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GIS-based Integrated Project Management Services during the Construction of Transport Infrastructure

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Abstract

This paper proposes the main design steps and demonstrates the usability of a GIS-based System able to provide integrated project management services during the construction of transport infrastructure. The System utilizes spatiotemporal data related to the various construction phases of a project (e.g. occupied area of a Metro station over a construction period) providing valuable assistance to the involved actors such as constructors, Public authorities and Public Transport Operators, as well as citizens and other road network users. The research presented was inspired by the need for continuous and up to date provision of information during the construction of a major project at the city of Thessaloniki, the Thessaloniki Metro project that has recently started.

1. Introduction

The construction of transport – and other - infrastructure in urban areas induces significant impacts on the daily mobility habits of the citizens who attempt to negotiate with travel delays and increased travel costs. Changes in trip features include departure time, trip route, rescheduling of the activity related with the trip as well as choice of public transportation as an alternative mean which may possibly face advantages as opposed to auto (e.g. bus lanes, access to areas restricted to autos etc.). Provision of information to citizens about the traffic diversions at the worksite areas during construction of infrastructure that affect highway and/or traffic network capacity becomes therefore a necessity; citizens are able to rearrange their trips if possible and the state and/or local authorities may better achieve their objectives that is to minimise the various impacts to the areas and citizens concerned.

Given the continuous changes occurring at the worksite areas of an infrastructure project, the up to date provision of information to citizens and other interested actors, prerequisites a “dynamic” information system able to be fed with the effective traffic diversions. Since most of the information involved are of spatial nature, and is also critical to be accessible by every potential user, such a system could well be based on GIS capabilities combined with Internet-based dynamic applications.

Continuous changes of traffic diversions can be met in several infrastructure cases. The construction of a new highway, or the improvement of an old one, the construction of a sewerage or water supply network, the construction of a metro line, the conversion of road intersections to multi-level ones are some typical examples. In all these cases traffic diversions that change in short time periods are needed as the project progresses.

2. Case Study

A real world case concerning the construction of a new transport infrastructure in an urban area was selected for the purposes of this work. The case refers to the Thessaloniki Metro system and in particular the construction of its first metro line. The specific line has a total length of approximately 9,4 km and includes 13 metro stations that will be constructed during a period of 6 years, from 2006 to 2011. For each metro station three or more construction phases have been planned, and for each phase a specific traffic diversion plan has been developed, depending on the road network occupation by the worksites. As a result, the map of the worksite areas – and consequently the overall traffic map of the city showing all interventions – during a specific time period of the metro construction phase for the whole spatial extend of the project, is obtained by combining the traffic diversions around every metro station being in effect during this specific time period. This information pertaining to traffic diversions could be easily accessed through internet, provided that a suitable Web based application will be developed. The proposed system is able to provide valuable information to the citizens for the prevailing and/or future traffic conditions around on or more metro stations and/or all metro stations during the various construction phases.

2.1 Technical Approach

As in almost all project cases, traffic diversions are designed and shown on CAD or similar format drawings. The source data for this particular case include a set of CAD drawings each of them depicting various layers of spatial information that is modified during metro stations construction phases. Every drawing of a metro station refers to a specific time period depending on the starting and ending dates of the corresponding construction phase. The spatial features of this information are mainly polygonal and represent: Existing Roads, Permanent/Temporary Public/Private Space's Occupation for Entrances / Main Station / Movable Working Site etc.

As already mentioned the above space occupations are differentiated during the metro construction period. The time spaces between the construction phases of the metro stations are also different. As a result every construction time period (i.e. project month) is related to a different combination of space occupations at the Metro stations and thus it influences traffic conditions that occur in the road network. Consequently, different traffic arrangements are set by traffic engineers due to the above mentioned worksite area variability over time. Figure 1 presents an indicative drawing of the space occupations occurring during a specific construction phase of a metro station.

