Data Fusion Integrated Mobile Platform for Intelligent Travel Information Management

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***Abstract* — This paper presents the concept and initial results of an European research project called *In Time*, regarding the integration via unified interfacing and the intelligent management of Multimodal Real time Travel and Traffic Information (MRTTI). The cooperation of different technologies, telematics applications and data fusion is used to produce more efficient travel management, with the final goal to reduce the energy consumption and emissions in urban areas, across the different modes of transports, by changing the mobility behaviour (modal shift) of the single traveller.**

Keywords – mobile real-time traffic and travel information; services; reliability; operability.

I. Introduction

Efficient transport and travel are two components without which a modern society cannot be conceived. Recently, the increased growth of traffic demand in major urban areas lead to increased usage of intelligent transport systems and technologies, especially those related to traffic management and information systems [2] (pp. 1-2). Different applications were developed lately for modern mobile devices, running on different operating systems (e.g., Windows Mobile, Windows Phone, Android, Symbian, Apple iOS etc.). These help people in finding their location, points of interest, routes or nearby facilities. But these applications only relate to the producer's software, quality of maps and/or static information. The idea of the *In Time* project [1] (*Description of Work*, pp. 9-38) was to develop a standardised interface, as a start point in conceiving a unified platform for the management of global mobile, real-time travel and traffic information for urban areas. The common interface will help a traveller across Europe to easier find his way and needed travel information, based on real-time information, no matter what the traffic information service provider would be. The usage of real-time information adds a lot of value to the efficiency of the information system, due to its possibility to re-configure routes, helping the user to avoid congested areas. One of the benefices is that it also helps users to change their modal transport behaviour, improving the usage of the public transport versus private cars. These actions finally produce less emissions and energy consumption in traffic, helping in obtaining greener cities. The *In Time* solution, with the commonly agreed standardized interface is now under testing in six European pilot sites to ensure the easy access of real-time multimodal traffic data for external Traffic Information Service Providers (TISPs) and to check several impacts: users' impact, traffic impact or the environmental one. This model already ensures the easy access to all urban traffic-related data within a larger region, resulting in the distribution to the end-users via several consistent information channels and in parallel enhancing the user acceptance.

The paper presents the concept and architecture of the system, the benefits, initial results of the first tests and possible future development of the applications.

II. The Novelty of the *In Time* Concept

The mobility is one of the attributes of a modern person. This is why the project *In Time* is focused on increasing the mobility of people in urban areas. *In Time* (acronym for Intelligent and Efficient Travel Management) is an EU funded project that aims at drastic reductions of energy consumption in urban areas, employing dynamic information for improving route guiding, transport and traffic information (using information related to multiple modes of transport). Until present, no such wide-scale system and service for collecting, integrating, converting and delivering real-time traffic information has been implemented. This system is required to ensure interfacing with different information systems, collection, processing and effective transport of data to final, either mobile or fixed users. Due to the fact that, at the present moment, there are no standardised interfaces to traffic and travel information systems or local relevant authorities (such as Traffic Control Centres, Road Police, parking management, weather information providers, port, airport or railway operators etc.), the *In Time* platform had to face a consistent challenge of how to unify the formats and contents of relevant information from these various sources. Requirements related to mobile real time travel and traffic information services [1] (*WP3.2.1*, pp. 10-38) have been identified on the basis of previous research projects (such as *eMOTION*, *i-Travel*, *LINK*, *KITE etc.*) and

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were grouped in several categories, that helped the design of the system architecture, presented further in Figure 1.

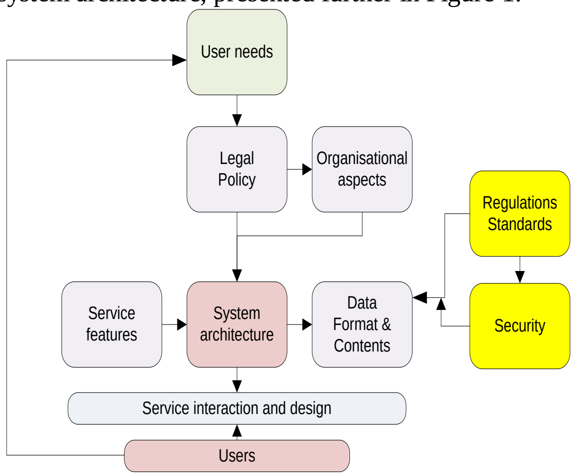

Figure 1 Factors that influenced the *In Time* system architecture design

Based on large market studies performed [1] (*WP2.2*, pp. 45-49 and *WP.3.4.1.*, pp. 11-33) in the first stage of In Time project, on the interviewing with the relevant stakeholders and users, a set of services has been identified. A selective list, containing the most relevant of them, is the following:

