Design of a MIS for the optimization of the taxi system in a metropolitan area

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Abstract

Within the framework of this paper, the design of a Management Information System (MIS) is presented concerning the operation of the taxi system with reference to a metropolitan area. More especially, the case study is referred to the Thessaloniki Metropolitan Area (TMA) where 1,750 taxis are in operation every day. No MIS exists now for the operation of the taxis in the TMA and therefore the proposed MIS is going to meet existing needs. The MIS was designed taking into account both the operator’s (taxi companies) point of view and also the customer’s point of view. The overall objective of the proposed MIS is the improvement of services provided by the taxis and thus the improvement of the attractiveness of the taxi system as a whole.

1 Introduction

Taxis in urban areas are an important part of the transportation system. In most large cities taxis are an important mode that offers a speedy, comfortable and direct transportation service. Taxis make considerable demands on limited road space and contribute significantly to traffic congestion even when empty and cruising for customers [1]. The proper operation of the taxi system depends on a number of parameters including the existing legislation framework, the operational characteristics of the taxi operators, the general characteristics of the transportation system in the area and the people’s attitudes concerning their daily
trips. The use of taxis in major cities in Greece, when expressed as a percentage of the total daily trips is 10% in Athens [2] (for the year 1996, total number of daily trips equal to 7,000,000) and 4,2% in Thessaloniki (for the year 1998, total number of daily trips equal to 1,600,000). When considering the medium size cities in the country the respective percentage is smaller (e.g., 1,6% for the city of Trikala, 2,2% for the city of Larissa, both cities found in central Greece). In Athens the average number of hours a taxi is in operation every day is 18,5. The average number of kilometers/day/taxi is 358. Each taxi carries on average 49 passengers/day [3]. Two two taxi profiles existed in Greece nowadays in terms of route and customer order specification are presented in Table 1:

Table 1: Taxi profile in terms of route and customer specification

<table>
<thead>
<tr>
<th>Taxi profile</th>
<th>Route specification</th>
<th>Customer specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxi belonging to companies</td>
<td>By demand, Fixed Random</td>
<td>Sole Shared (illegal)</td>
</tr>
<tr>
<td>Taxi with no information equipment</td>
<td>Random Fixed</td>
<td>Sole Shared (illegal)</td>
</tr>
</tbody>
</table>

There are various reasons why the taxi system needs changes in order to improve the level of service offered to the customers and also to have economically viable enterprises into operation. A very recent legislation is now imposed in the country, concerning the operation of the taxi system, and aiming at the optimization of their operation and services offered to the public. Within the framework of this paper, the design of a Management Information System (MIS) is presented concerning the operation of the taxi system with reference to a metropolitan area. More especially, the case study is referred to the Thessaloniki Metropolitan Area (TMA) where 1,750 taxis are in operation every day.

These taxis daily made a number of 72,893 trip routes with an average travel distance of 8,2 km when carrying passengers [4]. The way the taxi system is now functioning depends on the operation of a number of taxi unions each of which has different operational characteristics (e.g., different communication technologies). No MIS exists now in TMA and therefore the proposed MIS is going to meet existing needs of the taxi system. The logical schema of the MIS is presented in this paper. The MIS covers all aspects of both the operator point of view and also the customer point of view. The existing legislation is taken into account together with the current traffic regulations in the city. The overall objective of the MIS is the improvement of services provided by the taxi and thus the improvement of the attractiveness of the taxi system as a whole.

2 Characteristics of the taxi services system in TMA

A number of 1873 taxis are registered (1998) in TMA of which 120 taxis (on average) are out of operation in TMA every day due to various reasons (e.g car
maintainance). The variation of the taxi services system characteristics in TMA for the period 1988-98 is presented in Table 2.

Table 2: Characteristics of the taxi system in TMA

<table>
<thead>
<tr>
<th>Characteristics of the taxi system</th>
<th>Year</th>
<th>1988</th>
<th>1998</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of taxis</td>
<td></td>
<td>1,700 taxis</td>
<td>1,873 taxis</td>
</tr>
<tr>
<td>Average number of taxi/day</td>
<td></td>
<td>1,300 taxis</td>
<td>1,753 taxis</td>
</tr>
<tr>
<td>Average number of trips per taxi for 12 hours of daily operation</td>
<td>56</td>
<td>33 trips</td>
<td>21 trips</td>
</tr>
<tr>
<td>Estimated total number of trips/day</td>
<td></td>
<td>42,170 trips</td>
<td>36,813 trips</td>
</tr>
<tr>
<td>Average trip distance (in km.)</td>
<td></td>
<td>4.6 kms</td>
<td>3.4 kms</td>
</tr>
<tr>
<td>Estimated total veh-km/day</td>
<td></td>
<td>193,982 veh-km</td>
<td>125,164 veh-km</td>
</tr>
<tr>
<td>Average number of trips (with passengers) per taxi for 12 hours</td>
<td></td>
<td>72.3% * 33 = 23.9 trips</td>
<td>86.7% * 21 = 18.2 trips</td>
</tr>
<tr>
<td>Total number of trips (with passengers) per taxi for 12 hours</td>
<td></td>
<td>24 * 1,300 = 31,200 trips</td>
<td>18 * 1,753 = 31,554 trips</td>
</tr>
<tr>
<td>Estimated number of passengers served for 12 hours of daily operation</td>
<td>56</td>
<td>31,200 * 1.5 = 46,800 passeng.</td>
<td>31,554 * 1.5 = 47,331 passeng.</td>
</tr>
<tr>
<td>Percentage of taxis in the trip distribution per mode</td>
<td></td>
<td>6.12%</td>
<td>4.20%</td>
</tr>
<tr>
<td>Percentage of taxi trips having at least one of the trip ends in the city center</td>
<td>56</td>
<td>56%</td>
<td>57.1%</td>
</tr>
</tbody>
</table>

