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Investigating the Empirical Existence of Static User Equilibrium

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Abstract

The Static User Equilibrium is a powerful framework for the theoretical study of traffic. Despite the restricting assumption of stationary flows that intuitively limit its application to real traffic systems, many operational models implementing it are still used without an empirical validation of the existence of the equilibrium. We investigate its existence on a traffic dataset of three months for the region of Paris, FR. The implementation of an application for interactive spatio-temporal data exploration allows to hypothesize a high spatial and temporal heterogeneity, and to guide further quantitative work. The assumption of locally stationary flows is invalidated in a first approximation by empirical results, as shown by a strong spatial and temporal variability in shortest paths and in network topological measures such as betweenness centrality. Furthermore, the behavior of spatial autocorrelation index of congestion patterns at different spatial ranges suggest a chaotic evolution at the local scale, especially during peak hours. We finally discuss the implications of these empirical findings and describe further possible developments based on the estimation of Lyapunov dynamical stability of traffic flows.

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Keywords: Static User Equilibrium, Spatio-temporal Data Visualization, Spatio-temporal stationarity, Dynamical Stability

1. Introduction

Traffic Modeling has been extensively studied since seminal work by Wardrop (1952) : economical and technical elements at stake justify the need for a fine understanding of mechanisms ruling traffic flows at different scales. Many approaches with different purposes coexist today, of which we can cite dynamical micro-simulation models, generally opposed to equilibrium-based techniques. Whereas the validity of micro-based models has been largely discussed and their application often questioned, the literature is relatively poor on empirical studies assessing the stationary equilibrium assumption in the Static User Equilibrium (SUE) framework. Various more realistic developments have been documented in the literature, such as Dynamic Stochastic User Equilibrium (DSUE) (see e.g. a description by Han (2003)). An intermediate between static and stochastic frameworks is the Restricted Stochastic User Equilibrium, for which route choice sets are constrained to be realistic (Rasmussen et al. (2015)). Extensions that incorporate user behavior with choice models have more recently been proposed, such as Zhang et al. (2013) taking into account both

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the influence of road pricing and congestion on user choice with a Probit model. Relaxations of other restricting assumptions such as pure user utility maximization have been also introduced, such as the Boundedly Rational User Equilibrium described by Mahmassani and Chang (1987). In this framework, user have a range of satisfying utilities and equilibrium is achieved when all users are satisfied. It produces more complex features such as the existence of multiple equilibria, and allows to account for specific stylized facts such as irreversible network change as developed by Guo and Liu (2011). Other models for traffic assignment, inspired from other fields have also recently been proposed : in Puzis et al. (2013), an extended definition of betweenness centrality combining linearly free-flow betweenness with travel-time weighted betweenness yield a high correlation with effective traffic flows, acting thus as a traffic assignment model. It provides direct practical applications such as the optimization of traffic monitors spatial distribution.

Despite all these developments, some studies and real-world applications still rely on Static User Equilibrium. Parisian region e.g. uses a static model (MODUS) for traffic management and planning purposes. Leurent and Boujnah (2014) introduce a static model of traffic flow including parking cruising and parking lot choice: it is legitimate to ask, specifically at such small scales, if the stationary distribution of flows is a reality. An example of empirical investigation of classical assumptions is given in Zhu and Levinson (2010), in which revealed route choices are studied. Their conclusions question "Wardrops first principle" implying that users choose among a well-known set of alternatives. In the same spirit, we investigate the possible existence of the equilibrium in practice. More precisely, SUE assumes a stationary distribution of flows over the whole network. This assumption stays valid in the case of local stationarity, as soon as time scale for parameter evolution is considerably greater than typical time scales for travel. The second case which is more plausible and furthermore compatible with dynamical theoretical frameworks, is here tested empirically.

The rest of the paper is organized as follows : data collection procedure and dataset are described ; we present then an interactive application for the interactive exploration of the dataset aimed to give intuitive insights into data patterns ; we present then results of various quantitative analyses that give convergent evidence for the non-stationarity of traffic flows ; we finally discuss implications of these results and possible developments.

2. Data collection

2.1. Dataset Construction

We propose to work on the case study of Parisian Metropolitan Region. An open dataset was constructed for highway links within the region, collecting public real-time open data for travel times (available at www.sytadin.fr). As stated by Bouteiller and Berjoan (2013), the availability of open datasets for transportation is far to be the rule, and we contribute thus to a data opening by the construction of our dataset. Our data collection procedure consists in the following simple steps, executed each two minutes by a `python` script :

- fetch raw webpage giving traffic information
- parse html code to retrieve traffic links id and their corresponding travel time
- insert all links in a `sqlite` database with the current timestamp.

The automatized data collection script continues to enrich the database as time passes, allowing future extensions of this work on a larger dataset and a potential reuse by scientists or planners. The latest version of the dataset is available online (sqlite format) under a Creative Commons License[1].

2.2. Data Summary

A time granularity of 2 minutes was obtained for a three months period (February 2016 to April 2016 included). Spatial granularity is in average 10km, as travel times are provided for major links. The dataset contains 101 links.

[1] at `http://37.187.242.99/files/public/sytadin_latest.sqlite3`