Table 1 List of main services developed in the In Time project

Crt. No.	Services	
	Service name	***Service type***
1	Static road traffic information	Static, core
2	Dynamic road traffic information	Dynamic, core
3	Static parking information	Static, core
4	Static public transport information	Static, core
5	Walking information	Static, core
6	Dynamic road traffic routing information	Dynamic, core
7	Dynamic public transport information	Dynamic, core
8	Dynamic public transport journey routing	Dynamic, core
9	Dynamic parking information	Dynamic, core
11	Dynamic cycling planning	Dynamic, core
14	Dynamic traffic event information	Dynamic, add-on
15	Dynamic weather information	Add-on
17	Comparative pre-trip dynamic multimodal journey planning	Core, main mobile application

Taking into consideration the above services mentioned, a set of quality indicators related to the service itself and the connected meta-data have also been analysed. On its initial launch, the data management platform of the *In Time* services is able to process various information and data from various sources. Therefore, the quality of some meta-data categories is particularly important (as presented in the following Table 2):

Table 2 Meta-data categories of the unified data platform and service quality indicators

Crt. No.	Meta-data categories	
1	Availability of information in time	Always/seasonal/on request
2	Geo-referencing availability	Y / N
3	Regional-related information availability	Y / N
4	Content/service type	Static / dynamic
5	Max. update rate for dynamic content	Time interval
6	Content / service availability	Public / restricted
Crt. No.	**Service quality indicators**	
1	Dynamic data update time accuracy	[s]
2	Geo-referenced data quality	[lat/lon]
3	Data completeness	-
4	Matching with existing interface standard	-
5	Failure / error handling capability and reporting	-

As described above, the *In Time* data-fusion platform needs information from heterogeneous sources, with different timelines, formats, standards or interfacing requirements. Therefore, the design of the system's architecture had to take into account all these requirements. It is a difficult task to adapt into a single system so many components and to make it usable in an efficient manner. Therefore, it is expected that the services provided by this unified platform will achieve:

- Business-to-business services, enabling European-wide TISPs[1] to get access to regional traffic and travel data and services in pilot cities via a harmonised standardised open interface; this will also enable the TISPs to provide interoperable and multimodal real-time traffic and travel services (*e*-services) to their end-users; *e*-services will influence the on-trip travel behaviour by optimising journeys, taking into account the energy consumption; typical users foreseen: all persons employing mobile navigation devices;
- Web-based interoperable and intermodal pre-trip information will be provided by the pilot operators and will have the potential to influence the travel behaviour in the trip planning stage by taking into account the environmental aspects. Typical users foreseen: persons planning an urban trip for short term.

The initial research and design phase has now presently come to end and the integrated platform architecture has been successfully developed in six European pilot cities: Vienna, Munich, Florence, Bucharest, Brno and Oslo. The current phase is designed to perform wide testing of the system and its impact, both on social and environmental aspects.

[1] Traffic Information Service Providers

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III. *IN TIME* PLATFORM ARCHITECTURE

A. *Building the In Time platform architecture*

Due to its complex tasks, the *In Time* integrated data management platform has to rely on a concept such as the multimodal Regional Data/Service Server (RDSS), which has to act as a service-oriented middleware infrastructure, providing a specific set of services and data management operations designated to cover: individual traffic information, public transport information, location based services, intermodal transport planning and/or weather information. The core of this concept is the design of a commonly agreed standardised interface that must satisfy all the requirements of standards and data formats, permitting the management of various types of information from various providers. Using such a unified interface, the users are expected to gain access to real-time multimodal data from external traffic information providers. The principles of interoperability are shown in the figure below (Figure 2):

