ORIGINAL PAPER

# CONGESTION MINIMIZATION THROUGH SUSTAINABLE TRAFFIC MANAGEMENT. A MICRO-SIMULATION APPROACH

## Oscar Cárdenas, Alejandra Valencia, Cecilia Montt

Catholic University of Valparaiso, Valparaíso, **Chile**

**ABSTRACT**. **Background:** The congestion is a serious and often occurring problem in many countries. In present paper the management of a high circulation road connecting two mainstream cities in Chile is tackled. The cities are connected through a coastal road and is permanently under congestion effects. This situation leads to much discontent in the users and negatively impacts both economically and environmentally as well.
The aim of this paper was to create a proposal of solution of road transportation system based on a provided case study.
**Methods:** To minimize the impact of congestion in this problem setting, a micro-simulation is performed in VISSIM. This model, incorporates the road and its users and represents their driving behavior and its impact on congestion.
**Results:** Throughout the experiments conducted, the emissions of CO2 are calculated; this allowed to define a set of congestion minimization strategies that also reduce emissions. These strategies were validated under a set of real-world scenarios and were able to solve a set of specific road management problems and optimize average travel time for users.
**Conclusions:** The model, the strategies and a case study are introduced and discussed to solve the problem of congestion, also, future research directions are given.

**Key words:** simulation, traffic management, public transport, emissions.

## INTRODUCTION

In Valparaiso Chile, a World Heritage Site, there is a road named España Ave. joining Valparaiso and Viña del Mar. On this road, there is a zone receiving vehicle flow from two hills of Valparaiso named Pelle - Portales. The problem is there is congestion on both España Ave. and also in the intersection during the hours with greatest vehicle flow between 7:00-9:00 AM, referred to as the peak hours, which generates an increase in vehicular conflict, longer journeys between home, work or study and higher operating costs of vehicles and environmental impacts [Backfrieder, Oster-mayer, Mecklenbräuker, 2017, Thompson, 2007]. Therefore, the aim of this research proposes measures to help reduce the generated congestion and conflicts by simulating the intersection and applying urban traffic management for efficient use of roads.

For the development of the work using the VISSIM micro-simulation program, the objective is to study a proposal of a governmental project in the works that consists of an underpass in the aforementioned intersection [VISSIM, 2015].

Therefore, the focus of this research is to incorporate the study of priority measures for public transport into the governmental project; as a short bus lane, redesigning bus stops according to flow and passenger demand as well as priority measures at traffic lights using short-cycles that increase the performance of the intersection [Fernández, 2008, Daniels, et. al. 2018]. In addition to this, it is suggested to make efficient use of automobiles through the shared vehicle system in order to find

a mobility plan for those wishing to use a private car, and make the use of public transport more attractive for various purposes that involves reducing travel times and providing better use of traffic infrastructure proposed. A technical and economic assessment was also conducted [Barbosa et. al., 2017, Gibson, Fernández, 2009].

In the following chapters, the importance of micro-simulation, the characteristics of the research area and the methodology will be described, and the case study will be analyzed to then present the results, conclusions and economic assessment [Camus, 2014, Wiedemann, Reiter, 1992].

## MICRO-SIMULATION

In developing countries, mainly in Latin America, urban traffic management has to deal with a significant percentage of public transport vehicles. Thus, it is necessary to consider the greatest number of conflicts that occur between buses of any kind and the rest of the traffic – mainly automobiles – due to differences in their behavior. In this complex reality, the decision to harmonize the movements of different means of transportation needs to be assisted by modeling tools that provide benefits and costs of the measures to be implemented at each place. For that purpose, there is a wide range of micro-simulators offered in the market (AIMSUN, PARAMICS, TSIS, VISSIM, etc.) [SECTU, 1988, SERVIU, 2013, TCRP, 2003, VISSIM, 2015, TCRP, 1996].

Microscopic traffic models are potentially useful to discuss control strategies and make predictions of operational performance of the road network against different situations; therefore, they constitute an essential strategy for the tool management analysis, traffic control and traffic flow. Thanks to the current IT potential, they allow the single behavior of each vehicle to be reproduced in detail. They simulate each vehicle trajectory in time and space by using models to represent the interaction between them [Davidsson et.al., 2016, Xu, Chen, Yang, 2016, Wiedemann 1974, TRB, 2000].

