The Athens Dynamic Traffic Map for multimodal travel information services

ANTONY STATHOPOULOS\textsuperscript{1} and THEODORE TSEKERIS\textsuperscript{1,2}

\textsuperscript{1}Department of Transportation Planning and Engineering, National Technical University of Athens, 157 73, Athens, Greece;

\textsuperscript{2}Centre for Planning and Economic Research (KEPE), 11 Amerikis, 106 72, Athens, Greece;

(Received 9\textsuperscript{th} January 2008; Revised 27\textsuperscript{th} May 2008; Accepted 29\textsuperscript{th} May 2008)

\textbf{Abstract:} This paper demonstrates a dynamic map, referred to as the Athens Dynamic Traffic Map (ADTM), with interactive features for the provision of travel information to the users of an extended, multimodal transport network in the metropolitan area of Athens, Greece. The map offers a state-of-the-art geospatial representation of the time-varying road traffic conditions, in conjunction with information on the services provided by all available public transport modes. This unique combination of private and multimodal public transport information services allows users to update in a timely manner their pre-trip or en-route travel decisions, including departure time, route, destination, mode selection and combinations of them, depending on the prevailing traffic conditions and/or the existence of incidents and special events. The paper signifies the potential of the ADTM to enhance the efficient use of the transport network, and it describes several map features and details which can support the decisions of road and public transport users.
1. Introduction

The rapid development and adoption of Information and Communication Technologies (ICT), such as those of Internet services through the World Wide Web, have significantly improved the amount and quality of information provided to the users of urban transport networks. The deployment of such information systems is important for approximating the optimal (user equilibrium) network traffic conditions, which are underlined by the assumption of perfect information and imply the equalization of travel times among all used paths between a given Origin-Destination (O-D) pair (Wardrop, 1952). The Internet-based technology possesses unique features for transmitting and displaying travel information through maps (and, possibly, other media) with low cost one-to-many communication and less location-dependent communication media, such as Personal Digital Assistants (PDA) and third-generation (3G) cell phones, in real-time conditions (Wang and Yang, 1999). Currently, there are several Internet map-based applications providing information about urban public transport services (see Morrison, 2007). These applications can inform travellers about where and when to use one or more public transport modes (bus, metro, tram etc), possibly corresponding to different operators. In addition, a number of other Internet map-based applications relate to the provision of information about private transport and traffic conditions.

The present paper describes an Internet-based map with dynamic and interactive features, as applied in the Greater Athens area of Greece, with the aim to provide multimodal traveller information about the complete metropolitan transport network, including major road arterials and all available (urban and suburban) public transport modes. The map constitutes an attempt to build an integrated multimodal traveller information system, in the sense that it presents the user with corroborative information that could influence a decision to consider different mode choice options for a particular journey specified by the user (Kenyon and Lyons, 2003). The specific map, referred to here as the Athens Dynamic Traffic Map (ADTM), has been progressively developed over the last decade by the Laboratory of Railways and Transport of the National Technical University of Athens (NTUA, 2006) and it is accessible to any Internet user at the following URL: http://www.transport.ntua.gr/map/
2. Method

The information required for the display of the road traffic conditions by the ADTM is originated from a set of 163 magnetic (inductive) loop detectors, which are located at selected locations (sections of links) of major road arterials and provide raw data covering traffic volumes and occupancies. These data are real-time transmitted by the Traffic Control Centre of the city of Athens to the NTUA CSST (Control Strategy Selection Tool) communication handler at the signalization cycle frequency (i.e. every 1.5 min) for further processing and management purposes. All data are batch processed, by a combination of specific tools and algorithms. A traffic counting subsystem provides an appropriate data quality control by performing screening and data repair functions so as to identify and exclude or smooth data from malfunctioning detectors.

