Evaluating a system of exclusive lanes for autonomous vehicle platoons

Gustavo Covas, Eduardo F. Z. Santana, Fabio Kon

Department of Computer Science - IME / University of São Paulo

Introduction

The adoption of Autonomous Vehicle (AV) technologies has the potential to reduce traffic jams and increase traffic safety. However, despite recent advancements on automation technology, full autonomous vehicles are not expected to be available in the short-term [1].

In this work, we analyzed a proposal to allow AVs to share the roads with regular vehicles: Digital Rails (DR). The concept of DR was first elaborated by designers at Questtonó, a design consultancy firm.

The impacts of implementing DR in São Paulo were analyzed with traffic simulations modeled after real data and conducted using InterSCSimulator, a smart city simulator developed at IME/USP.



Figure 1: Concept art for Digital Rails, elaborated by Questtonó

Digital Rails

The authors of the Digital Rails proposal present three main pillars for the system:

1. Open data network: A network that vehicles can access to obtain data about traffic signals.
2. Exclusive lanes: On selected arterial roads, exclusive lanes would be assigned to the system.
3. Vehicle platoons: Vehicles using Digital Rails would organize themselves in platoons and travel through traffic signals progressions.

However, they left open the required level of vehicle automation, communication protocols, and platooning techniques. We assumed that these problems are solved and abstracted them away in our simulation model.

InterSCSimulator

InterSCSimulator is a smart-city simulator based on discrete events. It is written in Erlang and relies on SimDiasca as a discrete event simulation engine. The road network is represented as a graph where each road segment is a link between two vertices.

In traffic simulations, vehicles travel each link in a constant speed that depends on the link vehicle density on the moment the vehicle enters it. The speed v when entering a link with vehicle density k is given by:

$$v = v_{free} * (1 - (\frac{k}{k_{jam}})^{\beta})^{\alpha} \quad (1)$$

Where v_{free} is the maximum speed that a vehicle could develop in the link, k_{jam} is the maximum vehicle density supported by the link, and α and β are configurable parameters for the model.

Simulation Scenarios

We began simulating DR on a segment of Avenida Paulista, first developing a benchmark scenario based on reports published by CET and the current traffic signal timing plan. Using a mixed integer linear programming formulation [2], we calculated a traffic signal timing plan to allow DR platoons to travel without stops.

For a constant traffic flow equivalent to peak hours on Avenida Paulista, we simulated different ratios of vehicles travelling on DR platoons. We also developed scenarios to study the travel time for vehicles travelling on crossing roads.

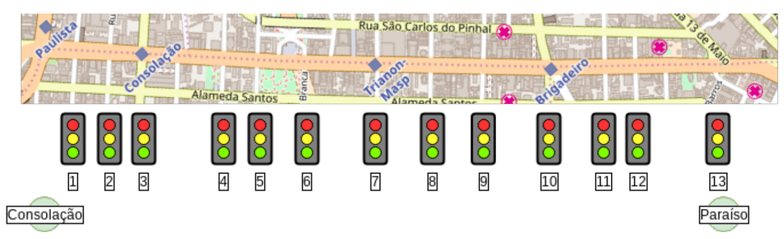


Figure 2: Location of traffic signals on the selected segment of Avenida Paulista.

Based on CET reports, we selected a region of São Paulo and some major routes with significant traffic volume to expand the DR system. The selected routes were:

1. Avenida 23 de Maio
2. Avenida Pedro Álvares Cabral / Avenida Brasil
3. Marginal Pinheiros (between Jaguaré bridge and Eng. Ari Torres bridge)
4. Ligação Leste-Oeste
5. Avenida Cidade Jardim / Avenida Europa
6. Avenida Paulista
7. Avenida Eusébio Matoso / Avenida Rebouças

The resulting network can be seen in the following figure:

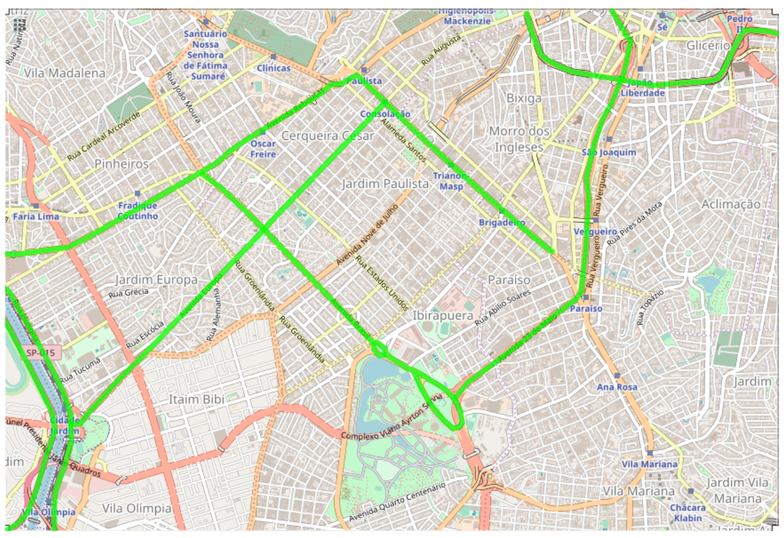


Figure 3: Proposed Digital Rails network in São Paulo, highlighted in green

Using a simulated mobility trace [3], we studied how different ratios of vehicles able to use DR would affect the average travel time on a regular day in the selected region. Since we did not simulate individual traffic signals, we re-calibrated the simulation model parameters to take the delay introduced by them into account.

Results

On Avenida Paulista, the average travel time was lower than the benchmark when more than 25% of the vehicles used DR. We also found that the travel time for vehicles on the crossing roads did not increase.

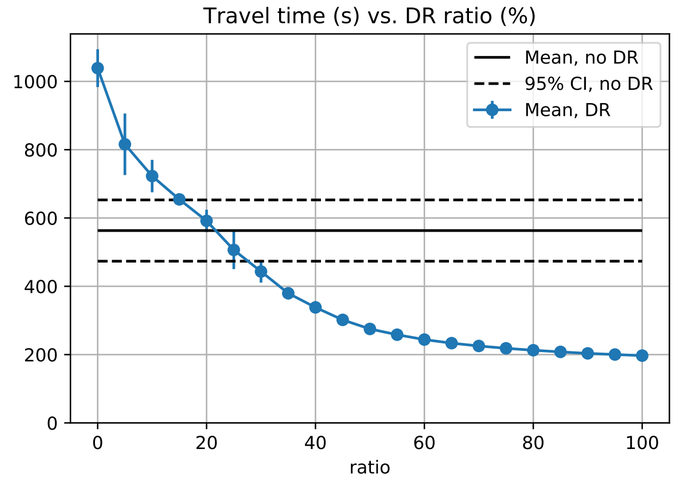


Figure 4: Travel time vs. ratio of vehicles using DR on Avenida Paulista, compared to the average travel time on the benchmark scenario.

With the proposed DR network, we compared the average travel time with the benchmark scenario. Since the range of travel distances was large, we divided the analysis in quartiles. The reduction of travel time was less expressive. Even with 100% of the vehicles able to use DR, the travel time was about 70% of the benchmark.

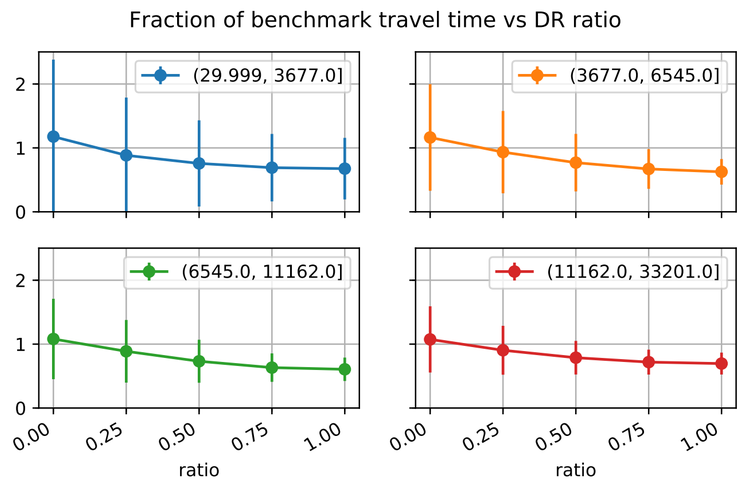


Figure 5: Evolution of travel time on the selected region of São Paulo with DR ratio, by distance quartiles. The legend on each plot indicates the travel distance range on each quartile.

Conclusion

Implementing Digital Rails on São Paulo could lead to reduced travel times, even for vehicles that will not use the system. However, our simulation model was simple and did not capture individual vehicle interactions. The DR proposal should be further evaluated by professionals with experience in traffic operations.

References

[1] T. Litman, *Autonomous vehicle implementation predictions*.
Victoria Transport Policy Institute, 2017.

[2] J. D. Little, M. D. Kelson, and N. M. Gartner, "Maxband: A program for setting signals on arteries and triangular networks," *Transportation Research Record*, no. 795, 1981.

[3] E. F. Z. Santana, L. Kanashiro, and F. Kon, "Geração de rastros de mobilidade para experimentos em redes veiculares," 2018.