private transport to public transport, reduce energy consumption (Agência Portuguesa do Ambiente 2006). However, despite this, the public transports are increasingly perceived as slow and unreliable. Operators must improve its transport service through improved travel times and the fulfilment of their schedules, not only to keep existing customers, but also to try to win new customers. However, the improvement in travel times is not a simple task, since there are multiple factors that influence it.

The main factor is the commercial speed, which is calculated as the ratio between the distance travelled and time elapsed between two extreme points of the route of the vehicle. The commercial speed is dependent on other speeds, such as maximum vehicle speed, the maximum legal speed, and speed between stations (Vuchic 2005).

The commercial speed has a major impact on performance and cost of transport service. Increasing the speed results in shorter journey times for passengers, and usually a reduction in investment costs by the operator, it can also improve the transport demand (Vuchic 2005).

Measures may be applied to the vehicle to improve the internal circulation by removing a row of chairs between the first port and the central door and reduce delays at stops. Vehicles with lowered floors can get better boarding speeds. The double doors can substantially reduce the time of shipment, and should be considered for all vehicles except for those used on suburban lines where the advantages of having a best time of shipment are outweighed by the advantages of maximizing the capacity of the vehicle (Vuchic 2005).

Changes can be made to the infrastructure such as building extensions along the longitudinal parking areas, which allows buses to stop without having to manoeuvre, reducing downtime and but also comfort. The elimination of parking permits the use of the full lane width and allows even better speed, because it reduces congestion and friction between vehicles. At intersections with traffic lights it is possible to give priority to public transport, reducing the delay in these points. This system can be constructed so that it is not necessary to stop the vehicle (Vuchic 2005). The location of the stops has a large impact on the speed of public transport. A measure that improves the speed is increasing distance between stops. On roads with traffic lights and synchronization between junctions creating green waves, when switching between the location of stops just before and just after the crossing reduces the delay time of vehicles (Vuchic 2005).

With the implementation of pre-purchased tickets and boarding passes boarding time decreases, and with the evolution of information technologies, the use of magnetic cards or contactless cards allow to further reduce the processing time of each passenger.

3 Micro simulation

A traffic simulation uses computational techniques to replicate and study traffic behaviour. Simulation models can be divided into microscopic, mesoscopic and macroscopic models, corresponding to the simulation of a vehicle, a line of vehicles or a vehicle flow, respectively (Li, Tang and Jiang 2010).

A model of urban traffic micro simulation can represent through a computer model a vehicle, and their decisions and moves based on a set of rules. Due to limitations of computational abilities this kind of simulation was limited to small studies, such as a street or an intersection. Recently, with the great increase of computational power it is possible to create large networks with the ability to simulate complex traffic conditions, as well as new problems, while allowing a visual representation of these, therefore, and for these reasons and because it is economically, safe and fast, micro simulation has been increasingly used in the evaluation of transport systems and traffic operations (Li, Liu and Li 2010).

To build an AIMSUN model it is necessary to input two types of information, the supply information that includes everything that is related to infrastructure and services, and the demand information that represents the needs of travel and is represented by matrixes of origin and destination (Casas, et al. 2010).

The creation of a transport simulation model is divided into three steps. The first involves the construction of the model, collecting and processing data to be used in the model. The second step includes verification, calibration and validation, which seeks to confirm that the implementation logic of the model is correct, and compares the results with actual measurements to check the adjustment and validity. Finally, the last stage corresponds to the results obtained in accordance with the objectives of the project (Casas, et al. 2010).

4 Case Study

A route served by Rodoviária de Lisboa (RL) was used as a case study. The company was part of the work, helping, not only to choose the route to study, but also providing information and support throughout the development.

As suggested by RL Avenida Moscavide, in Moscavide in the municipality of Loures was chosen for this study. It is an area with a strong presence of trade and services and consequently with a large circulation and movement of pedestrians. The business hours with the lowest speed was the period between 9:00 and 10:00, with a commercial speed of 9.79 km / h.