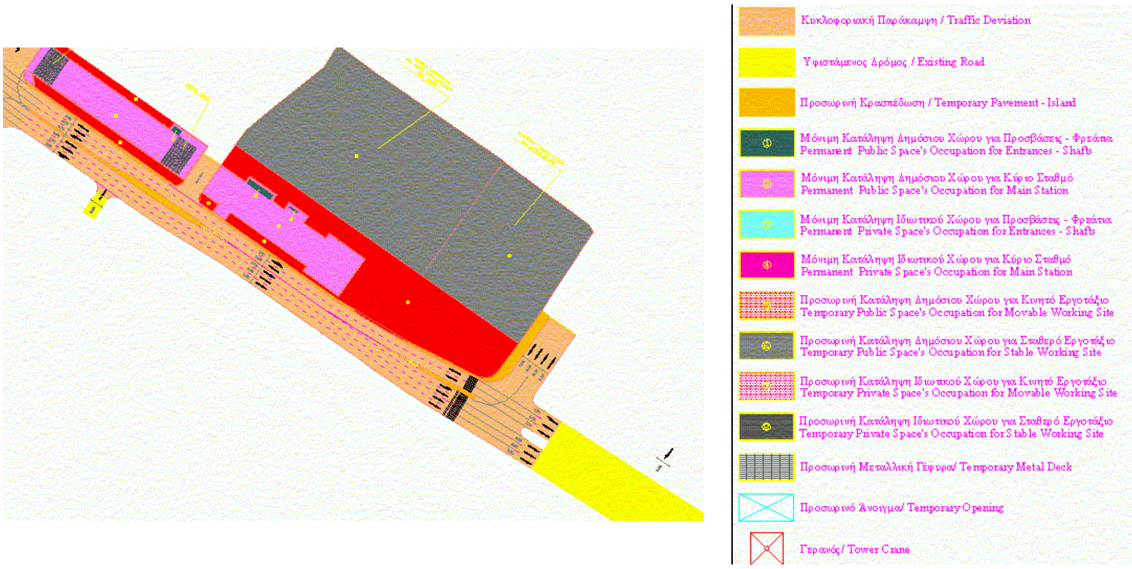

Figure 1: Indicative space occupation during a metro station construction phase
[Obtained courtesy of AEGEK S.A. and Attiko Metro S.A.]

The technical approach comprises five tasks and is analysed as follows:

I. Collection of Metro Station Drawings

Every Metro station is scheduled to be constructed in a certain number of construction phases. The starting and ending date of a construction phase is differentiated form one station to another. As a result the total number of drawings, as the indicative one shown in Figure 1, is equal to the combination of the construction phases of all the metro stations.

II. Transformation of Drawing Layers to Shapefiles

The layers of each drawing, representing the various occupation spaces in the area of the metro stations, are individually transformed to a respective number of polygonal shapefiles. Thus, the total number of shapefiles is equal to the number of drawings multiplied by the number of the layers existing in each drawing.

III. Addition of Starting and Ending Date Information

Every shapefile created in the previous task corresponds to a specific spatial feature of a metro station worksite area, for a specific construction phase of this station. The information of the starting and ending construction date for this construction phase is added in respective fields inside the shapefile’s attribute table.

IV. Geodatabase Creation

So far, every shapefile represents one of the 13 spatial features shown in Figure 1. These spatial features of the worksite area of a metro station correspond to a specific construction phase of the station. Shapefiles representing the same spatial feature are consequently grouped to a unique feature class of a geodatabase. Thus, the geodatabase consists of 13 feature classes, where each feature class contains the starting and ending date of its spatial features.

V. Query Building

The geospatial data of each feature class define the location of the spatial elements over the Metro line extend. The descriptive data of the starting and ending construction date define the appearance of the spatial elements over the time. Therefore, in order to display all the elements of the “Temporary Public Space’s Occupation” that are going to occupy the space of the total Metro line extend during a specific project month, an SQL statement of the following syntax should be applied on the geodatabase mentioned feature class:

```
Select * from Temporary Public Space’s Occupation
Where starting period < project month and ending period > project month
```

2.2 Demonstration

The tasks previously mentioned were applied for some space occupations, in order to indicate the applicability of the proposed approach. It should be stressed that the material presented in the following figures does not reflect to real geospatial data and was created for the research purposes of this presentation.

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Figure 2, presents an approximate trace of the metro line in Thessaloniki urban area as well as possible space occupation over the scheduled Metro stations.

