STOCHASTIC APPROXIMATIONS FOR THE MACROSCOPIC FUNDAMENTAL DIAGRAM

Jorge A. Laval[a,*], Felipe Castrillón[a], Yi Zhou[a]

[a]*School of Civil and Environmental Engineering, Georgia Institute of Technology*

1. ABSTRACT

This paper proposes analytical estimates of a network Macroscopic Fundamental Diagram (MFD) using probabilistic methods. It produces a distribution for the MFD, found to depend mainly on two parameters. This abstract focuses in Fig. 1, which shows the comparison between the MFDs from an exact traffic simulation and the 90% probability interval from our analytical method.

Existing analysis methods for the MFD fall into three types: (i) empirical [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12], (ii) analytical [13, 14, 15], and (iii) simulation [16, 17, 18, 19, 20, 21, 22]. Analytical results are based on the method of cuts for homogeneous corridors where all intersections "see" the same set of cuts, so the cuts from a single intersection sufice to compute the MFD for the whole corridor. Despite this apparent simplicity, this approach quickly becomes intractable and one needs to resort to simple but numerical algorithms to identify all possible cuts. Additionally, the homogeneous corridor method cannot be scaled up without complications to estimate the network MFD mainly because a network path cannot be guaranteed to have constant offset all along, even for homogeneous networks.

In this paper we introduce the concept of probabilistic homogeneous corridors, where all intersections see the same distribution of cuts. This allows tackling deterministic inhomogeneous corridors with different block length, signal timing, etc.

The example presented in Fig. 1 are networks with random offsets, while the general method will be presented in the final paper. The general method can be used to randomize other variables of our problem such as block length and signal timing, which is important because it allows the analytical estimation of MFDs on inhomogeneous networks, for which analytical methods are currently unavailable.

Random offset networks could be a good approximation for networks with traffic actuated signals or without coordination, and Fig. 1 shows that it provides tight bounds for the deterministic problem. The dimensionless formulation of this problem provides new insights, e.g.: (i) only two parameters determine the MFD distribution, (ii) the distribution of network capacity depends on a single parameter, (iii) the existence of a symmetry line in the MFD, which is crucial for mathematical tractability, and (iv) the block length does not affect the MFD when it is larger than twice the critical block length.

REFERENCES

[1] N. Geroliminis, C. Daganzo, Macroscopic modeling of traffic in cities, Paper No. 07-413, 86th Annual Meeting of the Transportation Research Board, Washington D.C., 2007.

*Corresponding author. Tel. : +1 (404) 894-2360; Fax : +1 (404) 894-2278
Email address: jorge.laval@ce.gatech.edu (Jorge A. Laval)