To characterize the supply various data were collected, such as physical characteristics of the route, width of streets and number, characteristics of intersections, movements permitted and priorities; imposed speed limits, which for urban roads have the speed limit of 50 km/h, and location of pedestrian crossings. The signalized intersections phases, yellow red and green time, cycle time and duration of each phase were also gathered.

For public transport was necessary to identify the routes, schedules, location of stops and downtime.

For the demand, information about flows of vehicles and pedestrians in each of the intersections, and movements in the second lane of parking and loading/unloading operations were collected.

5 Model

AIMSUN 6 was used to build the model. The construction process began with the creation of pathways using planimetry as support, and the information collected on the width and number of lanes. To define the capacity of the route a signalised street was chosen which suits the conditions of Avenida de Moscavide, and has the capacity of 1400 vec./h.

The public transport services were defined using the lines and plans in the software. To a line a set of schedules is associated that contain, in addition to the starting times of each bus, the average downtime and standard deviations for each of the stops (TSS - Transportation Simulation Systems 2010). The course was set along the avenue of Moscavide for all buses, and was defined that the buses stopped at the RL's first and last stop, while Carris buses used all the stops

Traffic states were used for the demand of individual transport, since the network is small and does not allow closed loops. These are characterized by flows of vehicles with entries in sections that are not linked to another section, and for the remaining sections and intersections, by percentages for each of the possible moves (TSS - Transportation Simulation Systems 2010).

Due to a license limitation the program did not allow the use of pedestrians simulator so it was necessary to create a model for use in non signalized crosings, considering that in signalized crossings pedestrians used the time available. For this, traffic lights with fixed cycles were used, in which time of red matches the time that the flow of pedestrians needs to cross the pedestrian crossing.

This model has some shortcomings, notably fails to reflect the randomness associated with pedestrians, forces the stop across the lane width, and also simulates pedestrians crossing in large groups.

As the AIMSUN does not have a model for the simulation of the second lane of parking or loading/unloading operations, it was necessary to arrange an alternative that would allow this behaviour to be simulated as realistically as possible. Public transport lines were used as replacement. Stops were placed in locations where there is more second lane parking and load/unload operations.

After building the model it needed to be verified, calibrated and validated. In the verification process the tool “check and fix network”, found no errors. There was also a visual check using the micro simulator to see if all behaviour would be as expected.

For the validation of the model it was used as criteria the t-student test of the difference between the commercial speeds measured in the model and in Avenida de Moscavide, For a confidence level of 95% ($^{\propto}/_{2} = 0{,}025$), and 660 degrees of freedom, the confidence interval was $[-1{,}39; 0{,}32]$ as it contains 0, it passes the criteria, and the commercial speed obtained was 9,81 km/h.

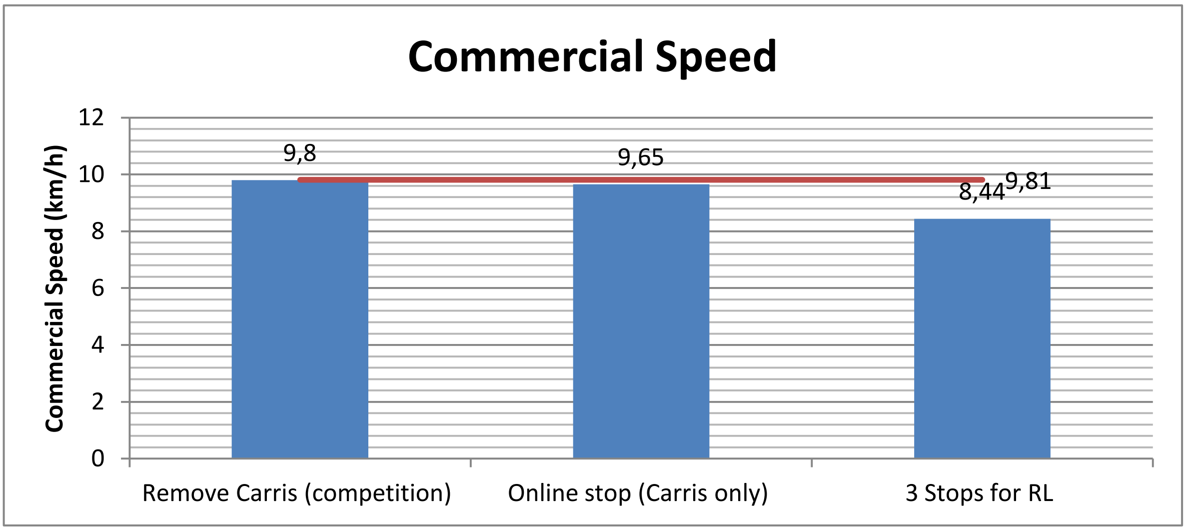
A whole series of changes to test were created, such as: creating a new stop for the RL, transforming one of the stops in an online stop, completely removing Carris, doubling the parking in the second lane and tripling the loading/ unloading operations, eliminating the parking in the second lane and the loading/unloading operations, doubling and tripling the parking in the second lane; doubling and tripling the loading/unloading operations; varying the dwell time. (80%, 90%, 110%, 120%); varying the traffic flows. (80%, 90%, 110%, 120%), and varying the number of pedestrians (0%, 125%, 150%).

