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# The role of trip lengths in control strategies and Macroscopic Fundamental Diagram traffic models

Sérgio F. A. Batista<sup>\*1</sup>, Deepak Ingole<sup>†1</sup>, Ludovic Leclercq<sup>‡1</sup> and  
Monica Menendez<sup>§2,3</sup>

<sup>1</sup>Univ. Lyon, IFSTTAR, ENTPE, LICIT, F-69675, Lyon, France

<sup>2</sup>Division of Engineering, New York University Abu Dhabi, United  
Arab Emirates

<sup>3</sup>Tandon School of Engineering, New York University, USA

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## 1 Introduction

2 Aggregated traffic models were introduced by Godfrey (1969) and later revisited by  
3 Daganzo (2007) and Geroliminis & Daganzo (2008). These traffic models require  
4 the partition of the city network (see e.g., Saeedmanesh & Geroliminis, 2016, 2017,  
5 Lopez et al., 2017, Casadei et al., 2018) into regions, where the traffic conditions are  
6 approximately homogeneous. Such partition defines the regional network. In each  
7 region, the traffic states are measured through the vehicles' accumulation  $n(t)$  and  
8 are regulated by a Macroscopic Fundamental Diagram (MFD). The MFD reflects  
9 the relationship between the average circulating flow of vehicles and the average  
10 density in the region.

11 The regional network definition brings new challenges. Figure 1 depicts the  
12 challenge of scaling up trips to the regional network. The green and blue trips follow  
13 a sequence of links in the city network, with a fixed length. The green and blue  
14 trips cross a different sequence of regions, following the city network partitioning.  
15 The ordered sequence of crossed regions by a trip is called regional path. The green  
16 and blue trips describe different travel distances inside each region, as highlighted  
17 in the gray region. Therefore, regional paths are characterized by distributions  
18 of trip lengths, containing information of the plausible travel distances in the city

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\*✉ sergio.batista@ifsttar.fr