The VISSIM micro-simulator is used in this work VIssim is the most complete simulation program today, which employs a vehicle monitoring and switching lane model as well as other modellings that have been incorporated [Wiedemann and Reiter 1992], where the movement of a vehicle is described with a driver who wants to drive faster than the speed exhibited by previous vehicles. If more than one lane is available, vehicles will tend to pass, which is modeled by a rule based on lane switch algorithms.

VISSIM modeling urban and rural traffic as well as pedestrian flows. The software simulate private transportation, rail and road based public transportation.

The microscopic simulation allows to consider individual characteristics of the vehicles, but at the same time to make interactions with the other vehicles, therefore, allows the researchers to have a continuous vision of the state of the traffic under determined conditions.

VISSIM models the behavior of the driver in three phases which are: car following model, lane change, lateral movement and control by traffic light. VISSIM uses the psycho-physical perception model [Wiedemann 1974-2009]
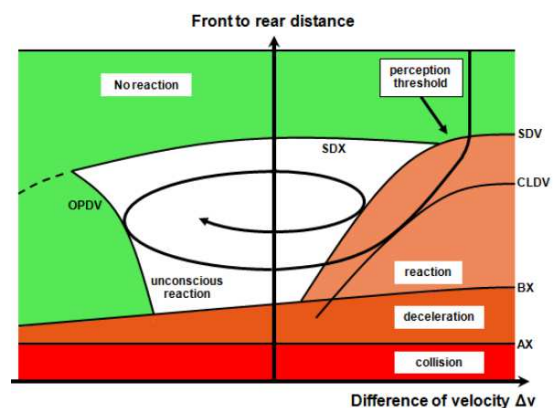


Source: Wiedemann 1974

Fig. 1. Car following model

"The basic concept of this model is that the driver of a faster moving vehicle starts to decelerate as he reaches his individual perception threshold to a slower moving vehicle. Since he cannot exactly determine the speed of that vehicle, his speed will fall

below that vehicle's speed until he starts to slightly accelerate again after reaching another perception threshold. There is a slight and steady acceleration and deceleration. The different driver behavior is taken into consideration with distribution functions of the speed and distance behavior." [Wiedemann 1974-2009] This comportment is observed in Figure 1.

VISSIM may be deployed to answer various issues, how: comparison of junction geometry, traffic development planning, capacity analysis, traffic control systems, signal systems operations and re-timing studies, public transit simulation [VISSIM, 2015].

## RESEARCH AREA

According to [MIDEPLAN 2009], España Ave. shows characteristics of being a road with a high capacity to move traffic flows, considering a total of around 6500 [veh/h] in both directions (UOCT, 2011), at morning peak hours (07:00 - 09:00 A.M) and a design speed between 50 and 80 [km/h].

On the other hand, the Pelle-España Ave. area, in addition to the high flow of vehicles, has a strong component of public transport, whereas the composition of the flow is different through Pelle, where the circulation of taxis is significant. There are also stops that ease the unloading of passengers when arriving at Pelle, as well as the location of the Portales station of the VALPARAÍSO SUBWAY, which generates significant pedestrian flow. Its complexity is enhanced by the fact that it attracts a lot of trips to the area (academic and working area), so the research area is comprised as shown in Figure 2.


Fig. 2. Area of Pelle-España Ave

Regarding the design features, the España Ave. axis approaching the intersection with Pelle is bidirectional, irregular in terms of the number of lanes in certain segments, just as it is from Viña del Mar to Valparaiso, where it is a 3-lane road, but when approaching the traffic light intersection, it reaches 5 lanes, with 2 exclusive lanes turning towards Pelle. When passing the stoplight, the bus stop 1 with an inlet to later return and have 3 lanes towards Valparaiso. In the reverse direction, when approaching the intersection it comes the bus stop 2 with an inlet and after the traffic light the bus stop 4 with an inlet, to then have 3 lanes towards Viña del Mar. As for Pelle, it is bidirectional with 2 lanes towards Placeres and 3 lanes towards España Ave. with a median strip when approaching the intersection, used as a pedestrian rest, almost 2 meters wide (Figure 3).


Fig. 3. Characteristics of Pelle-España Ave

## METHODOLOGY

For purposes of modeling the Pelle zone, it is necessary to gather data such as traffic flows, traffic lights programming, bus delays at bus stops, occupation rates of buses and automobiles, speed and line length measurement, according to the well-known methodology of data collection, with the purpose of determining the process of simulation of the current situation and the calibration of the model. Within the calibration process, dimensions of vehicles (specifically buses) and average speeds are added within the modeled network [MIDEPLAN 2009] and [SECTU 1988].