In the early phase of the research, an algorithm was developed to allow the real-time estimation and evaluation of the traffic conditions. This algorithm was based on the use of suitable critical values (thresholds) derived from measured traffic volume \(v(j)\), expressed as vehicles per unit of time (traffic flow), and road occupancy \(o(j)\), a measure of congestion, expressed as the loading fraction of the roadway (i.e. the percentage of time that a vehicle is present inside the inductive loop), and field observations of the maximum (called ‘floating-car speed’ in traffic engineering terms) travel speed \(u_{\text{max}}(j)\) on link \(j\) along selected routes, over different (peak and off-peak) periods of the day. This process led to the adoption of four classified nominal maximum speed levels:

IF \(o(j) < 60\%\) AND \(v(j) \geq 2000 \text{ veh/hr}\) THEN \(u_{\text{max}}(j) = 35 \text{ km/hr}\)
IF \(o(j) < 60\%\) AND \(1000 \text{ veh/hr} \leq v(j) < 2000 \text{ veh/hr}\)
OR \(60\% \leq o(j) < 75\%\) AND \(v(j) < 1000 \text{ veh/hr}\) THEN \(u_{\text{max}}(j) = 25 \text{ km/hr}\)
IF \(o(j) \geq 75\%\) AND \(v(j) < 1000 \text{ veh/hr}\) THEN \(u_{\text{max}}(j) = 15 \text{ km/hr}\)
ELSE \(u_{\text{max}}(j) = 20 \text{ km/hr}\)

Based on the above definitions, speed estimates were derived in the form \(u(j) = f(v(j))\) through a simple linear model, including \(u_{\text{max}}\) as a threshold parameter that supported a 15-min travel distance application shown in Section 4.

In a later phase of the research, further tests of several alternative (linear and nonlinear) mathematical relationships for travel speed estimation were
made to support a demonstration program of travel time displays (also shown in Section 4). These tests led to the adoption of a different calculation procedure based on a functional equation of the form \( u(j) = f(o(j), v(j)) \) which was found to provide the smallest deviation between estimated and observed travel speeds at some link \( j \) along the selected routes over the whole day period, as follows:

\[
\begin{align*}
  u(j) &= u_{\text{max}}(j) [1-o(j)], \text{ during peak periods} \\
  u(j) &= u_{\text{max}}(j) / u_{\text{min}}(j), \text{ during off-peak hours}
\end{align*}
\]

where, in both cases, \( u_{\text{max}}(j) \) and \( u_{\text{min}}(j) \) are modified as: \( u_{\text{max}}(j) = (a + L)v(j)/1000 \), with \( a = 3.0 \) a calibrated parameter and \( L \) the assumed average vehicle length, and \( u_{\text{min}}(j) = o(j)n \), where \( n \) is the number of link lanes. The path travel times are then estimated by adding the travel times required for traversing each link of the specific route. These time estimates are considered as key determinants of mode and route choice in transportation theory and are given as corroborative information of various forms, outlined in Section 4.

3. Map Design

The graphical representation of road traffic conditions on the ADTM involved the coding of the primary and secondary road network. In addition, all available fixed-route (own right-of-way) urban public transport systems, i.e. those of the tramway, suburban railway and underground metro (including the light rail), were coded as a different network layer on the ADTM. For this purpose, a CAD model was developed, where a set of points in a Cartesian space \((x, y)\) was employed to designate the physical nodes of the each (road and public transport) network. Two files, the first containing the node coordinates (junction points) and the second containing all links between nodes, were used to define the complete network in coded form on which all information is gathered for further processing and display.

The analysis of the traffic data yields their geospatial representation along selected routes between specific nodes of the road network. In order to update the display of road traffic conditions, a file containing the freshly collected and processed information is generated every quarter of an hour. The magnitude of traffic volume \( v \) in each link, that provides a plausible
measure of the intensity of road use and is used for the calculation of congestion level, is represented by a number, which is translated to a colour (Table 1) according to its level of severity.

The level of congestion \((l)\), in terms of the average portion of link capacity utilised by vehicular flow, is additionally displayed to allow users to better understand and assess the difficulty of traversing a specific part of the network. For instance, in some parts of the network, the traffic volume may be large without causing severe traffic congestion problems, due to the increased link capacity (in major arteries) or the efficient coordination of traffic signal operations. The link congestion level is represented by a number, which is translated to a colour (Table 2).

The processed data files are transmitted using an FTP procedure from the batch processing site to the UNIX-based Web Server of the NTUA School of Civil Engineering via the NTUA telematics (ISDN) network. Combining all the information contained in the data files, a set of GIF images are generated and stored in the Web Pages of the School of Civil Engineering Web Server. The main GIF image contains the whole area of Athens. The
other GIFs comprise blown-up parts of the network, which are generated along with the main image, every quarter of an hour via a UNIX script and displayed by clicking on the corresponding part of the main image.