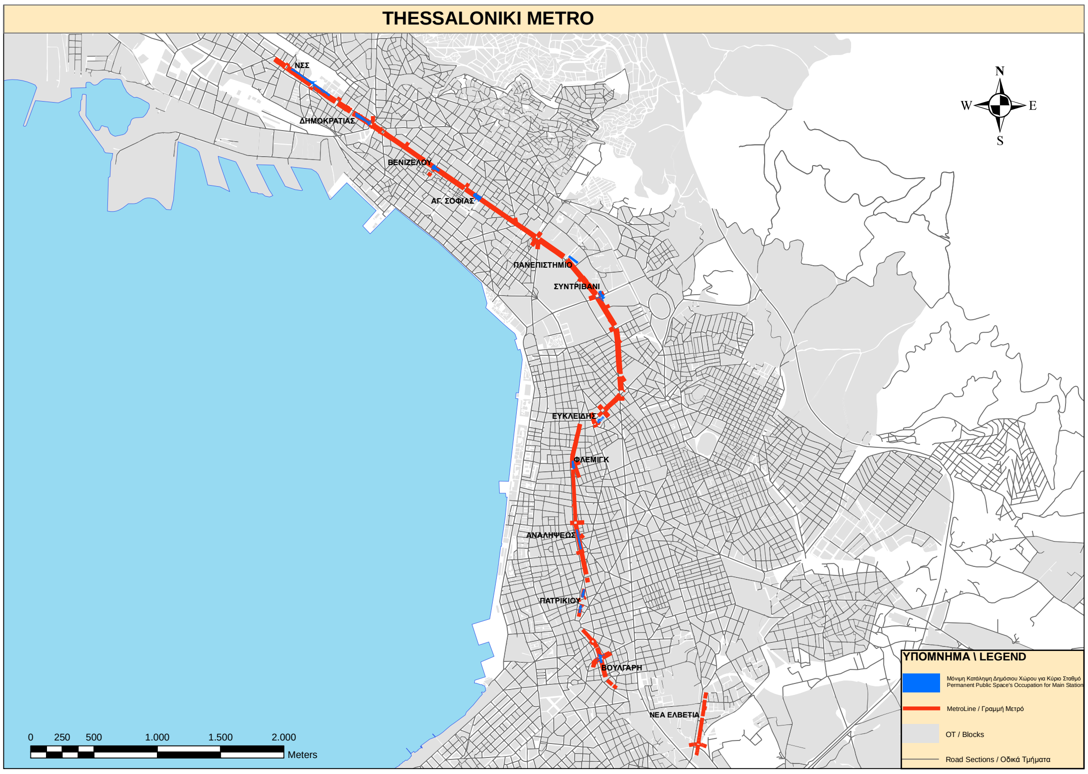

Figure 2: Indicative design of Metro line and public space’s occupation
[Obtained courtesy of Attiko Metro S.A.]

Figures 3, 4 and 5 focus on a specific Metro station, where some space occupations were designed for three construction phases. The appearance of space occupation is a function of time, which was inserted inside the polygonal spatial feature attribute table. As a result, depending on the project month, different space is occupied in the selected Metro station.