Some of the changes like removing Carris, making the stop online and applying variations of traffic and pedestrians are considered to assist in the decision to change or not the way to a more a favourable one, or to help chose routes for new bus lines in the area. The other changes have the same objectives as those set out above, however, allow testing and accounting for possible actual measures to implement.

6 Results

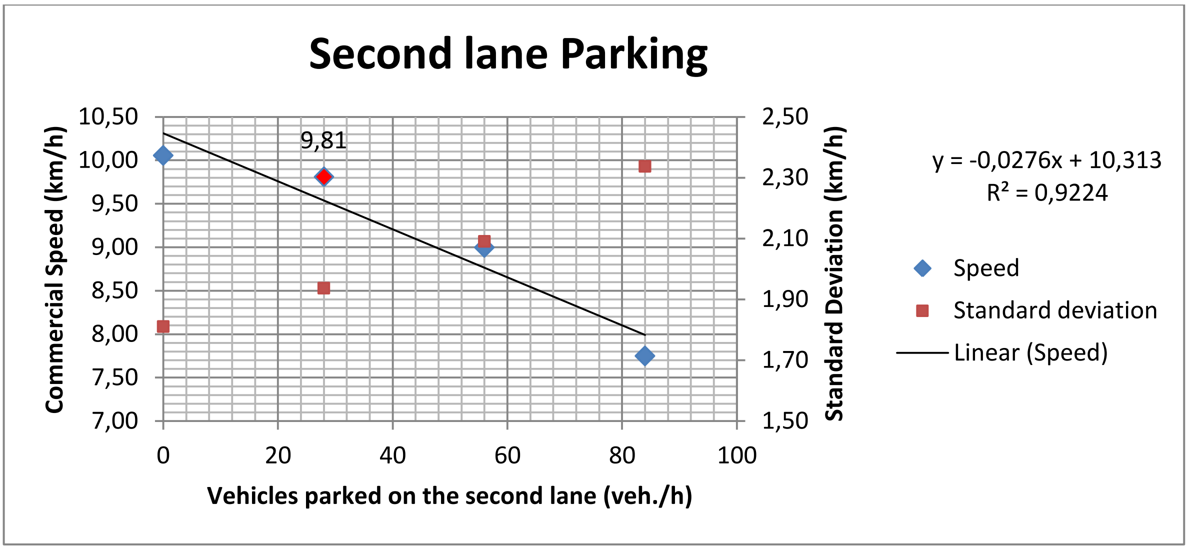
To obtain results, 50 simulations were made for each of the experiments, calculating the average commercial speed of buses and standard deviation. The t-test of difference of means was also done between each of the experiments and the initial value. The standard deviation provides information on the reliability of the average speed; with higher standard deviation will have major delays or advances of the bus, so in addition to getting a higher commercial speed it is also important to ensure a low deviation.