As the project of the ADTM evolved over the years (1997 - 2007), the ideas to display actual traffic conditions and short-term forecasts of an urban network had not been implemented elsewhere at the time and hence the various aspects of the initial design could not be compared. Therefore, they were experimentally tried and assessed both locally and internationally by a small number of focus groups. Two major decisions were made: one concerned the content and colour of the background and the second the color scheme of the traffic volume and congestion levels. The limestone-brown (terra-tan) was selected to indicate the antiquity-related background of the area and was later changed to bright orange (paired with the bright blue for the sea) to reflect the prevailing colours of the Athens Summer Olympics. These choices made the ADTM stand out as a contemporary technological application of that era to the possible detriment (being a calculated risk) of readability or clarity of information. Traffic and congestion levels are shown on the basis of a two-tier scheme. A two-colour (red-green) representation of traffic situation in order for the user to assess “at a glance” the network conditions and compare its implications to other choices they could make, and a detailed 5-colour representation for detail monitoring of traffic and the evolution of congestion (see tables 1 and 2) were adopted. Conditions represented by the red colour are identical in both display schemes. Nonetheless, it is noted that a number of other criteria could be employed to decide on the colour scheme to represent volume, congestion or speed (e.g. see Morrison, 1971).

4. Demonstration of Travel Information Services

This section describes the various dynamic and interactive elements of the ADTM. Based on Kraak and Brown (2001), the present Internet map can be considered as dynamic, being automatically updated every 5 minutes. In some sense it geospatially represents the ever-varying movement of aggregate vehicular flows along the links and paths of the network. In addition, the ADTM is interactive, in the sense that the map display can be...
specified by the user, through providing facilities for zooming and panning and by providing direct geo-specific links to detailed local area maps. Figure 1 shows the typical cartographic background of the ADTM. The coloured paths show the fixed-track rapid transit lines of the metro and tramway, as explained in the legend appearing in the left-hand side of Figure 2. Also shown in white is the main road network and major two-way arterial streets (with black median) and black is the system of urban motorways (with no distinction between tolled and non-tolled) and the new suburban railway which runs parallel or in the median of the peripheral motorways. Figure 2 demonstrates an application-related use of the map after the user had “rolled-over” metro line 2, which is now added to the map to enhance the choice set in view of the traffic situation of the area. A number of further user options appear in the left-hand column of the screen, including general and zoom-in views with alternative road performance measures (traffic
volume and congestion level) and travel times along selected routes.

If the user clicks at a specific public transport station, a box appears that provides detailed information on the services offered, such as the lines of feeder bus services and other public transport connections, and parking availability (e.g., park-n-ride facility) around the station. Moreover, users can click on the “additional information” option to obtain detailed plans of the area with street names and other transport and public facilities surrounding each stop or station and location of exits, timetables with bus/train arrival times and a list of places served by the existing lines. As the scale of the region-specific map (see the upper right corner of Figure 2) is changed by zooming in or out, additional streets and street names appear or disappear respectively. This information is provided by linking to the database of the Athens Urban Transport Organization and the availability of any detailed information appearing on ADTM is dependent on this external database.

Figure 3 shows cartographic details of the coded road and public transport network in the central area of the city (cut-out area of Figure 1) with the
exact location of metro stations and the major two-way arterial streets (shown with a black median). Figure 4 presents the outcome of zooming in to the central area view of the ADTM with highlighted metro line 1 (i.e. the light rail line) as an example. The map display provides a combined information of the area’s congestion levels, as indicated by the map colour scheme (see Section 3), and available public transport services (metro and tram lines) in the central area, also shown in their designated colours.