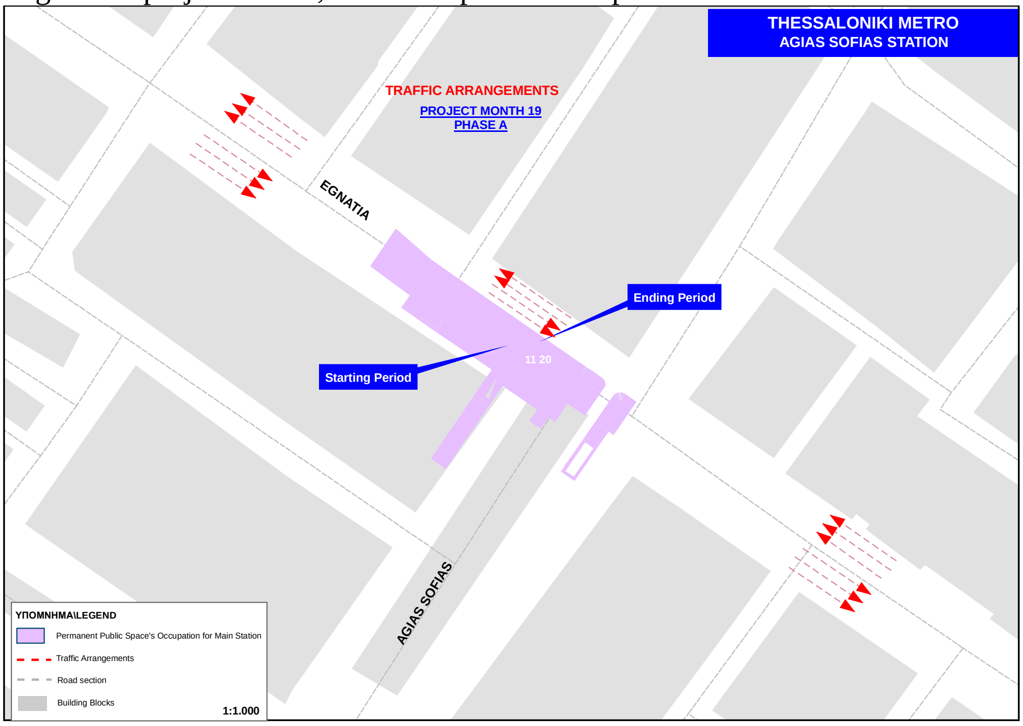

Figure 3: Indicative space occupation during a Metro station construction phase

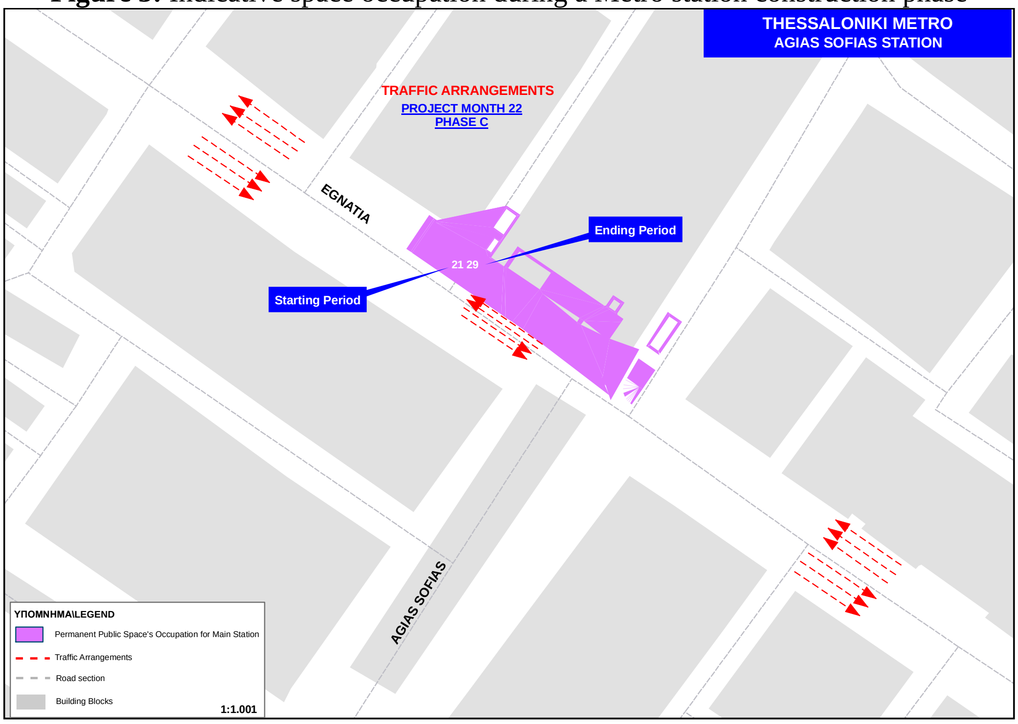

Figure 4: Indicative space occupation during a Metro station construction phase (differentiation from Figure 3)