In (Graph 1) it is possible to compare some of the main experiences with the starting values. By removing completely the Carris buses from Avenida de Moscavide commercial speeds decreased 0.1% showing that for identical conditions, the existence of another operator has very little influence on the commercial speed. When the Carris bus stop is set as an online stop, there is a slight decrease in speed the speed in RL bus. Halving the distance between stops (from 500m to 250m) accounted for a reduction in commercial speed by 14%.



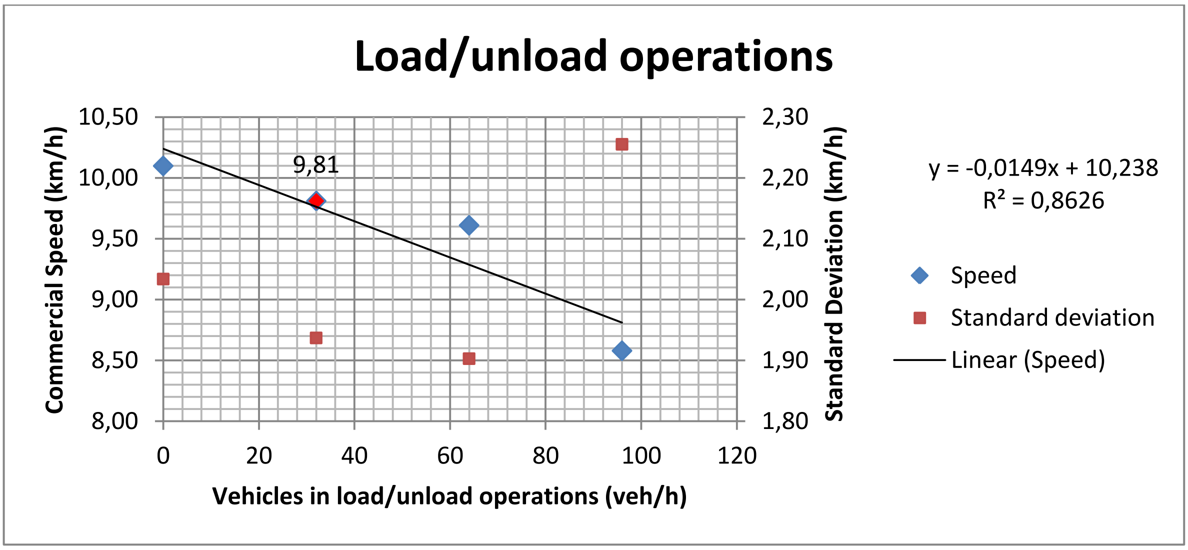
Graph 1 - Operational Changes

Graph 2 presents the commercial speed and standard deviation of the number of vehicles parked on the second lane. The linear regression between speed and number of commercial vehicles in the second lane shows a negative slope and an $R^2$of 0.9224, indicating that the regression fits to the data. This value is quite high in some cases due to the small number of observations used in regression. As can be seen in the graph the standard deviation increases when the vehicles parked in the second lane increase.



