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Spatio-Temporal Analyses for Dynamic Urban Road Network Management

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Abstract

The dynamic urban network management in urban areas is in high demand, since speed information is currently available via Information and Communication Technology (ICT) Infrastructure. However, such information has not been incorporated into routing decision making systems efficiently. Although several efforts exit, these are not correlated and integrated. Since the integration problem has spatial and temporal dimensions, Spatial Information Science could aid to solve this problem via mature methods, approaches and tools. The main aim of this study is to demonstrate the opportunities of spatio-temporal analyses within dynamic urban road network management, where the concepts are supported with a case study from Istanbul Metropolitan Area. In the proposed methodology, the speed information retrieved from detectors were associated with the OpenStreetMap and quickest paths were simulated within determined time intervals. Different shortest routes are proposed to users in various time spans via incorporated speed information and network analyses. For the same origin and destination, 2.5 minutes difference is observed within the study area. The results were promising, where the added value of this study is presenting an approach for integrating various spatial-temporal data to aid dynamic urban road network management.

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Keywords: traffic speed information; Goegraphic Information Systems (GIS); Traffic; dynamic routing.

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1. Introduction

The need for dynamic route management is apparent, however current traffic management systems are not mature enough to accomplish it. The reason for such a problem is mainly depends on; complexity of the urban network, insufficient real-time data collection system and non-integrated decision support systems for traffic routing problem. Some efforts exit, where nowadays several service providers for selecting the best-routing option for destinations are available. However, these provide partial solutions, since the traffic management efforts are uncorrelated and not integrated. Additionally, this issue could only be solved via the cooperation of citizens and informed decision making. Since the traffic related information is available nowadays via Information and Communication Technology (ICT) Infrastructure, the solution for such a spatial problem should be dynamic as well. Hence, it is a spatio-temporal problem, where Spatial Information Science could aid to solve this problem via mature methods, approaches and tools.

The main aim of this study is to demonstrate the opportunities of spatio-temporal analyses within dynamic urban road network management, where the concepts are supported with a case study from Istanbul Metropolitan Area. The designed methodology is processing and analyzing speed information on hourly bases for week days and week-ends, where different shortest routes are proposed to users via network analyses. The well-known algorithm of Dijkstra is used to solve the shortest path problem for a connected digraph with non-negative weights. For a given source node in the graph, the algorithm finds the shortest path between that node and every other. For the network distance calculations, topological elements of the network data are used to perform the distance calculations from the origins to destinations, where for this study speed- time spend- is an additional parameter for the calculation.

This paper is organized as follows. The following section is background that illustrates some relative significant studies and works. The third section presents shortly important facts regarding the study area, used data and followed methodology. Finally, in the fourth section the obtained results are presented and general comments and conclusion are given.

2. Background

The major challenge presented in dynamic traffic management is the optimal utilization of all the routes according to their limitation in number and capacity. In most cases, as Shashikiran (2011) stated, it is inconvenient to construct new routes or increase roadway capacities. So identifying ways to maximize the utilization of the existing transportation network becomes more important. An effective way to do that is through Dynamic Routing (or adaptive routing) which has been intensely studied and investigated by road network designers and managers. Designers and managers use the Dynamic Routing to examine the capability of road networks to find alternative routes in response to a change in the system. Mak (2011) defines Dynamic Routing as a utilization of the online communication patterns and real-time information to effectively avoid overcrowding or faulty components and reduce the possibility of packets being continuously blocked, thus it helps minimize congestion and avoids hot-spot areas for road network users. Dynamic Routing within urban areas requires dynamic simulations, where the emerging information and communication technologies (ICT) could generate new sources of data and opportunities. However, such data requires new approaches for data acquisition, modeling, analyses and visualization. Recently, real-time traffic data is available for almost all cities, however, such information is not incorporated into our daily transportation routines.

Several studies have been performed trying to dynamically find the best routing system in road networks to, as possibly, avoid traffic congestions and hot-spots. In this context, traffic flow models and algorithms were developed to predict the traffic congestion occurrence in the networks. For that, free traffic congestion road networks were needed to be designed and managed. In order to do such things, various significant data of road network components were collected and analyzed by different methods and tools gradually improving over time. Here we display, shortly, some relative studies in this direction. Leblanc and Abdulaa (1979) presented a computationally efficient technique for determining the optimal design of an urban road network, by assigning of network flows and the determining of improved link parameter values so that congestion is minimized. Both of Wang et al. (2005) and Wang et al. (2009) developed general approach to the real-time adaptive of the complete traffic state in freeway routes or networks, based on the stochastic nonlinear macroscopic traffic flow modeling and extended Kalman filter. Cantarella et al. (2006)