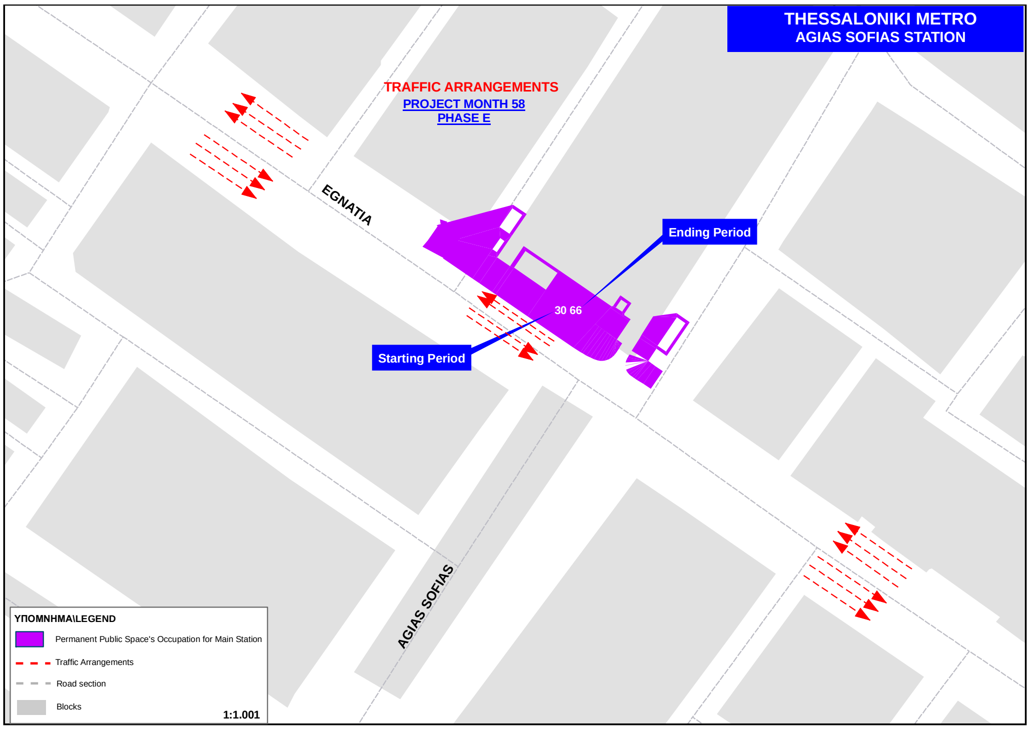

Figure 5: Indicative space occupation during a Metro station construction phase (differentiation from Figures 3 and 4)

Figures 6 and 7 provide indicative space occupation in the area of three Metro stations for two different construction instances.

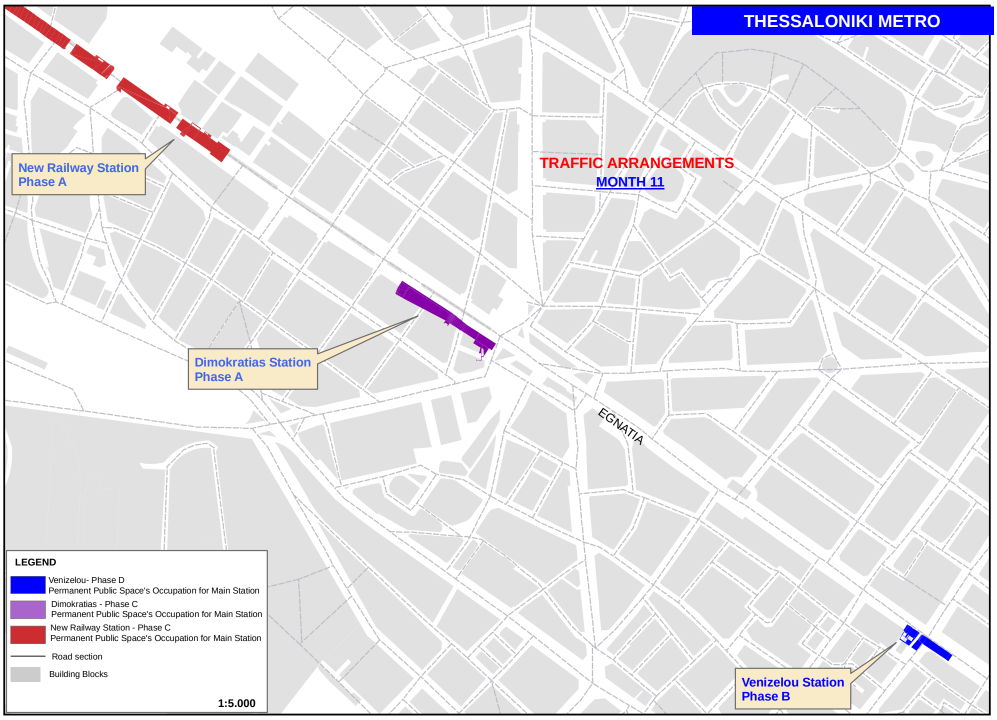

Figure 6: Indicative space occupation for the 11th month of Metro construction over the area of three Metro stations