Once the model has been assessed, a base situation is modeled (a project proposed by SERVIU, a public body linked to transport), followed by an improved situation that

corresponds to the optimization of the base situation, including analysis proposals, carpool and the priority of public transport with only short bus lanes stops. Subsequently, the comparison of results is performed given VISSIM reports and conclusions of the work.

## MODELLING AND CALIBRATION

In this point, the procedure of modelling and calibration of the current scenario of VISSIM 8.0 [VISSIM PTV 2015] of España Ave-Pelle is explained.

### Input data and model

The Simulation is performed for the area shown in Figure 5; and in this zone, there are schools, universities and a train station.

The input data correspond to the information described in the methodology and movements in Figure 4. The calibration was carried out by comparing queue lengths and average speeds. When the parameters were adjusted, differences of less than 10% were measured, thus the final modeling of the intersection corresponds to Figure 3.
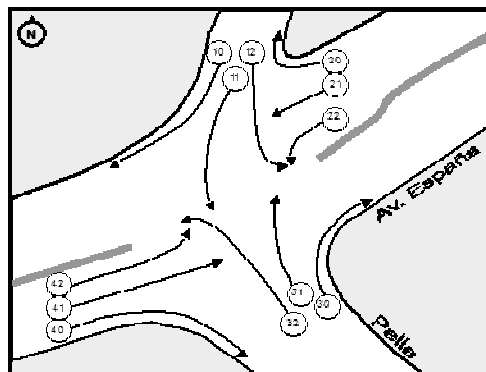


Fig. 4. Movements in the España Ave-Pelle area

### Analysis of results and diagnosis

A brief analysis indicates that the intersection shows saturations due to the high demand of public transport interacting at bus stops and the strong presence of light vehicles, and the behavior of the drivers and the lack of limits in the area increase inefficiency in the use of roads.

Regarding queues, they can reach a greater distance than 300 meters in congestion scenarios at peak times from Viña del Mar to Valparaíso and vice versa.

Pelle, España Ave. and the entrance to the Portales Cove opposite Pelle has a 3-stroke traffic light, which allows all possible movements, except for the left turn from España Ave. towards Portales. Since it is the only traffic light in the proximity, it operates with a cycle of 142 seconds: 37 seconds of green light for Pelle access and the remaining time gives priority to the flow coming from the España Ave. Therefore, Pelle Street produces the highest saturation, where you can reach queues of more than 15 vehicles per Lane. This situation results in the complete lock of the axis, blocking the Pelle intersection upstream.

Another situation that generates conflicts in the zone is non-established stops to pick up and drop off passengers, and geometry, mainly horizontal, in particular the sinuosity in the area, preventing vehicles from maneuvering with fluidity, thus reducing traffic speeds [SERVIU 2013].

## MODELING OF BASE AND IMPROVED SITUATION

This chapter describes the proposal of the project of SERVIU as a base situation and, as an improved situation, the priority measures for public transport with short bus lanes in España Ave., traffic light optimization and use of a shared vehicle.

The project seeks to reduce directional conflict and impact of intimidation caused by the nature of the traffic flow through the intervention of a 3-lane underpass in each direction. This would cause higher volumes of traffic flow to have continuous circulation, without being affected by the regulation of traffic lights, whereas other volumes from Pelle distribute their movements by the accesses regulated by traffic lights; see Figure 5.

With this proposal, an important space recovery for pedestrians is achieved, not only reducing congestion, but also intimidation, emissions caused by stops, idle effects and an increased visual perception in terms of safety.

However, the project does not provide efficient operation of the use of bus stops, as their efficient use is given by the number of places recommended according to the time buses are stopped [TCRP 1996], but it is also worth analyzing the efficiency of the bus stops by their number of places [Fernández 2008]. Currently, buses have an average stop time of 10-30 seconds, and having a flow higher than 180 [bus/h] per direction in theory justifies designing 3 to 5 places at bus stops with greater passenger demand (axis España Ave.); however, when the number of places is 5, divided stops must be considered, since the efficiency is optimal at a maximum value of places if they are equally arranged.



Fig. 5. SERVIU Project in España Ave.- Pelle Area

The improved situation has the same characteristics of the base situation, incorporating traffic light optimization, implementation of short bus lanes and carpool.