The present dynamic map evolved from the original map format of 1997 (shown in Figures 5 and 6 below) after the end of the Athens Summer Olympics of 2004. Figure 5 illustrates the map display of the traffic volumes, based on the estimation procedure and colour coding described in Section 3. Also, Figure 6 illustrates a map display of the average distance that could be driven within the next 15 min (equal to ten 1.5-min signalization cycles) from major network access points being indicated by
the corresponding traffic lights. The user could select one point at a time by clicking on the traffic signal (resulting in the green light being turned on) and green lines would then appear extending along a set of prescribed destinations, based on the travel speed estimation procedure \( u(j) = f(v(j)) \) described in Section 2. In this application, the ADTM enables the estimation of the travel distances that could be driven along 17 major routes from 6 key network access (entry) points. If data for a road section that is part of a prescribed route was not available at the time of the request, that route would not be coloured. Such problems result at certain times in urban streets when a vehicle is blocking a loop detector buried under the road surface for a period that exceeds a threshold value (as is the case for the route along Pireos street).

![Figure 3 Cartographic details of the central area of the city (scale 1:50000)](image)

![Figure 4 Zooming of the internet map display in the central area of the city (scale 1:150000)](image)

The ADTM in its original format displayed stored information about historical (previous day) traffic conditions, in terms of the various performance measures, in order to help users to adjust their perception on the relative generalised cost of alternative transport means and the reliability of the network operating conditions on a day-to-day basis. The original map was then extended outside the boundaries of the central area.
Figure 5. General view of the map display of traffic volumes (scale 1: 80000).

Figure 6. Map display of the estimated distance to be driven within the next 15 min from a selected network access point (Patission) towards different directions.

(depicted in Figures 5 and 6) to encompass medium- to long-range travel time estimation during a large demonstration project during the pre-Olympics era (2000 - 2003). It provided information on the travel time required to reach specific locations in and around the central area of Athens, by providing mirror displays of actual Variable Message Sign (VMS) panels installed along the three highways leading to the city centre, whose traffic conditions are shown in colour (red for a congested section, green otherwise). Travel time estimates were obtained from the corresponding travel speed through the use of the functional relationship $u(j) = f(o(j), v(j))$ (see Section 2) and they are indicatively related to the congestion levels shown by the two-colour scheme. Figure 7 depicts the location of the clickable VMS panels by the grey flags along three highways connecting the central area of Athens (shown in the shadowed area) and Figure 8 shows the message of a selected VMS panel, which displays the maximum travel time required to reach a central area access point (location ‘Faros’).

Another important feature of the ADTM is the ability to adjust the map display for the screens of diverse communication devices, like PDAs and 3G.
cellular phones, at varying levels of spatial resolution. Figure 9 shows a ‘lighter version’ of the ADTM for PDA devices, which can be selected from menu category OTHERS, “PDA Connection”. These map information services can also be supplemented by subscriber-based information about the congestion severity in selected parts of the network, in relation to the typical average traffic congestion, and time-based traffic alerts about the occurrence of incidents or special events. In this way, users can have timely access to the ADTM, from different places, such as at home and the workplace, private car through on-board devices, and public transport stops or stations/terminals through information kiosks, through the use of Point-to-Point Protocol (PPP) or Indirect Transmission Control Protocol (ITCP).

It should be mentioned here that a recent change in the policy of the Greek Ministry of Environment, Physical Planning and Public Works, which oversees the Athens Traffic Control Centre, to charge 0.5€ per traffic loop per day has forced the Laboratory of Railways and Transport of the NTUA to temporarily operate on simulated data drawn from an extensive database.
spanning more than a decade.

5. Conclusions

The rapidly growing traffic congestion and the increasing complexity of trip making in contemporary metropolitan areas has encouraged the adoption of advanced information and communication technologies for transmitting real-time geospatial travel information to transport network users. The Athens Dynamic Traffic Map (ADTM) constitutes an advanced internet-based tool with unique features for providing timely and easy-to-use integrated multimodal traveller information. This information can enhance the (joint) use of public transport modes, and can facilitate the scheduling of multi-destination (chaining) trips with different modes. Current efforts focus on expanding the geographical and thematic
integration of the ADTM to include travel information for the whole Region of Attica, encompassing both intra-urban and inter-urban (sea ferry, inter-urban train, inter-urban bus) transport services.
Software

The ANSI-C language was used for the development of the application and known graphic libraries (CAD, GIS, VISIO) were used to create the GIF images.

Acknowledgements

The authors are grateful to Prof. Chris Wright and two reviewers who made constructive and helpful comments on earlier version of this paper.

References