†✉ deepak.ingole@entpe.fr

‡✉ ludovic.leclercq@entpe.fr

§✉ monica.menendez@nyu.edu

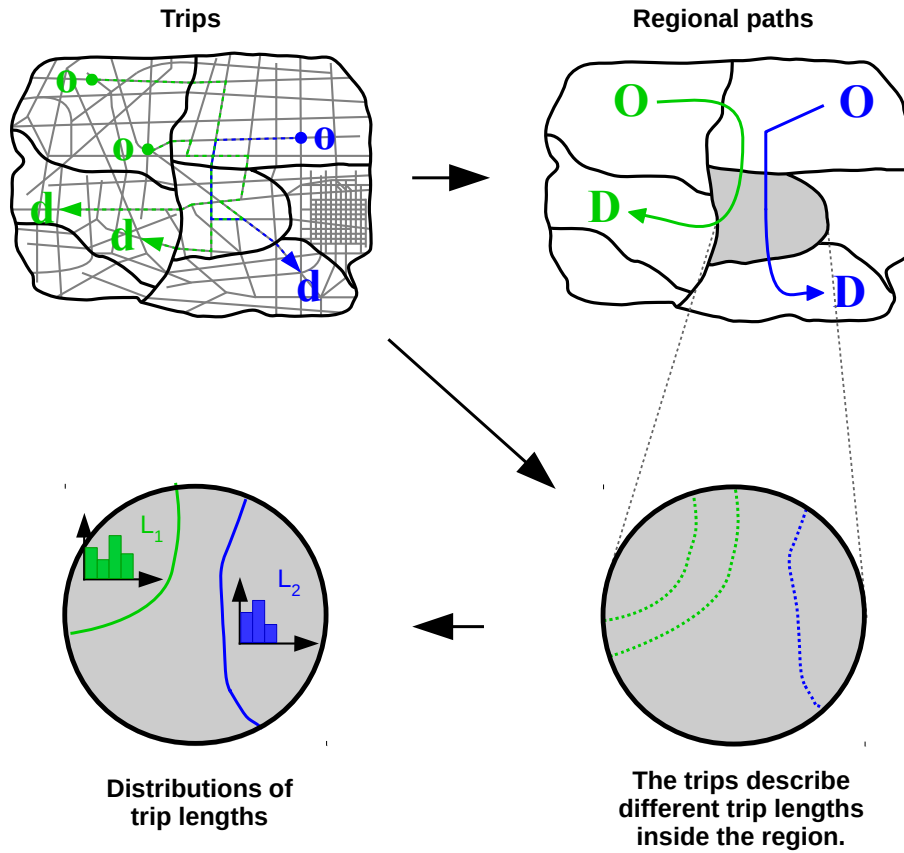


Fig. 1 – The scale up of trips into regional paths, that are characterized by trip length distributions.

1 network. Batista et al. (2018) and Batista et al. (in prep.) propose a methodological  
 2 framework to calculate trip length distributions based on a set of trips and different  
 3 levels of information from the regional network. The first level calculates trip length  
 4 distributions considering the travel distances of all trips crossing one region. This  
 5 assigns a common trip length distribution for all regional paths that cross the same  
 6 region, independently of their Origin and Destination (OD). We refer to this level as  
 7  $M_{standard}$ . The most detailed level only considers the trips that define the same  
 8 regional path. This allows to derive different trip lengths for all regional paths that  
 9 cross the same region. We refer to this level as  $M_{reference}$ . The authors show that  
 10  $M_{standard}$  is not able to capture the trip lengths variability of all regional paths  
 11 crossing the same region. Moreover, they also show that the calibration of the trip  
 12 lengths clearly influences the modeled traffic dynamics inside the regions.

13 Up to now, most of the MFD applications have been designed to test control  
 14 algorithms or design perimeter control strategies. Daganzo (2007), Keyvan-  
 15 Ekbatani et al. (2012) and Ekbatani et al. (2013) tested perimeter control strategies  
 16 for a one region network, where all vehicles were assigned a common average travel  
 17 distance. Some theoretical studies (see e.g., Haddad, 2017, Zhong et al., 2017, Yang

1 et al., 2018) focused on the outflow-MFD application, where all vehicles were as-  
 2 signed the same trip length. Aboudolas & Geroliminis (2013) and Kouvelas et al.  
 3 (2017) tested perimeter control strategies in real city networks, but an average trip  
 4 length for all regions was also considered.

## 5 Research contribution

6 In this paper, we propose to investigate the role of the trip lengths calibration  
 7 for perimeter control strategies. The goal is to quantify the effects of improper  
 8 assumptions on the travel distances in the regions on Model Predictive Control  
 9 (MPC) based control strategies. In this extended abstract, we discuss some initial  
 10 and preliminary results obtained by a Proportional-Integral (PI) gating control  
 11 scheme on a real network.

## 12 Test scenario and methodological framework

13 The test network is depicted in Figure 2 (a). It includes the 3<sup>rd</sup> and 6<sup>th</sup> districts of  
 14 Lyon and the city of Villeurbanne (France). The network has 3127 nodes and 3363  
 15 links and is divided into seven regions. Figure 2 (b) depicts the MFD functions.  
 16 They were calculated by assuming a bi-parabolic shape to fit microscopic simulation  
 17 data obtained from Symuvia (Leclercq, 2007).