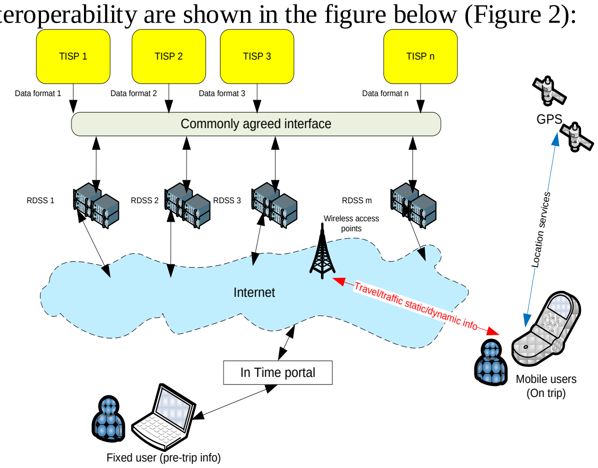

Figure 2 Principle of interoperability

The designed structure of the Commonly Agreed Interface (CAI) and the related reference standards and protocols took into account specific requirements of integration and harmonisation:

- Harmonisation of standards used by each TISP for each single domain of the integrated data management platform;
- Harmonisation across domains.

The first element means that each of the domains of *In Time* platform (traffic, public transport, parking etc.) in existing pilot systems usually make use of proprietary standardised interfaces. In the most common cases the situation is different from pilot to pilot and therefore the need for harmonisation. The second item means that, in order to achieve the goal of providing data and services really suitable for the implementation of the applications by TISPs (which integrates those data and services coming from different domains and different RDSSs) it is necessary to take into account the dependencies between the different domains.

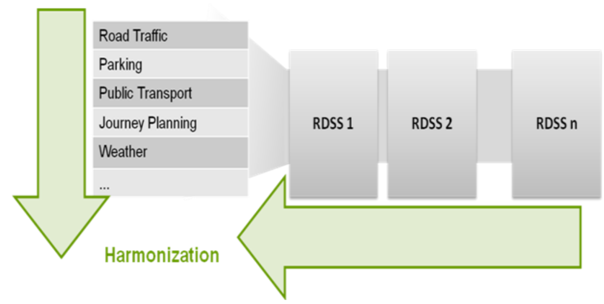

Figure 3 The "bi-dimensional" harmonisation of technical standards

Using a Model Driven Architecture (MDA) approach the specifications of the system have been designed based on the following operations:

- Modelling of data and services based on existing domain standards;
- The existing domain standards are selected and harmonised for the design of a conceptual model;
- A Geography Markup Language (GML) Application Schema and Web Service Definition Language (WSDL) were generated for obtaining exact specifications.

The CAI includes a single information space, based on a conceptual data model obtained by harmonising several international and European standards along ISO 19100 Geographic Information Standards. It includes domains such as: individual traffic (based on *DATEX II*[2]), public transport (*Transmodel*[3], *IFOPT*[4], *SIRI*[5], *TPEG*[6]), location based services, weather reporting, inter-modal transport planning.

B. *Ensuring the Path for Information Provision and Use*

The internal services of the application must ensure the correct information flowing between the different architecture entities and terminals. Amongst these, the Data Services and the Mapping Services are the most often used resources, due to the intensive employment of location based and routing information in the application. These services expose *In Time* standard interfaces for the provision of data (WFS[7]) and the maps (WMS[8]).

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[2] DATEX II – a standard for the exchange of traffic related data.

[3] Transmodel – a reference data model for the public transport.

[4] IFOPT *(Identification of Fixed Objects in Public Transport)* defines a model and identification principles for the main fixed objects related to public access to public transport.

[5] SIRI *(Standard Interface for Real Time Information)* – an XML protocol which allows distributed computers to exchange real-time information about public transport vehicles and services.

[6] TPEG *(Transport Protocol Experts Group)* – a standard for delivering traffic information via digital formats such as DAB, DMB, DVB or over the Internet.

[7] WFS – Web Feature Service – a standard interface for providing requests for geographical features over the Internet

[8] WMS – Web Map Service – a standard protocol for serving georeferenced map images generated by a map server over the Internet

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Figure 4 below shows this process.