Source: [4,5]

3 Detailed MIS considerations

The proposed MIS aims at the optimization of the taxi system of TMA and it concerns taxis belonging in cooperatives/companies only. This means that for these taxis there is an administration and monitoring center which it has already established a communication network with their members. The MIS will be compounded with a GIS incorporating all the relative geographical information about the TMA. The MIS will have effect on the following three discrete levels: a) individual level, b) organizational level, c) social level.

On individual level, it will be easy for the taxi drivers to get any information needed in real time. Besides that, the use of the MIS will allow the individual taxi drivers to make more efficient travel choices and will also help them by reducing anxiety and stress associated with travel planning. Concerning the customer side, trips by taxi will be faster and perhaps will cost less when compared to the cost of the previous situation (without the MIS).

For the taxi companies, the use of the proposed MIS will have as a result a more efficient use of the road network by their vehicles. It will also result to
significant reductions in travel time, to fewer delays and to less fuel consumption and emissions. For the local society, there will be an improvement of the provided services by the taxi system and also a relief to the problem of traffic congestion, and thus a reduction in the values of air pollutants. It must be mentioned at this point that the renewal of the taxi fleet (use of new technology diesel engines) during the last decade seem to have an important effect on the temporal decrease of SO$_2$ and TSP in the Thessaloniki city center [6]. Further improvement to the environmental conditions can be expected as a result of the better organization of trips of these vehicles in the city road network.

The information systems for taxis can be divided into two categories depending on the communication technology used and the information provided: the classical and the advanced information systems. The first category is based only on communication technologies for information dissemination e.g., the taxi center communicate with the vehicles mainly by the use of specific radio frequencies. This type of information systems might be considered satisfactory as regards information about customer picking (place, time, destination). These systems do not deal with detailed transportation problems of each taxi driver (e.g., which road to use, traffic conditions in the area etc.) Therefore, the taxi driver decides and acts intuitively, based on his empirical knowledge and rough estimation of the current traffic situation.

On the contrary, the so-called advanced information systems can provide, in addition to the above mentioned basic information, dynamic route guidance, real time traffic condition information, route scheduling and other necessary information concerning the trip. This can be accomplished by use of a MIS that will incorporate all modern communication and computer technologies. Thus, it will be possible to provide customized information to each driver for every trip.

The main objectives of this system, which proposed for TMA include:

a) The selection and filtering of the information needed from the taxi system in order to be fully operational and effective.
b) The provision of this information (e.g., routing, scheduling, address finding, yellow-pages needs) of every taxi driver.
c) The elimination of data sifting through the reduction of information provided to the taxi drivers taking into account the specific needs of the individual driver.
d) The quality improvement of the information provided to the driver.

The taxi drivers will receive and send the information by use of various communication media e.g., Internet, mobile telephones, radio communication, information kiosks etc. If the cost is acceptable by the taxi companies, the installation of computer systems in taxis, will allow for quick and easy on-line interactive communication of drivers with the MIS, through Internet. This interaction between user and the system may be facilitated through multilingual and menu-driven interfaces and multimedia presentations consisting of both
visual and auditory exchanges. Some of the information provided by the proposed MIS, in order to satisfy the diverse taxi activities, could be:

- Vehicle location (using Automatic Vehicle Location - AVL technology) and intelligent mapping
- Address search (possibly by using address geocoding)
- Yellow pages and/or touristic information directory
- Multimodal public transport information (train departure and arrival time, urban and interurban bus schedules etc.)
- Social events agenda
- Dynamic route guidance
- Route scheduling
- Multilingual dictionaries and multimedia applications

The proposed MIS should facilitate a number of functions such as data analysis, model-based analysis and powerful visual representation. With the support of object-oriented programming and system integration techniques integrated system infrastructure can be developed. This system will incorporate essential functions of Geographic Information Systems (GIS), database systems and model management techniques to support overall routing, scheduling and decision-making processes. The architecture of this integrated system is shown in Figure 1.