## Optimization of traffic lights

Regarding traffic lights, a short-cycle time of 90 seconds is modeled with the same group of phases of the base situation to have a better performance, especially at Pelle access. The allocation of a 90-second cycle is not arbitrary and may be smaller, as it has been shown that the traffic lights schedule influences the commercial speed if priority measures are implemented for public transport at traffic lights. Thus, increases of up to 5% in commercial speed might be expected if the

traffic lights are scheduled as established by [Gibson and Fernández 1996]. Therefore, for modeling we consider the optimal spacing of bus stops, a short-cycle traffic light schedule and a ratio of effective green light (green / cycle) equal to or greater than 0.6 that deliver better performance indicators by reducing delays to public transport.

## Implementation of short bus lanes

This type of lanes only allows traffic for public transport, leaving the rest of the lanes for private vehicles through hurdles or studs. They are usually located on the right side of the artery, although there are also some stretches to the left of the road, so these do not have a unique design since they can also have 1 or 2 lanes depending on the bus flow. These arteries also have stops that modify their spacing according to the demand existing in each place [Camus 2014]. The idea is that these routes operate during peak hours, from Monday to Friday from 7:30 a.m. to 10:00 a.m. and from 5:00 p.m. to 9:00 p.m., except on holidays (MTT, 2016). The main advantage of this system is that you can move a large number of people in a short time and at a much lower infrastructure cost than a subway. However, for proper operation, it must be designed together with a general bus system restructure [Thompson 2007]. On the other hand, it is important to note that to implement short bus lanes in this project, a minimum recommended bus flow according to some criterion such as [TCRP 2003] of 60 [bus/h] per direction must be met. This is fully complied with, since there are 359 [bus/h] per direction on España Ave. The base project does not include the case of using bus stops by the Metropolitan Transportation of Valparaíso (MTV) and for that reason, a redesign in the system of buses is being made so the implementation of short bus lanes has a positive effect on the model.

It is arbitrarily modeled as evidence to stop at bus stops on 14 of the most frequently used lines out of the 45 currently operating in España Ave., the rest use the underpass without stopping in the modeling.

**Use of the shared vehicle**

For the case of the shared vehicle, only input data (traffic flow volume factors) are modified.

Given that the use of a shared vehicle makes possible drivers into possible passengers, it naturally implies that there is less involvement of light vehicles within the network, and therefore, the volumes of the measured situation are reduced.

The abovementioned justifies using the vehicle in at least 30% of the whole circulating in the area to obtain significant positive results.

This situation proposes taking into consideration an alternative project as a future work, which recommends the use of mobile applications and the Internet to generate the carpool, encourage this travelling method (through advertising) providing information to the community and institutions, both public and private partnerships that reward the use of the shared vehicle for those who provide an optimum service given the ratings they receive from other users. They may have certain royalties in terms of parking, fuel bonus, among others. The modeling of the improved situation is shown in Figure 6.

The colored areas represent the overtaking lane and they indicate the start of the segregated lanes with a continuous line.



Fig. 6. Modeling of current situation and improved situation of España Ave.- Pelle Zone

# RESULTS

The main approach of this chapter is through simulation reports to make general comparisons of performance indicators.

**Co$_2$ emissions**

One of the most important aspects nowadays when evaluating projects is the level of sustainability it offers in the optimization of processes; therefore, the proposals for this case are not foreign to the established requirements regarding the environmental impact.

The results show that the emissions generated in both the base and the improved situation dropped from 1263 [gCO2 x km] to 686 [gCO2 x km]. Although it is true that the SERVIU proposal is an alternative solution that reduces several impacts of congestion, it cannot avoid congestion at the entrance of the

intersection, since nowadays all buses make free use of all the bus stops and for that reason there are increased emissions of gases into the atmosphere. But not in the case of the improved situation, the optimization of traffic lights including a stopping system for certain MTV lines (which requires deeper research for future work) contributes to the objective of the remodeling of the Pelle area. The effect of this project reduces emissions by 54.3% compared to the base situation.

## Fuel consumption

The emission level also means lower fuel consumption from 18 [km x l] to 9.8 [km x l] resulting in a decrease of 50.2% of the improved situation compared to the base situation.

## Travel times

Travel times of vehicles entering the intersection and the comparison of the base and improved situation are shown in Figure 7, where "Travtm" means travel time and (10) corresponds to light vehicles, (20) to trucks and (30) to buses.