18 The calculation of the trip lengths and regional paths are based on a virtual  
 19 trips set in the city network. To gather this set, we randomly sample 3 million  
 20 origin and destination nodes in the city network and calculate the shortest-path in  
 21 distance between each of them. To obtain the regional paths, we filter all trips by  
 22 the specific sequence of regions they cross. For each regional OD pair, the regional  
 23 paths are ranked according to the number of trips they have associated. For our case  
 24 study, we consider three OD pairs: 1-7; 4-2; and 6-4. To define the regional choice  
 25 set for each OD pair, we gather the two regional paths with the largest number of  
 26 trips associated. We calculate the trip lengths distributions following the  $M_{standard}$   
 27 and  $M_{reference}$  described in the Introduction (see also Batista et al., 2018, in prep.,  
 28 , for more details). The regional paths and demand assignment coefficients are  
 29 listed in Table 1. The average trip lengths calculated by  $M_{standard}$  and  $M_{reference}$   
 30 are listed in Table 2. The demand scenarios for the three OD pairs are shown in  
 31 Figure 2 (c). The traffic states are simulated through an accumulation-based MFD  
 32 model (Daganzo, 2007, Geroliminis & Daganzo, 2008), for a total simulation period  
 33 of  $T = 20000$  seconds.

34 Our goal is to control the maximum vehicles' accumulation in region 3 (i.e.  
 35  $(n_3(t))$ ). For this purpose, we designed a gating control composed by three PI  
 36 controllers with an anti-windup scheme to track the desired set-point, i.e.  $(n_3(t))$ .  
 37 Figure 3 depicts the PI-based gating control scheme that is implemented. The  
 38 inflows of regional paths 1 – 3 – 5 – 7 ( $I_{3,1}^1$ ), 4 – 3 – 2 ( $I_{3,2}$ ) and 6 – 5 – 3 – 4 ( $I_{3,3}$ )  
 39 are manipulated by the PI controller before entering region 3. The new inflows are  
 40  $u_{3,1}(t)$ ,  $u_{3,2}(t)$  and  $u_{3,3}(t)$ . The manipulation by the controller is done such that  
 41  $n_3(t)$  is maintained at the set-point. The outflows ( $o_{3,1}$ ,  $o_{3,2}$ ,  $o_{3,3}$ ) will continue to the  
 42 next regions in the sequence of the corresponding regional paths. In this example,

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<sup>1</sup>The first subscript refers to the region that is being controlled. The second subscript refers to the regional paths will cross region 3.