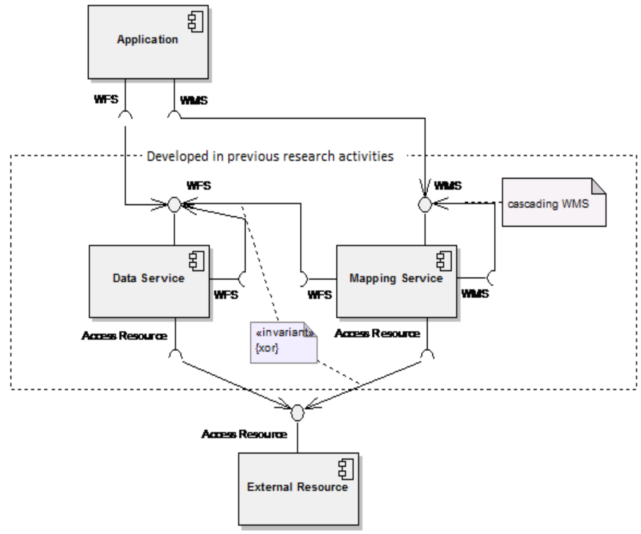

Figure 4 Integrated platform components for information provision and use

IV. Local Pilot City Implementation and Initial Tests

Bucharest (Romania) is one of the pilot cities to demonstrate the *In Time* integrated platform functionalities. Here, the road traffic signalling and the public transport are managed by a common system [5] (pp.3-4), the Bucharest Traffic Management System (BTMS). This infrastructure incorporates local equipment and outstations (traffic detectors, traffic controllers, WiFi hotspots, CCTV, fibre optic communication network etc.) and central computers in the traffic control centre. The *In Time* system interfaces with BTMS and collects dynamic information from this traffic/travel information provider. As expected, the BTMS employs proprietary and in general different standards from the systems in other cities (Tables 3 and 4). The service provider (TISP) can request an *In Time* service already available at the RDSS or in case this *In Time* service is not available at the RDSS, it can request the required content from the RDSS, to allow him to create this *In Time* service himself. The quality of the services offered is one of the most important factors that define the utility of the system. This feature may be considered from a dual point of view: the quality of the information offered by local systems and the quality of service offered by the *In Time* system. Only the second one is important for this analysis. Of course, in the quality of the In Time service also has to be considered the delay in delivering real-time information from the local systems. The local tests performed in Bucharest showed the critical influence of traffic congestion in estimating the correct time of arrival at destination (ETA), especially for the "car" and "public transport" modes. Thus, the quality of the dynamic information delivered to the In Time system proved crucial. For example, Table 5 shows differences in ETAs and time lags recorded for some tests performed in Bucharest.

Table 3 Availability and interfacing with services in Bucharest, compared with other pilot cities

Service	Bucharest	Brno	Florence	Vienna
Routing	*Proprietary (+WDSL[9])*	TMC[10]	Proprietary	Proprietary
Location	*Proprietary*	TMC	WFS	WFS
Messaging	*Proprietary (+WDSL)*	TMC	WFS	Proprietary (XTIS[11])
Mapping	*WMS*	Proprie-tary	WMS	WMS

Table 4 Contents and standards available in BTMS compared to other pilot cities

Content	Bucharest	Brno	Florence	Vienna
Traffic Data	DATEX	Alert-C[12]	DATEX	TICXML [13], DATEX
Public transport	*Proprietary*	Proprie-tary	Proprietar y	Proprietary
Map data	*Images through OGC WMS [14]*	Proprie-tary	Images through OGC WMS	Images through OGC WMS

As it can be observed from the above Tables 3 and 4, different formats and standards had to be feed in a single database, via a commonly standardised interface. The Bucharest system's architecture is presented in a simplified manner in the Figure 5. The main sub-systems of the BTMS are PTM (Public Transport Management) [3] (pp. 2-5) and UTC (Urban Traffic Control). These sub-systems form an integrated component for obtaining dynamic traffic/travel information. The BTMS is connected to the RDSS via a VPN tunnel, in order to protect the information and the traffic management system. Traffic messages and other information is converted into the needed format by the CAI and then delivered to the users via RDSSs.

These tests of the In Time system include:

- Checking the existence and correct operation of all available services in the pilot city (functional testing);
- Checking the quality of the services provided (validation testing);
- Checking the impact of the services:
  - Social impact over the users;
  - Traffic impact;
  - Environmental impact.

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[9] WDSL – Web Service Definition Language – a specification for describing network services as a set of endpoints operating on messages, containing either document-oriented or procedure-oriented information

[10] TMC – Traffic Message Center

[11] XTIS – Extended Tool Integrated Services

[12] Alert-C – European standard for language independent exchange of traffic information via a RDS-TMC channel

[13] TIC-XML – common XML schema containing already translated and coded data from a traffic information centre (TIC)