Total travel times of the improved situation show a progress of 24% for private transport (TRAVTM (10)) and 42% for public transport (TRAVTM (30)) with respect to the base situation. An initial observation indicates that proposed measures have greater effects on public transport than on private transport.
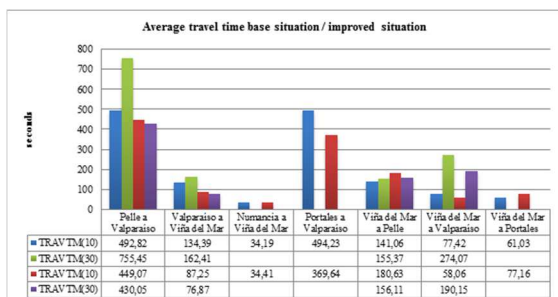


Fig. 7. Comparison of average travel times

## Queues

The total average queue length of the base situation is 47.58 m and the improved one shows a total queue average of 38.99 m,

exhibiting a variation of 18%. Figure 8 graphically shows the results between the base and improved situation.
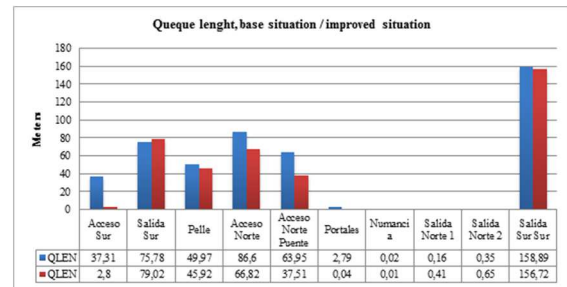


Fig. 8. Comparison of queue lengths

## Stops

The number of stops is significant, from which direct fuel consumption and emissions of gases to the atmosphere are derived. Figure 9 shows the comparison of the stops per vehicle in the base and improved situation for vehicles of private and public transport.
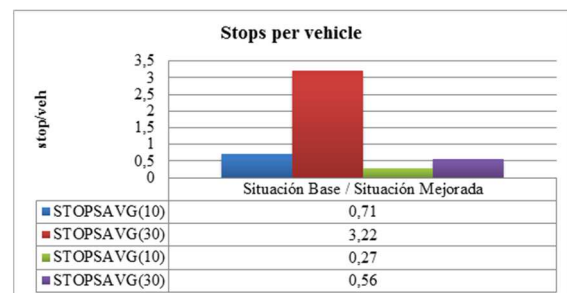


Fig. 9. Comparison of stops per vehicle

According to Figure 9, the stops have significant improvement, mainly those of public transport with a decrease of 82.6% and a 62% for private transport compared to the base situation.

## Average speeds

Speeds have increased regarding the base situation, not only for private transportation (10) of 4 km / h, but also for public transport (30) 7 km x h, as shown in Figure 10.

The variation between the improved and base status signifies a 14% increase in travel speeds.
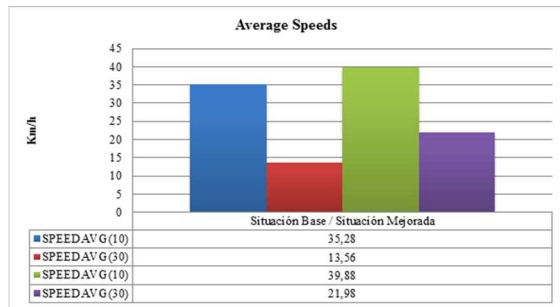
Fig. 10. Comparison of average speeds

## Delays and Level of Service (LOS)

The average delays per vehicle are important to determine the level of service. In Figure 11, the comparison of average delays between the base and improved situation is shown, compared to the delays produced in each entrance caused by the effect of the stops at traffic lights.

Delays for private transportation to the improved situation decreased by 13.48 sec, corresponding to 28.9% relative to the base position and in 80.31 seconds for public transport, which equals a decrease of 53.2%.