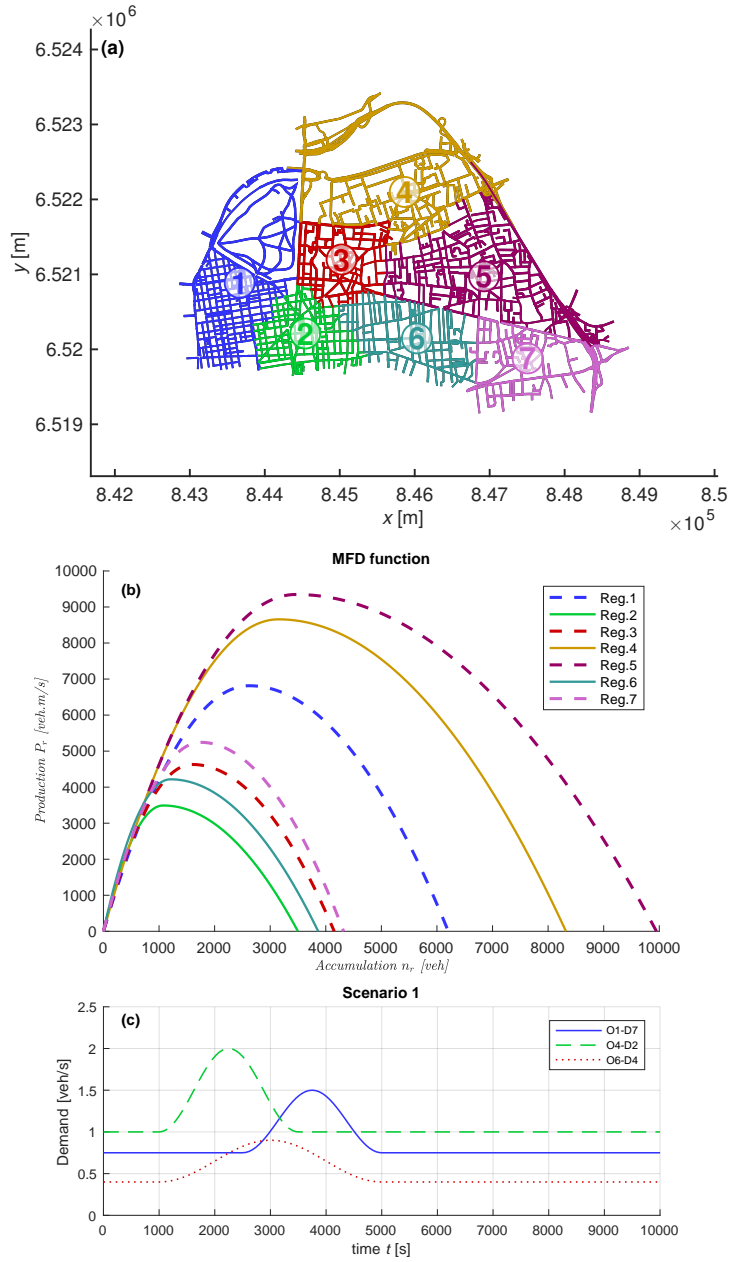


Fig. 2 – (a) Villeurbanne and the 3<sup>d</sup> and 6<sup>th</sup> districts of Lyon (France) traffic network, divided into seven regions. (b) MFD function of each region. (c) Demand scenarios.

O	D	Regional path	Assignment coefficient
1	7	1-2-6-7	0.15
		1-3-5-7	0.85
4	2	4-1-2	0.25
		4-3-2	0.75
6	4	4-3-2	0.00
		6-5-3-4	1.00

Tab. 1 – Regional paths and the assignment coefficients used for this study.

Method	Regional path	Region						
		1	2	3	4	5	6	7
Standard	1-2-6-7	987	649	~	~	~	694	926
	1-3-5-7	987	~	880	~	1042	~	926
	4-1-2	987	649	~	1347	~	~	~
	4-3-2	~	649	880	1347	~	~	~
	6-5-3-4	~	~	880	1347	1042	694	~
Reference	1-2-6-7	788	1121	~	~	~	1424	676
	1-3-5-7	927	~	1297	~	1032	~	1142
	4-1-2	2761	335	~	2227	~	~	~
	4-3-2	~	708	1049	1191	~	~	~
	6-5-3-4	~	~	458	733	861	584	~

Tab. 2 – Average trip lengths ( $m$ ) calculated by the methods  $M_{standard}$  and  $M_{reference}$ .

1 we assume that the set of regional paths and trip lengths remain unchanged. In  
2 the full paper, we will consider the vehicles' re-routing due to the control effects on  
3 the travel times and time-dependent trip lengths. The proportional ( $k_p = 1$ ) and  
4 integral ( $k_i = 0.05$ ) gains of the PI controller are obtained using trial and error  
5 methods.

## 6 Preliminary results and discussion

## 7 Acknowledgments

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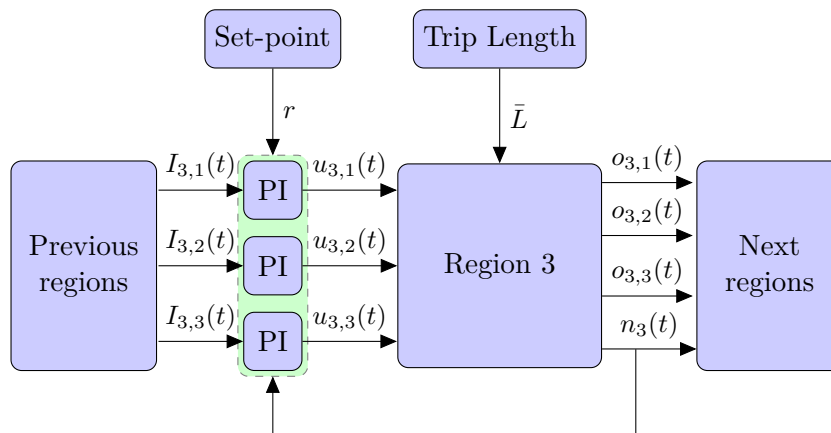


Fig. 3 – Representation of closed-loop gating control using PI controllers.