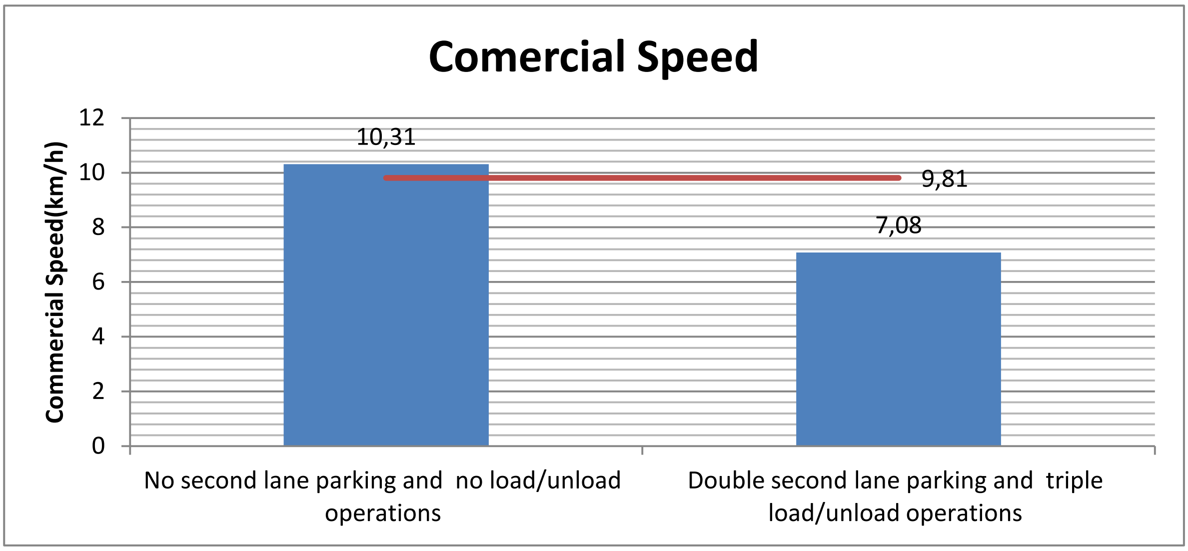
Graph 2 – Parking Variation

The speed variation with the number of loading/unloading (Graph 3) has behaviour similar to the number of vehicles parked in the second lane. R^2 is 0.86, which represents a good approximation of the values to the line, however, is lower than the $R^2$of the second lane parking.



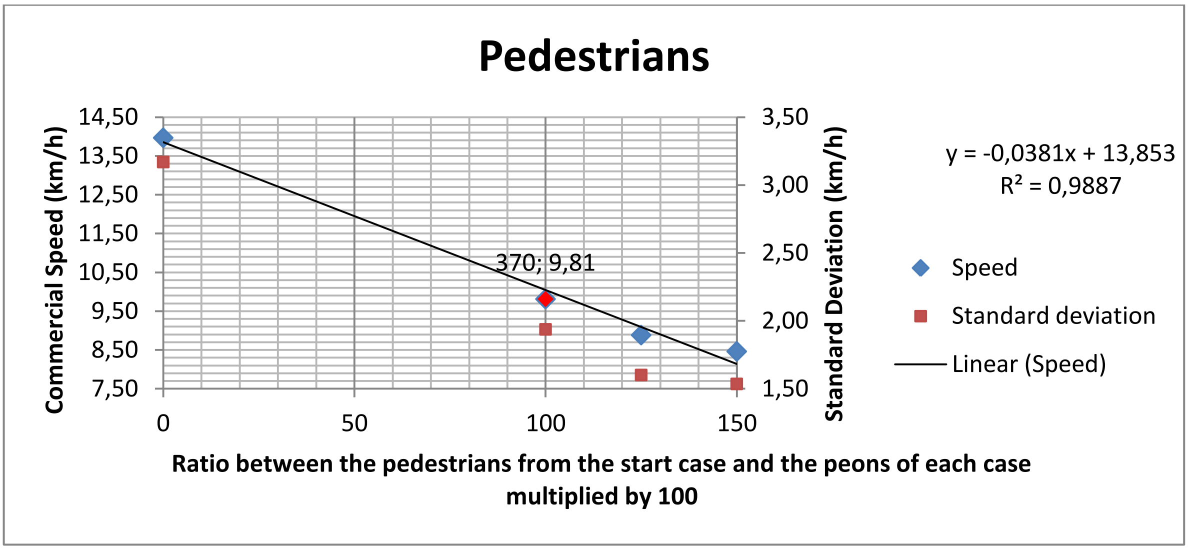
Graph 3 – Second Lane parking variation

If the loading/ unloading operations and parking in the second lane are completely removed (Graph 4) an increase of 5.1% is obtained. By doubling the parking lot, and tripling the loading/unloading there is a decrease of 27.8%.