Figure 1. The architecture of an integrated MIS for the taxi system
The proposed MIS for the taxi system is consisted of the following components:

a) GIS component
GIS is functioned as a display and communication system (subsystem) to store and manipulate locational, topological, thematic and non-spatial data. Besides, it supports cartographic display and spatial query and also presents routing and scheduling results in a map form (as appeared in Figure 2). According to Keenan “……in order to provide decision support for a wide range of problems, routing techniques should be combined with systems that can take advantage of new technologies” [7]. The existing GIS for TMA need to be developed further in order to incorporate all necessary information for the taxi system activities.

b) Database manager
The database manager will support a user-friendly and commonly adopted environment for database development and handling the routing and scheduling results as the defined database formats. The database manager for the taxi centers (back-end) will be in Oracle environment. Respectively, the front-end systems used by the taxi drivers will be based in MS Access. The information exchange between the two database environments will be possible by the use of Open Database Connectivity (ODBC) techniques.

c) Model manager
The model manager component proposed in the system aims to handle various commonly accepted routing and scheduling models for taxi transport. (by demand, random, fixed). A variety of routing problems has been identified in the bibliographic review of Laporte and Osman (8). As regards taxis, Yang and Wong have proposed some models for taxi transport in urban areas [1,9,10]. All available models will build the necessary model base for taxi routing and scheduling. The model base will satisfy the routing needs for all categories of taxi use, namely by demand, fixed and random. Recently, Desrochers et.al., described the theoretical framework for building a model and algorithm management system for vehicle routing and scheduling problems [11].

The operator of the taxi center or the individual taxi driver will access this model base in order to get assistance for its specific problem. The solution proposed will be based on the most appropriate model for the specific problem. The solution will also take into account all available traffic information in the area where the trip is made.

In Figure 2 an output of taxi routes in the area of eastern Thessaloniki as produced by the prototype Decision Support System [12] for vehicle routing and scheduling is presented.

The design and development of the proposed MIS will serve the following main goals, as regards the taxi system function:
Better management and monitoring of the taxi fleet
Provision of satisfactory routing and scheduling solutions
Continuous information dissemination about transport, communal, social and other aspects
Easy access to yellow-pages directories, multilingual dictionaries, automated translation tools, etc
Fast adjustment of the taxi route scheduling in dynamic events
Better administration and conflict avoidance of customer picking-up
Safer environment for the taxi drivers

Concerning the proposed routes by the system, the existing traffic conditions in most of the major Greek cities make quite difficult and rather complicated the tasks of vehicle routing and scheduling, something which has to be expected if congested areas [13]. Therefore, since the inability to produce optimal solutions for taxi routes is somehow expected, the system will be developed to generate at least approximate (at a satisfactory level) route solutions for each case.

The outputs of the system include:
- Road network information (e.g., traffic volumes, travel time, addresses, congestion level etc.)
- Thematic maps with information having geographical reference (e.g., special land uses)
- Taxi routes, optimized to some extent
Oracle or respectively Access table updates to show the status of the vehicles into operation (e.g., routes, orders, customers, schedules etc.)

Statistical data concerning the operation and performance of the taxi system (e.g., total passenger kilometers-pkm, travel time, number of customers served, number of received orders etc.)

Data requirements of the system include the following:
- Taxi fleet and terminal status information
- Transportation network (geometrical/functional characteristics)
- Detailed digitized maps
- Information about orders from the public, origins/destinations etc.
- Route schedules
- Traffic and social events information
- Work schedule of the available taxi fleet
- Customer profiles and special interests information
- Yellow and other pages information

Except the existing equipment for radio communication, the following hardware will be necessary in the proposed MIS:

1) X windows terminal (in taxi centers)
2) GIS engine platform (in taxi centers)
3) GIS data server (in taxi centers)
4) RDBMS (Oracle) server (in taxi centers)
5) Internet server (in taxi centers)
6) High-speed data and session control network (both in taxi centers and in vehicles)
7) Lap tops (in vehicle)
8) Portable printing devices (possibly in vehicle)

The software requirements of the proposed system include:

1) GIS software
2) RDBMS (Oracle) software for the taxi centers
3) RDBMS (MS Access) software for the taxis
4) Unix operating system for the taxi centers
5) Windows XP operating system for the taxis
6) Internet browser software
7) Network manager (TCP/IP)
8) Communication and data security software

The conceptual schema of the proposed MIS database component is given in Figure 3. It must be noted that in this schema any subsidiary or temporary tables are not included.
4 Discussion

Taxis contribute at a significant level to the overall traffic problems in urban areas (10% of total trips in Athens and 4.2% in Thessaloniki are made by taxis). In order to overcome the problems related to traffic congestion and also to improve the level of service offered to the public by the taxi system, the use of a MIS is considered to be essential. The proposed MIS is of relatively low cost compared to the benefits expected (for the operator/taxi companies, the customer...
and the society). The new legislation in Greece provides a strong support for the establishment of taxi companies in order to allow taxis to compete in an environment where new Public Transport modes exist or will exist in the near future (e.g., metro, tram and suburban rail in Athens, metro in Thessaloniki). The use of new technologies (AVL, GIS etc.) will expand the capabilities of the proposed system especially nowadays where the cost of these technologies is decreasing.

References