Region	TTS ( $\times 10^5 [s]$ )						
	Uncontrolled		Controlled				Mismatch
	$M_s$	$M_r$	PID		MPC		
$M_s$			$M_r$	$M_s$	$M_r$		
1	2.31	4.45	2.64	5.54	2.54	6.41	5.61
2	1.11	1.16	1.11	1.16	1.11	1.16	1.16
3	2.07	2.53	2.03	2.46	2.03	2.46	2.47
4	2.77	2.68	2.95	3.31	3.06	2.66	2.87
5	2.19	2.03	2.29	2.42	2.25	2.36	3.37
6	1.03	1.12	1.03	1.12	1.03	1.12	1.12
7	1.60	1.86	1.60	1.86	1.60	1.86	1.86
Total ( $\times 10^6 [s]$ )	1.31	1.58	1.36	1.79	1.36	1.80	1.85

Tab. 3 – Total Time Spent (TTS) in all regions.

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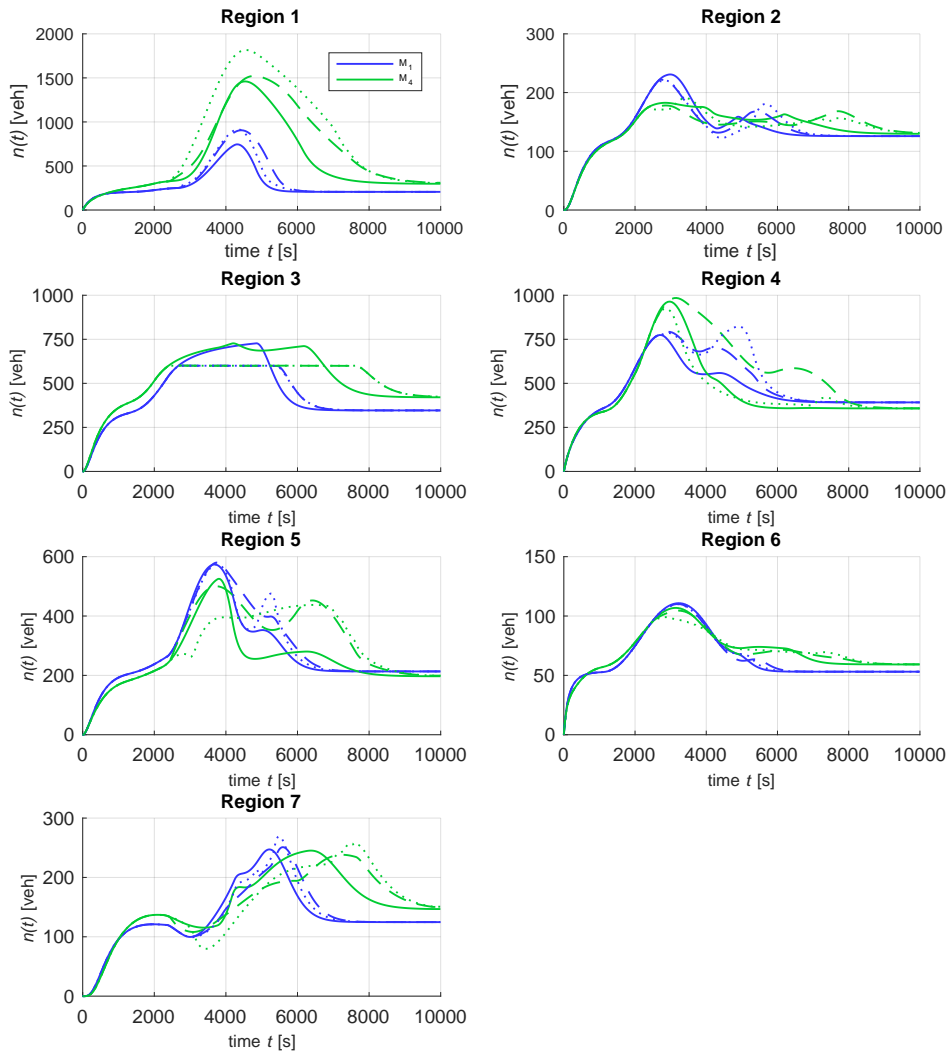


Fig. 4 – Evolution of the vehicles' accumulation  $n(t)$  for all seven regions.