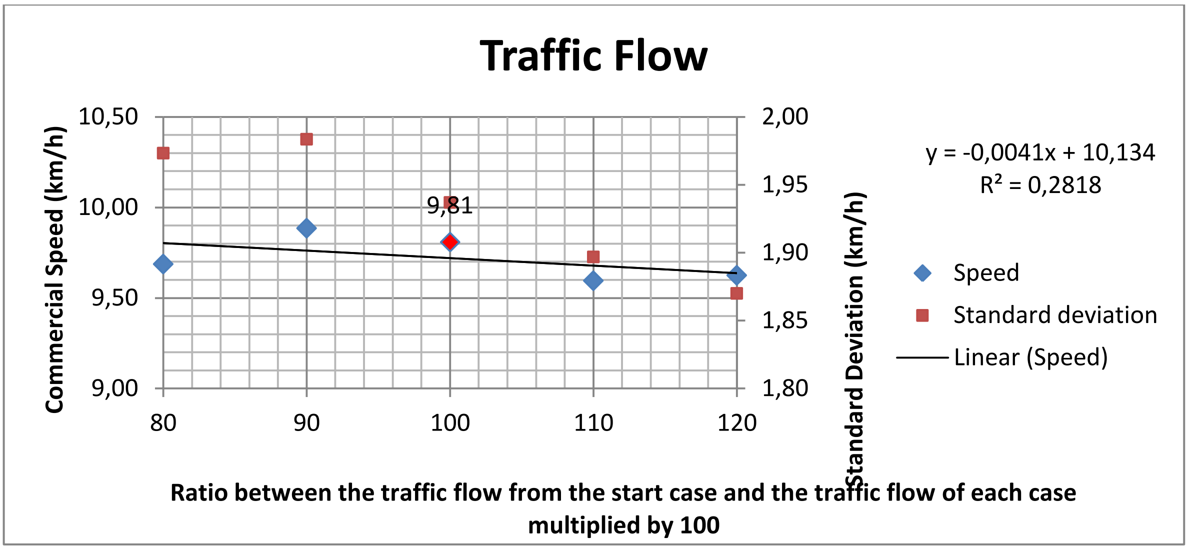
Graph 4 – Second Lane Parking and Loading/unloading operations

As can be seen by the results of Graph 5 pedestrians have great influence on the commercial speed. The increase in the number of pedestrians reduces the commercial speed. By completely removing pedestrians there is an increase of 42.4%, the highest achieved in all experiments. The R^2 of 0.9886, the highest so far, shows that the values obtained for the number of pedestrians have a strong linear relationship. The standard deviation also decreases with increasing number of pedestrians; this is probably related to the model used for pedestrians, since the model is not random and assumes that the pedestrians cross in large groups spaced in time, defined by the cycle.