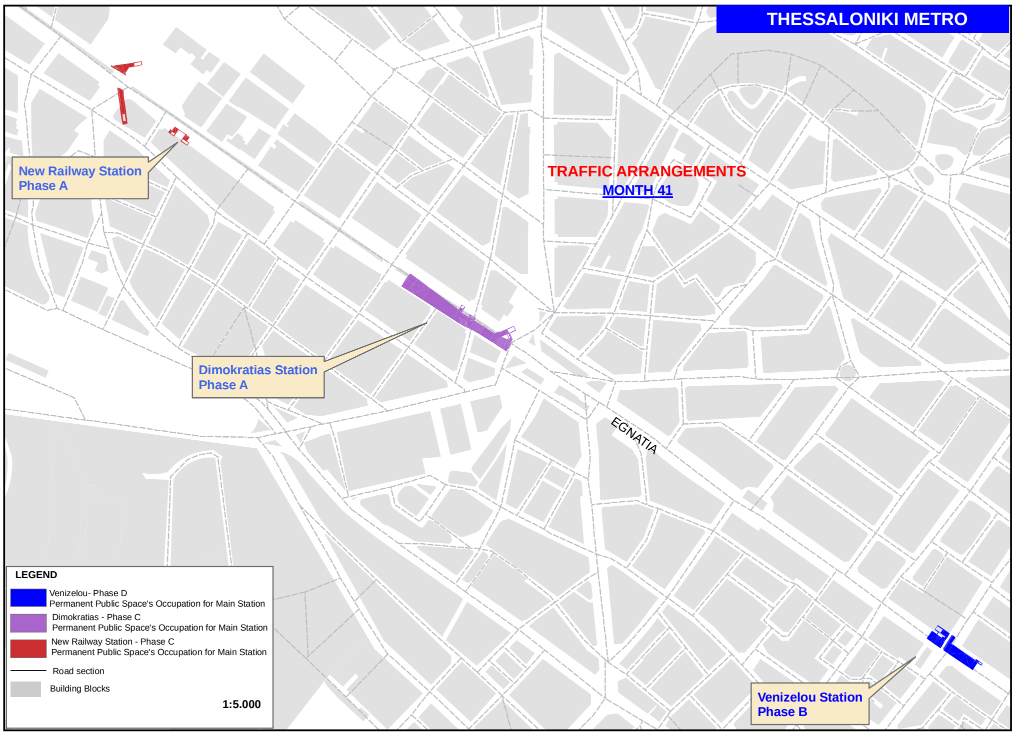

Figure 7: Indicative space occupation for the 41st month of Metro construction over the area of three Metro stations

3. Exploitation of Application

The presented application can be exploited in many different ways and by different actors. Different actors include the construction firm itself, the owner of the project ie the State authorities, the other involved Public authorities responsible for the road network and its operation such as the Highway Authority and the respective Municipality(ies), the Public Transport Supervisory Authority and the Public Transport Operator etc. Each actor needs some of the information retained and exploited by such a GIS based application for its own purposes and goals. Table 1 provides an indicative overview of the different actions that are assisted by the use of the application by each involved actor.

The number of actors and actions can be increased/decreased depending on the type of infrastructure, the area concerned (urban or rural) and the complexity of the project under discussion. It also depends on the administrative structure of the state or region / municipality where the construction takes place as well as on the procurement method and the legal / institutional settings associated with the project

Table 1: Overview of actions related to involved actors during the construction phase of an infrastructure project

Actor \ Action	Prepare modified traffic diversion plans	Change / modify traffic network signs	Calculate new traffic signal settings	Modify public transport bus routes	Inform trip makers / citizens / product distributors	Supervise construction progress
Construction firm	●					●
Firm’s Traffic Consultant	●					
Supervisory Authority					●	●
Owner of the project						●
Road network operator		●				
Traffic Signal Operator			●			
Public Transport Authority				●	●	
Public Transport Operator				●		
Information Service Provider					●	

Some of the actions of Table 1 can be achieved without any special tools or mechanisms. For example the preparation / modification of new traffic diversion plans and the change of traffic signs can be fulfilled with no other supplementary tools and/or mechanisms. On the other hand, some other actions such as the information provision to citizens and other interested road network users requires the development of suitable tools that can convey the necessary information. The development of Web-based systems and of various subsystems, including Internet Map Server, Relational Database Management System, Communication infrastructure etc are some of these tools that seem to be the most suitable ones. However, it is not always clear who is responsible to develop / exploit such as system.

4. Further Developments

The above approach can be well applied in almost every infrastructure or other project case that involves occupation of public space and in particular road network space and thus affects the offered capacity by the transportation system. In the case of large and complex projects, where traffic diversion plans and phases can be easily altered due to external factors - archaeological excavations, utility networks, etc – the usefulness of such application is important and can save thousands of lost travel hours. In addition, it adds considerably to the image of both the responsible involved public authorities and the construction firm.

The next step in this first effort is the development of a standardised approach where the various input data and files can be properly tagged and automatically entered into a spatial database management system which in turn will be integrated inside a web-based generic application applicable to different infrastructure project cases.