The Highway Capacity Manual has defined certain criteria to determine the level of service (LOS stands for "Level of Service") [TRB 2000], which are detailed in Table 1.
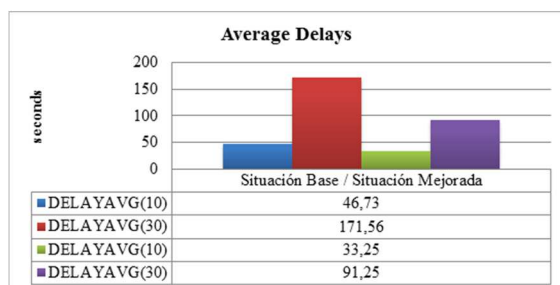


Fig. 11. Comparison of average delays

Table 1. HCM Level of Service Criteria

| Level of Service (LOS) | Delay per vehicle (Seconds) |
|---|---|
| A | <=10 |
| B | >10 Y <=20 |
| C | >20 Y <=35 |
| D | >35 Y <= 55 |
| E | >55 Y <=80 |
| F | >80 |

With this last chart and the results of the base situation the level of service is D in the best scenario (42.75 sec total average), which is a sensitive status against any congestion contingencies and events that may happen (accidents and isolated cases of traffic jams). On the other hand, the improved situation achieves an increase of the level of service B (16.11 total average sec).

In summary, the improved situation regarding the base situation manages to relieve the problem of congestion and proves the hypothesis that short-cycles (120 sec versus 90 sec) as established by [8] at traffic lights and the use of short bus lanes positively influence speeds and queues, improving efficiency by 14% and 18% respectively

On the other hand, the hypothesis raised about the participation of the shared vehicle contributes to a decrease in the presence of private vehicles, benefiting everything as a whole from a 38.3% increase in the journey speed of buses.

## ECONOMIC ASSESSMENT

The economic assessment considers annual social benefits to save fuel and travel time, investment costs are involved in order to obtain the benefit-cost ratio and the internal rate of return (IRR) to assess the feasibility of the research.

The total annual travel cost for the base situation is US $65,551/year, while the improved situation for this cost is US $20,965/year. Said cost between the base and improved situation leads to a 68% optimization.

The total annual cost of fuel consumption is US $14,459,137 for the base situation and for the improved situation is US $4,751,096. The latter represents a cost reduction of 67.14% between the base and improved situation.

In terms of annual benefits, a total of US $35,734,133 is obtained. Social investment costs reach a total of US $39,705,048 for 2017. When evaluating the 20-year research and

a discount rate of 6%, an internal rate of return of 101% is obtained. This value is understood, since an assessment is made from users' perspectives, as demand increases through time, as a user's perception of all measures offered to reduce their costs in travel times and fuel consumption are more valued.

## CONCLUSIONS

This work allows primarily for it to be indicated that the Pelle-España Ave. junction obviously requires an intervention in the design of its road infrastructure. It is advisable to carry out SERVIU's proposal, not only because it reduces congestion in the area, but it also positively influences in other issues such as pollution.

However, not considering the redesign of the public transport system (TMV) would cause a serious problem in terms of the proposed design, since the number of places required by the bus stop (supply) and the high presence of passengers (demand) would not have the adequate response capacity, introducing congestion at exits towards Valparaiso (at peak morning hours) and, as an assumption, towards Viña del Mar (at peak afternoon hours).

As for the suggested proposals, considering the use of short bus lanes at bus stops, the use of shared vehicles of a 30% minimum and a cycle of traffic light of 90 seconds on the base situation is able to relieve the problem of congestion.

On the other hand, and in a complementary way, it is of interest to use unsteady message indicators regarding the schedule to use these proposed lanes, with the aim of adequately informing the user of their presence.

Obtained results would have better yields if observations are considered regarding the design proposed by SERVIU, redesigning stops based on the bus flow and the demand according to some of the recommended criteria (as for example recommendations of the TCRP [11].

Regarding the experience of using PTV VISSIM 8.0, a friendly interface with great versatility and workflow in modelling is raised, but there are some difficulties in certain aspects related to the reports and their subsequent interpretation; for example, there is no distinction between the delay at bus stops and passengers, and in terms of speeds, journeys of the public transport are reported, but there is no remark on their commercial speed.

Another observation regarding the reports is the urban traffic performance indicators, specifically referring to the degrees of saturation and the capacities of traffic devices (road sections, stops and intersections); these are also not clearly specified.

The results of public transport are also deficient in detailed information on bus stops such as parking times, internal waiting times, stop rates and degrees of saturation. Therefore, given that VISSIM is one of the most complete software on the market, it does not have specific models describing in great detail the operation of public transport, these being one of the systems allowing congestion to be reduced.