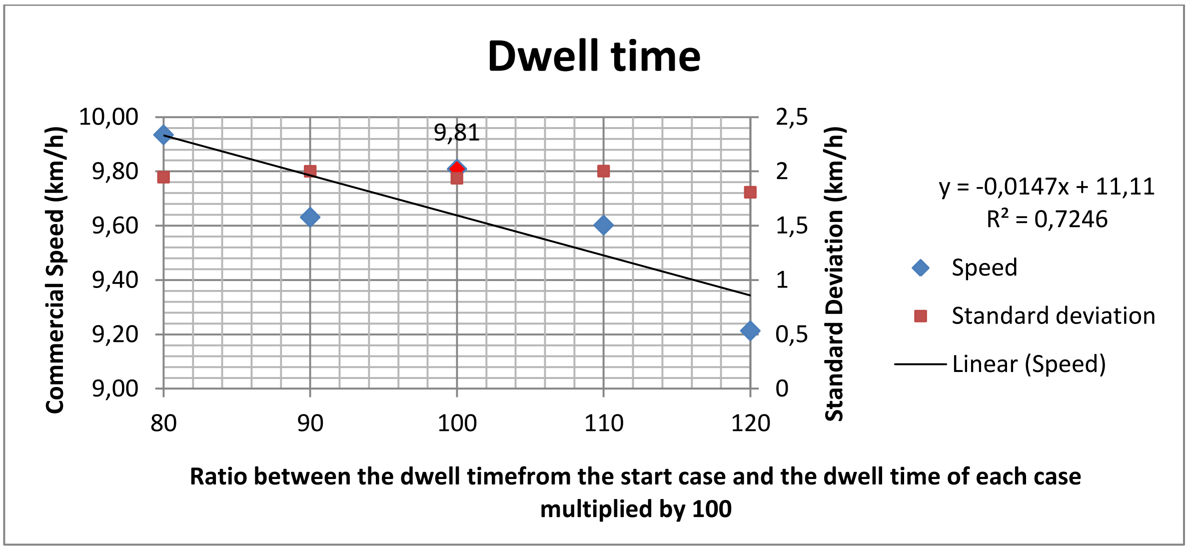
Graph 5 – Pedestrians Variation

The variation of traffic flows (Graph 6) shows that there is no clear relationship between increased commercial speed and traffic. The linear regression shows that with increased traffic commercial speed decreases. However, the R^2 of 0.28 shows that the values do not adapt well to the regression. The variability of values can be explained by the small variations and by the resulting flows which are about half the capacity of the roads.



Graph 6 – Traffic Flows variation

When varying the dwell time (Graph 7), the relationship between dwell time and the commercial speed is not obvious as can be seen in the graph. With linear regression the commercial speed decreases when increasing the dwell time. The R^2 of 0.724 shows that there is a reasonable linear relationship between commercial speed and dwell time. One would expect that by increasing the dwell time of each bus, commercial speed would be degraded, which does not happen in some of the situations presented in the graph. This can be explained by the small variations compared with the standard deviation, which amounts for more than 70% of the average.



Graph 7 – Dwell time variation

With these results it is possible to create several measures to implement in Avenida de Moscavide.

The removal of a stop increasing the distance between stops will improve the commercial speed, however, decreases the accessibility of public transport.

The use of stops on the road in contrast with stops in a bay makes it easy to re-enter the traffic flow improving dwell time and, in turn, the commercial speed. However, this affects the vehicles, private and public transport, and decreases the safety of customers.

Further decreasing the second lane parking on the road improves circulation, and the complete removal of the parking lot would have the same goal.

The creation of spaces and times for loading/unloading operation would reduce its impact on the mobility of vehicles in Avenida de Moscavide.

The variation in the number of pedestrians has a strong impact on the commercial speed, but it is not practicable to reduce the number of pedestrians from the road. In this case the traffic flows do not have such a strong influence on the commercial speed as pedestrians, however, both results can be used in choosing an alternative route if the objective is not to serve directly Avenida de Moscavide

Change billing procedures through the implementation of pre-purchased tickets or contactless ticketing, or the use of measures such as lowered floors and improved internal circulation will improve downtime, which in turn allows for a better commercial speed.

7 Conclusions

The increase of commercial speed of public transport has benefits not only for operators and customers, but also for the whole community. The increased speed reduces operators' costs and increases their revenues, but also improve customer travel times, reduce congestion and improve mobility throughout the community. Therefore, improving the commercial speed of public transport must not only be an objective of the operators, but also an objective of local and central government.

Factors that showed major changes during the different simulations described above were the change in the number of pedestrians, with variations that reached 42.4%, and changes in second lane parking and loading/unloading, in which gave variations of 27%. When a decrease in the distance between stops from 500m to 250m commercial speeds dropped by 13.9%. A change in dwell time could be a variation of 6%. In other cases the changes were less than 5% but should not be neglected. By Removing Carris the commercial speed variation is 0.1% thus indicating that, in this case, the existence of a competing operator has little influence on the commercial speed.

These results support the measures proposed, such as the importance of the distance between stops, allowing evaluating and comparing the advantages of having fewer stops and better commercial speeds with the commercial advantages of having more stops and greater accessibility. It was proven the importance of monitoring the parking in a second lane that has a strong impact especially in buses, for they do not have the ability of a smaller car, being forced to reduce its speed or even completely stop, which will affect the speed trade. The loading/ unloading also have a similar impact on commercial speed; however, for it the measures are to create their own spaces or even hours for loading/unloading services.

With the accounting of the impact of pedestrians on the service it is possible to choose alternative routes that do not increase travel time. The reduction of dwell time has a direct effect on the commercial speed that is intrinsic to the very definition of this speed. Although the results presented have not always supported this fact, measures to improve downtime, such as improving circulation within the vehicle, the use of double doors or the use of electronic systems to collect bus fares have an impact on the final commercial speed.

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