[14] OGC (WMS) – Open GIS (Geographical Information System) for the web

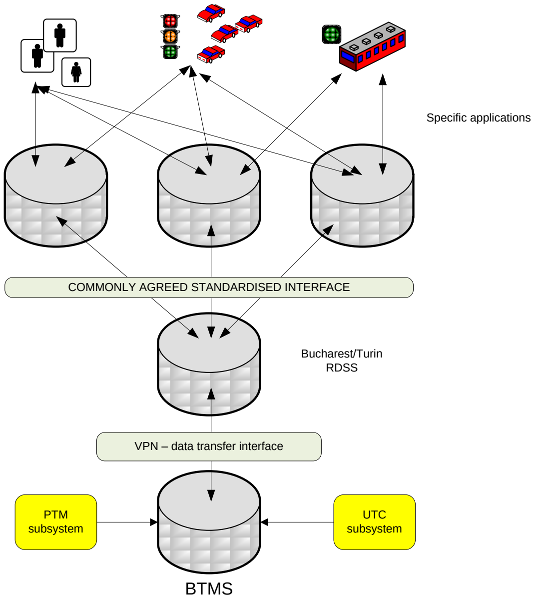

Figure 5 The Bucharest pilot *In Time* physical architecture

After the successful testing of the existence and correct operation of the *In Time* system functionalities, one of the most difficult problems is to determine the quality parameters. This is particularly difficult as the test operator has to determine if the poor response time, for example, is due to the *In Time* system or to the data service provider. Generally speaking, the existing quality concepts are close to the quality model of ISO 19113. This concept is unfortunately not exactly usable in this case, because the scope of that procedure is to use a quality model within the whole information chain and not only for a dataset from data producers. The quality characteristics *availability*, *up-to-datedness*, *completeness* and *correctness* define the connection between the geographic data and the final mobile user. The computation of *availability* can be effected by failure rate in the physical support. It indicates that the degree of probability of a failure of a dataset within an assumed period and can be measured by the function:

$$R(t) = \frac{n_{ZV}(t)}{N} \quad (1)$$

where the quotient is the number n_{zv} of missing entities at the moment t and the number N of entities in the system.

The concretion of the *"up-to-dateness"* can be effected by comparing the rate of update with the rate of change: comparison of how the dataset is changing and how the content in accordance with the universe of discourse is changing. This quality parameter can describe whether the geo-information is actually valid or not.

The omission rate is a quality parameter for completeness and can be described by the following equation:

$$CM = 1 - \frac{n_{IC}}{N} \quad (2)$$

where N is the number of entities in the modelled reality and n_{IC} the number of correspondent missing entities in the database. In a similar way can be defined the other quality parameters of the model. Beside the quality parameters of the model itself, when testing such a complex system it is important to also determine, from the users' point of view, the responsiveness of the information chain. Because the *In Time* system and services have been started very recently, only preliminary tests have been carried on in Bucharest. In the table below there are shown some of the time lags determined on different mobile devices (time measured between sending the command and receiving the answer – tested on 3 devices, information updated via GPRS/3G network) and estimations of arrival time at destination, that the mobile application delivers to the user.

Table 5 Initial results for time lag measured at the information request

Test type / mobile platform	Apple iOS	Symbian OS 5^{th} edition	Windows Mobile 6.x
Time lag for presenting selected dest.	1-2 s	1-2 s	1-2 s
Max. time lag to determine routes to destination	14 – 80 s	20 – 82 s	17 – 55 s
Max. ETA error, "Pedestrian" mode	5 min	5 min	5 min
Max ETA error, "Car" mode	10 – 18 min	10 – 15 min	n/a
Max ETA error, "Public Transport" mode	- 5 min... + 25 min	- 5 min... +40 hours (!)	n/a

The maximum ETA error for "Public Transport" mode for the Symbian application showed strange figures in some isolated cases (see Table 5), due to possible mistakes in selecting the public transport lines, but this is probably a software issue that is to be solved in the next project steps.

V. FUTURE DEVELOPMENTS

The services that the *In Time* integrated platform is providing include a large number of physical and virtual entities: local systems/interfaces, local software applications, fixed or mobile communication networks, data processing and converting etc. Therefore, in order to ensure a good operation time and presence of these services especially to mobile users, several communication methods are to be taken into consideration. Moreover, for obtaining a good "visibility" of these services, they have to be expanded in the near future, integrating more and more applications from the transport field: expansion to other transport modes information/routing (trains, airplanes, ferries etc.) and coverage expansion (covering not only urban areas, but also interurban). In the local pilot of Bucharest city, several tests have also been performed in order to determine the usability of different WiFi hot spots for obtaining dynamic MRTTI also in bus stations, parks, street junctions etc. In this spirit, the tests took into consideration also the usability of some WiFi special hot spots, such as the ones used by the public transport. The local BTMS communication infrastructure is comprised of 150+ Access Points installed in intersections of Bucharest and WiFi clients installed on each public transport vehicle. Therefore, several tests were performed in order to