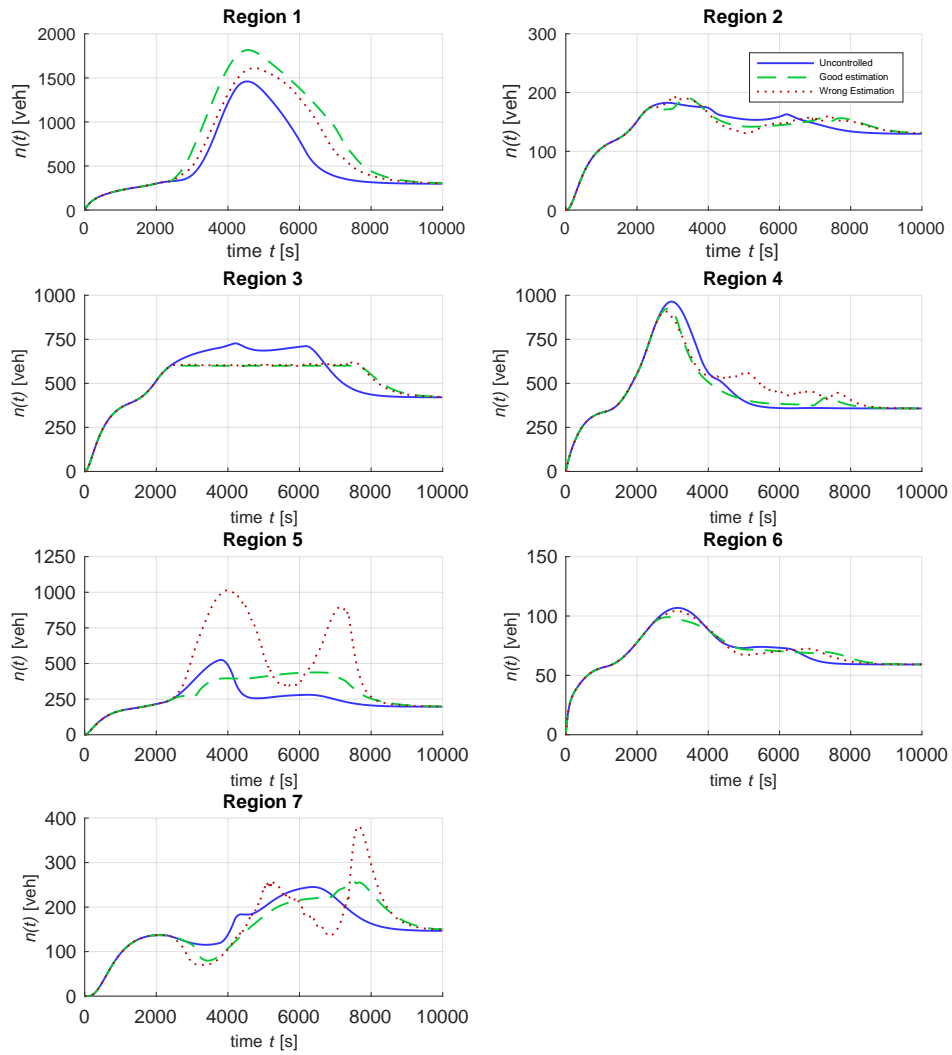


Fig. 5 – Evolution of the vehicles' accumulation  $n(t)$  for all seven regions.

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