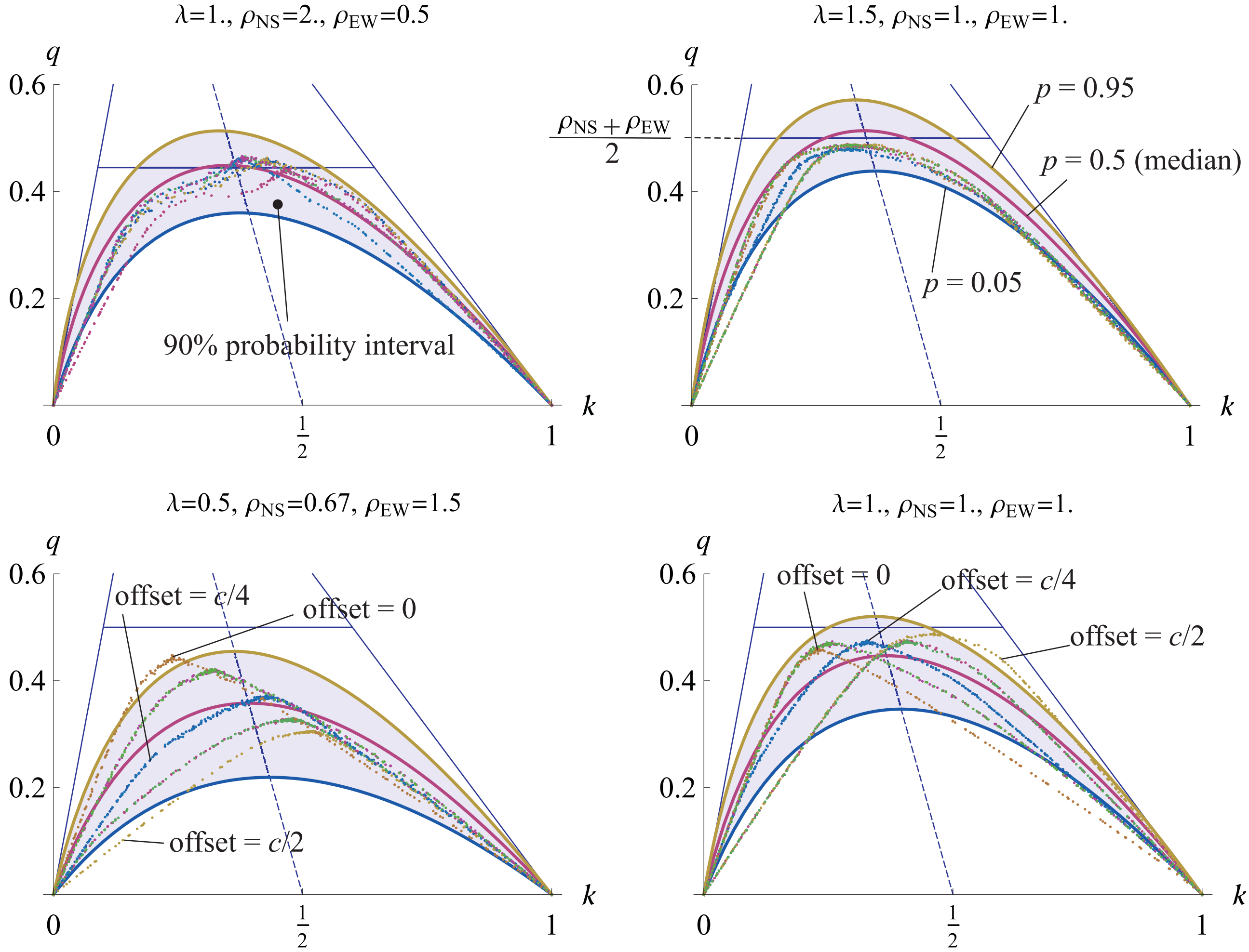

Figure 1: Comparison between the MFDs produced by an exact traffic simulation and the 90% probability interval produced by our analytical method.

[2] N. Geroliminis, C. Daganzo, Existence of urban-scale macroscopic fundamental diagrams: some experimental findings, Transportation Research Part B: Methodological 42 (2008) 759–770.

[3] X. Wu, H. Liu, N. Geroliminis, An empirical analysis on the arterial fundamental diagram, Transportation Research Part B: Methodological 45(1) (2011) 255–266.

[4] M. Saberi, H. S. Mahmassani, Exploring the properties of network-wide flow-density relations in a freeway network, Transportation Research Record (2315) (2012) 153–163.

[5] B. D. Helbing, Derivation of a fundamental diagram for urban traffic flow, The European Physical Journal B 70 (2009) 229–241.

[6] N. Geroliminis, J. Sun, Properties of a well-defined macroscopic fundamental diagram for urban traffic, Transportation Research Part B 45 (2011) 605–617.

[7] N. Geroliminis, Y. Ji, Spatial and temporal analysis of congestion in urban transportation networks, 90th Annual Meeting of the Transportation Research Board, Washington D.C., 2011.

[8] M. Cassidy, K. Jang, C. Daganzo, Macroscopic fundamental diagram for freeway networks: Theory and observation, 90th Annual Meeting of the Transportation Research Board, Washington D.C., 2011.

[9] V. L. Knoop, The impact of traffic dynamics on the macroscopic fundamental diagram, 92th Annual Meeting of the Transportation Research Board, Washington D.C., 2012.

[10] V. Gayah, C. Daganzo, Clockwise hysteresis loops in the macroscopic fundamental diagram: An effect of network instability, Transportation Research Part B.

[11] C. Buisson, C. Ladier, Exploring the impact of homogeneity of traffic measurements on the existence of macroscopic fundaental diagrams, Transportation Research Record 2124 (2009) 127–136.

[12] C. F. Daganzo, V. V. Gayah, E. J. Gonzales, Macroscopic relations of urban traffic variables: Bifurcations, multi-valuedness and instability, Transportation Research Part B Methodological 45 (2011) 278–288.

[13] C. F. Daganzo, N. Geroliminis, An analytical approximation for the macroscopic fundamental diagram of urban traffic, Transportation Research Part B: Methodological 42 (2008) 771–781.

[14] C. F. Daganzo, A variational formulation of kinematic waves: Basic theory and complex boundary conditions, Transportation Research Part B 39(2) (2005) 187–196.

[15] C. F. Daganzo, A variational formulation of kinematic waves: solution methods, Transportation Research Part B 39(10) (2005) 934–950.

[16] Y. Ji, W. Daamen, S. Hoogendoorn, S. Hoogendoom-Lanser, X. Qian, Investigating the shape of the macroscopic fundamental diagram using simulation data, Transportation Research Record: Journal of the Transportation Research Board (2161) (2010) 40–48.

[17] A. Mazlomian, N. Geroliminis, D. Helbing, The spatial variability of vehicle densities as determinant of urban network capacity, Philosophical Transactions of the Royal Society A 368 (2010) 4627–4647.

[18] N. Geroliminis, B. Boyacı, The effect of variability of urban systems characteristics in the network capacity, Transportation Research Part B 46(10) (2013) 1576–1590.

[19] J. Haddad, N. Geroliminis, On the stability of traffic perimeter control in two-region urban cities, Transportation Research Part B 46(9) (2012) 1159–1176.

[20] J. Haddad, M. Ramezani, N. Geroliminis, Cooperative traffic control of a mixed network with two urban regions and a freeway, Transportation Research Part B 54 (2013) 17–36.

[21] V. Knoop, S. Hoogendoorn, Variable macroscopic fundamental diagrams for traffic networks, 9th Conference on Traffic and Granular Flow, Springer (in print), 2011.

[22] V. Knoop, J. V. Lint, S. Hoogendoorn, Route advice and its effect on the macroscopic fundamental diagram, 9th Conference on Traffic and Granular Flow, Springer (in print), 2011.

[23] C. F. Daganzo, In traffic flow, cellular automata = kinematic waves, Transportation Research Part B 40 (5) (2006) 396–403.

[24] M. J. Lighthill, G. Whitham, On kinematic waves. I Flow movement in long rivers. II A theory of traffic flow on long crowded roads, Proceedings of the Royal Society of London 229 (A) (1955) 281–345.

[25] P. I. Richards, Shockwaves on the highway, Operations Research (4) (1956) 42–51.