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determine the availability and some communications' parameters, like *delay* and *throughput*, by using these WiFi Acces Points, on the 2,4 GHz and 5 GHz bands [4] (pp.3-5). The measurement area was selected in central Bucharest. There were chosen two types of intersections: busy ones (from the RF communications point of view) and free ones, with few interference and usage of WiFi spectrum. We present further the results in the junction with the most busy RF environment (many governmental buildings and public/private Access Points) – Victoriei Square. Spectrum analyses in both bands have also been performed, seeking for an observation regarding the usage of WiFi protocol in the mentioned locations. While both 2.4 GHz and 5 GHz bands are installed, the most significant activity was detected in 2.4 GHz band. This is why we considered presenting only the results regarding this band. The Victoriei Square area of study had the following characteristics (Figure 6):

- High usage of the 2.4 – 2.5 GHz spectrum, very low in 5 GHz spectrum; beside the WiFi and Bluetooth, high power CW continuous carrier transmitters have been detected;
- A large number of Access Points (over 40) have been identified in the area; WiFi channel utilization reaches in some moments 90%, especially in the zone of channels 1 to 5.
- There have been identified many interferences due to adjacent WiFi channels and also to the powerful RF continuous carrier transmitters in the area;

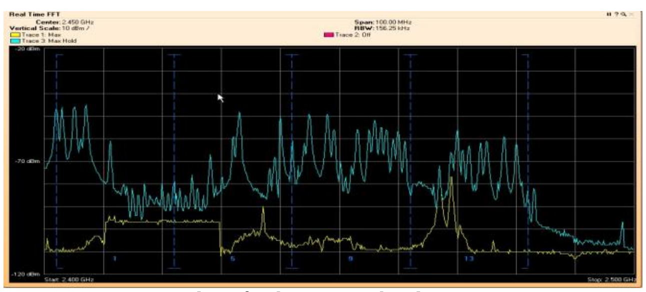

Figure 6 Spectrum analysis for the 2.4 GHz band

The next diagram presents the channel utilisation for the 2,4 GHz band in this area (Figure 7):

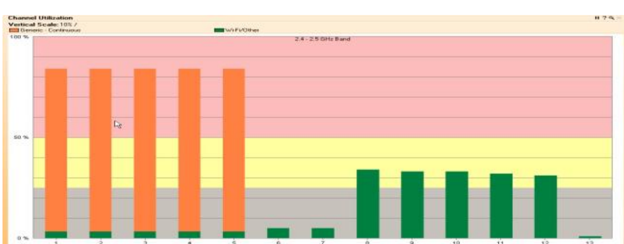

Figure 7 Channel utilisation for Victoriei Square WiFi hot spot

Regarding the WiFi protocol, the test results determined that even in this area, considered the worst case scenarios, the IP communication is possible. The maximum measured delay was about 1,2 seconds and data throughput din not decreased under 1Mbps.

In the future it will be also possible to deliver *In Time* content via any other WiFi access points in urban areas.

VI. CONCLUSIONS

The analysis of In Time system's performances performed in Bucharest showed several critical aspects:

- The errors in the ETAs depend more on the quality of the real-time traffic information (for the car and public transport modes) and less on the mobile communication network quality, although it is important to have good GPS and communication channels coverage [4] (pp. 2-3);
- The accuracy of the real-time information delivered by local traffic information providers is crucial for the precision of ETAs.
- The tests demonstrated the concept is valuable also for fuel consumption / pollutant emissions reductions, delivering better routes and therefore diminishing congestion in traffic.

It is expected that the usage of the *In Time* services will increase in the future, employing also available urban hot spots in support of the information broadcasting. The integrated services that the *In Time* project introduces will increase in usefulness and will constitute a tool to easily find traffic/transport related information anywhere. In the future, the expansion of these services will help the urban society in reducing the emissions and fuel, or energy consumption by choosing more appropriate modes for urban transport or saving time and fuel when travelling.

ACKNOWLEDGMENT

The authors would like to thank all the *In Time* project partners for their fruitful cooperation. They hope that the concept of the system and the services provided will continue to be developed via new research projects and a common, harmonised European standard in the next future.

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