The future work of this paper focuses on evaluating a greater number of experiments of priorities for public transport, evaluating, for example, what measures are better in relation to the different types of routes, their interaction with mixed traffic and the impact of these on the planning of the cities.

## REFERENCES

Backfrieder Ch., Ostermayer G., Mecklenbräuker Ch.F., 2017. Increased Traffic Flow Through Node-Based Bottleneck Prediction and V2X Communication. IEEE Transactions on Intelligent Transportation Systems, 18, 2, 349-363, https://doi.org/10.1109/TITS.2016.2573292

Barbosa S.B., Ferreira M.G.G., Nickel E.M., Cruz J.A., Forcellini F.A., Garcia J., Guerra J.B.S.O., 2017. Multi-criteria analysis model to evaluate transport systems: An application in Florianópolis, Brazil.

Transportation Research Part A: Policy and Practice , 96, 1-13.
https://doi.org/10.1016/j.tra.2016.11.019

Camus C., 2014. Analysis of the Theory and Practice on Measures to Grant Priorities to Public Transportation. Report to apply the title of Engineer in Civil Works, Los Andes University.

Daniels M.J., Harmon L.K.,  Vese Jr. R., Park M., Brayley R.E., 2018. Spatial dynamics of tour bus transport within urban destinations. Tourism Management, 64, 129-141.
https://doi.org/10.1016/j.tourman.2017.08.0 07

Davidsson P., Hajinasab B., Holmgren J., Jevinger A., Persson J.A., 2016. The Fourth Wave of Digitalization and Public Transport: Opportunities and Challenges, Sustainability 2016, 8(12), 1248;
https://doi.org/10.3390/su8121248

Fernández, R, Elements of the Theory of Traffic, 2008 pp. 40 – 42 – 150 – 153.

Gibson J., R. Fernández, 1996. Effect of a signalized intersection downstream on the capacity of a bus stop with multiple places. Engineering Notes. 19(4), 31-40.

MIDEPLAN. 2009. Recommendations for the Design of the Urban Traffic Space, REDEVU. Santiago, Chile.

SECTU, 1988. Methodology Urban Traffic Projects. MIDEPLAN. Santiago, Chile.

SERVIU, 2013. Engineering Design, Improvement of Traffic Node España Ave.

/ Pelle, Commune of Valparaiso 3rd Edition.Valparaíso, Chile.

TCRP, 1996. Guidelines for the Location and Design of Bus Stops. Report 19. Texas Transportation Institute. NATIONAL ACADEMY PRESS. Washington, D.C.

TCRP, 2003. Transit Capacity and Quality of Service Manual, 2nd edition. Report 100. Transportation Research Board. Washington, D.C.

Thompson I., 2007. Buses on Segregated Roads. New Society, 212. ISSN:0251-3552.

TRB, 2000. Highway Capacity Manual. Special Report 209. Washington, DC-Transportation Research Board.

VISSIM PTV, 2015. User Manual Vissim 7.0. Germany.

Wiedemann R. 1974. Simulation des Ver-kehrsflusses [Traffic flow simulation] Schriftenreihe des Instituts für Verkehrs-wesen, 8, Universität (TH) Karlsruhe.

Wiedemann R., Reiter U., 1992. Microscopic Traffic Simulation: The Simulation System MISSION, Background and Actual State. Proj. ICARUS Final Report Brussels, CEC 2.

Xu X., Chen A. Chao Y., 2016. A review of sustainable network design for road networks. KSCE Journal of Civil Engineering; Seoul. 20, 3, 1084-1098.
https://doi.org/10.1007/s12205-016-1729-1

## MINIMALIZACJA ZJAWISKA KONGESTII POPRZEZ ZRÓWNOWAŻONE ZARZĄDZANIE RUCHEM ULICZNYM. MIKRO-SYMULACJA

**STRESZCZENIE**. **Wstęp:** Kongestia to obecnie poważny i często występujący problem w wielu krajach. Zagadnienie poddane analizie w prezentowanej pracy dotyczy zarządzanie ruchem ulicznym połączenia komunikacyjnego dwóch dużych miast w Chile. Miasta te są z sobą połączone nadbrzeżną drogą, gdzie często obserwuje się zjawisko kongestii. Sytuacja ta wpływa na niezadowolenie mieszkańców tych miast i ma negatywny wpływ zarówno w wymiarze ekonomicznym jak i środowiskowym.
Celem pracy jest stworzenie propozycji systemu transportu drogowego w oparciu o przedstawione studium przypadku.
**Metody:** W celu minimalizacji negatywnym skutków kongestii w analizowanym przypadku, została wykonana mikro-symulacja przy użyciu VISSIM. Otrzymany model, uwzględniając zarówno infrastrukturę jak i jej użytkowników, pokazuje wpływ różnych zachowań tych uczestników ruchu na kongestię.

**Wyniki:** W trakcie przeprowadzanych badań, obliczano również emisję $CO_2$. To pozwoliło na określenie strategii minimalizacji kongestii równocześnie redukujących emitowanych zanieczyszczeń. Wybrane strategie zostały przetestowane dla realnych scenariuszy i są w stanie rozwiązać pewne problemy zarządzania ruchem oraz optymalizować średni czas przejazdu.
**Wnioski:** Zaproponowano model, strategie i obrazujące je studium przypadku dla rozwiązywania problemu kongestii. Zaproponowano również dalszej kierunki pożądanych badań.

**Słowa kluczowe:** symulacja, zarządzanie ruchem ulicznym, transport publiczny, emisja.

# MINIMALISIERUNG DER ERSCHEINUNG VON VERKEHRSSTAUS DURCH NACHHALTIGES MANAGEMENT DES STRASSENVER-KEHRS. EINE MIKRO-SIMULATION

**ZUSAMMENFASSUNG. Einleitung:** Verkehrsstaus stellen ein ernstes und oft auftretendes Problem in vielen Ländern dar. Die im Rahmen der vorliegenden Arbeit analysierte Frage betrifft Management des Straßenverkehrs innerhalb der Verkehrsverbindungen zwischen zwei Großstädten in Chile. Die betreffenden Städte sind mit einer am Seeufer verlaufenden Verkehrsstraße, auf welcher die Erscheinung des Verkehrsstaus oft beobachtet wird, miteinander verbunden. Der Sachverhalt ruft Unzufriedenheit bei Einwohnern dieser Städte hervor und beeinflusst negativ die Wirtschaft vor Ort und die Umwelt. Das Ziel der Arbeit ist es, einen Vorschlag des gängigen Verkehrssystems anhand eines dargestellten Studienfalls zu unterbreiten.
**Methoden:** Zwecks einer Minimalisierung der negativen Folgen des Verkehrsstaus im betreffenden Fall wurde eine Mikro-Simulation anhand von VISSIM durchgeführt. Das ermittelte Modell, das sowohl die Verkehrsinfrastruktur, als auch deren Nutzer berücksichtigt, zeigt den Einfluss unterschiedlicher Verhaltensweisen der Verkehrsteilnehmer auf den besagten Verkehrsstau auf.
**Ergebnisse:** Im Laufe der durchgeführten Untersuchungen wurde auch die Kohlendioxid-Emission berechnet. Dies erlaubte die Ausarbeitung von Strategien für die Minimalisierung des Verkehrsstaus, die gleichzeitig die emittierten Umweltverschmutzungen zu reduzieren vermochten. Die ausgewählten Strategien wurden angesichts der reellen Szenarien durchgetestet und daher sind sie imstande, gewisse Probleme beim Straßenverkehr-Management zu lösen und die durchschnittliche Durchfahrtszeit zu optimieren.
**Fazit:** Es wurde ein Modell, bestimmte Strategien und ein diese Strategien beschreibender Studienfall zur Lösung des Verkehrsstau-Problems vorgeschlagen. Ferner wurde die Ausrichtung von betreffenden, erwünschten Forschungen empfohlen.

**Codewörter:** Simulation, Management von Straßenverkehr, öffentlicher Transport, Emission

Oscar Cárdenas
Transportation Engineering School,
Faculty of Engineering
Catholic University of Valparaiso
Brazil Ave. 2147, 2374631 Valparaíso, **Chile**
e-mail: oscar.cardenas.e@mail.pucv.cl

Alejandra Valencia
Transportation Engineering School,
Faculty of Engineering
Catholic University of Valparaiso
Brazil Ave. 2147, 2374631 Valparaíso, **Chile**
e-mail: alejandra.valencia@pucv.cl

Cecilia Montt
Transportation Engineering School,
Faculty of Engineering
Catholic University of Valparaiso
Brazil Ave. 2147, 2374631 Valparaíso, **Chile**
e-mail: cecilia.montt@pucv.cl