PUBLIC TRANSPORT MANAGEMENT SYSTEM

Jernej Korinšek
Miha Ambrož
Ivan Prebil
University of Ljubljana
Faculty of Mechanical Engineering
Chair of Modelling in Engineering Sciences and Medicine
Aškerčeva cesta 6, SI-1000 Ljubljana, Slovenia
miha.ambroz@fs.uni-lj.si, jernej.korinsek@fs.uni-lj.si, ivan.prebil@fs.uni-lj.si

ABSTRACT

The paper presents the software solution "BUSO" for viewing and management of data about scheduled public transport. The software application provides search tools and display of entities on maps and orthophoto. The user can enter, edit and catalogue station points, lay out line segments over the existing digital road infrastructure, enter road segments missing from the road network together with their projected and calculated or measured lengths, enter, edit and organize individual bus lines, and display information about the selected entities (station points, line segments, itineraries, roads, settlements, communities). The user can use the software to enter station point properties on the field and to plan and lay out itineraries, join them into lines, regions and prepare the data for export in different forms. A special module enables field acquisition of road axes by using a GPS receiver. The software can be connected to existing information systems for management of public transport data. Due to its openness and modular structure the software can be adapted to user needs and connected to other traffic information systems.

1 INTRODUCTION

Public passenger transport in the Republic of Slovenia is organized as an institution of public utility service since 2004. The Slovenian Roads Agency has concession contracts with passenger public transport operators. It has been observed, that the amount of public transport has been decreasing in the last few years. The principal shortcomings of the existing system are the following:

- The operators claim disproportionally high operational costs, justified by the required high number of vehicles during peak periods, whilst the vehicles remain unexploited outside those periods.
- The state financing does not cover the entire difference between the authorized and real costs of public passenger transport, which is why it is virtually impossible for the authorities to create new bus lines.
- All the operators have the same authorized cost per vehicle-kilometre.
- There are considerable differences in the "profitable" to "non-profitable" bus line ratios between operators. The operators in central and northern Slovenia register relatively high incomes, whilst those from eastern Slovenia mostly operate the lines that do not generate income.
- The public utility service financing from the state budget is inflexible and cannot be adjusted during the concession period.

The goal set by the authorities is to set up a harmonized public transport schedule system, together with a unified public transport ticket. One of the conditions that have to be met in order to achieve this goal is an effective information system for public transport management. A Public Transport Management System to satisfy this condition is being introduced into operation at Slovenian Road Agency. The part that is used to manage the
operational part of the public transport (road infrastructure, bus station points, bus line segments, bus lines) is presented hereafter.

2 SYSTEM STRUCTURE

The entire Public Transport Management System is divided into two integral parts. The first part is the database server with the Database of Traffic Data (DTD). The second part consists of clients (users) that access the database server through client software applications (Figure 1).

- Server – DTD database
- User / client
- On-the-spot Cataloguing
- Analysis
- Road measurement

Figure 1: Schematics of the system structure

The core of the data is represented by a relational SQL database, whilst the supporting visual layers are implemented by shapefiles, raster maps and orthophoto GEOTIFFs.

The DTD contains the data about public transport and the related traffic infrastructure for the entire area of the Republic of Slovenia. The data has been acquired from the institutions that manage the road and railway infrastructure, from the operators of public transport, and from the central geodetic authority of Slovenia. The acquired data was stored in different formats – the visual data for map displays as shapefiles, and most other data in text or spread sheet files of various formats. All the acquired data was transferred into the database tables using an agreed set of assignment rules. This way the database management applications will be able to form queries upon the data in table form as well as upon the data in graphical form.

The DTD contains the following data, arranged into groups by the source or provider:

- The data provided by the Slovenian Roads Agency (DRSC):
  - road axis data for the entire road network of Slovenia in shapefile and DBASE format,
  - list of bus stations (on the road network and on the border crossings) in shapefile and DBASE format.

- The data provided by the Surveying and Mapping Authority of the Republic of Slovenia (GURS):
  - colour digital orthophoto (DOF 5) in TIFF format (scale 1:5000),
  - vector topographic data about roads and railways in DXF and SHAPE format (scale 1:25000),
  - municipality and locality polygons in SHAPE and DBASE format,
  - state topographic map of Slovenia, combined colour layers in TIFF format (scale 1:50000),
  - state overview map of Slovenia, combined colour layers in TIFF format (scale 1:250000).
The maintainer of the current public transport database provided the following data:

- a sample dataset from the current public transport database, including the bus lines and schedules operated by one bus transport operator,
- export of the entire data from the current public transport database in XLS and CSV format.

3 CLIENT APPLICATION FOR INFORMATION DATABASE MANAGEMENT

The application is built modularly and is thus prepared for inevitable adjustments in the introductory use period and for easy feature-additions and further development later on. The application is fully GUI-based. The user can activate individual modules by main menu commands or toolbar buttons (Figure 2). The modules open within the application main window. All the modules can be active simultaneously, which is also the most common mode of operation as the data generally flows between modules.

3.1 The Map Module

The main functionality of the map module is display and manipulation of data in visual form on a graphical underlay. The user has an option to select and display arbitrary underlay layers. The available layers include GPS, line segments, bus station points, roads of different category, localities, municipalities, maps in scale 1:50,000 and 1:250,000 as well as 1:5,000 scale orthophoto. At any time each of the layers can be switched on or off and the user has an option of selecting the colour of the displayed entities. Orthophoto underlay layer – aerial snapshots in 1:5000 scale (DOF5), provided by the Surveying and Mapping Authority of the Republic of Slovenia (GURS), is used for graphical display of bus station points, road network and railway network. The orthophoto underlay is composed from separate parts of the image (GEOTIFFs) and seamlessly joined into a graphical display of the entire area covering the Republic of Slovenia.

To save storage space, a compressed orthophoto underlay can be used (f.i. in MrSID format), enabling usage on portable computers with limited storage capacity.

The map module is functionally linked to the data from DTD. On the module every kind of data with a geolocation can be displayed and manipulated, thus making it the heart of the application.

The user actions related to the map module can be performed from the toolbar, which contains tools for view manipulation (zoom and pan), the entity information and selection tool and auxiliary tools for manipulation and data import functions. On the left hand side of the

Figure 2: Client application modules selection menu
window there is a legend of data layers, through which every data layer can be set and manipulated.

![Map module context-sensitive menu system with orthophoto underlay](image)

**Figure 3: Map module context-sensitive menu system with orthophoto underlay**

To simplify user data interaction, a special context-sensitive menu system management (Figure 3) has been implemented. By right clicking on the map or on a municipality, locality region or a map entity, the user can choose from many important data-manipulation functions or display settings for that particular region, depending on the currently selected data and active task.

In order to simplify bus station point identification as much as possible, the application provides the means of searching using the search and query module.

The user can add new bus station points to the database or edit the existing ones. To each bus station point the user can assign type (local, long distance, school-line, discontinued, etc.), name, unofficial name, an arbitrary text remark, affiliation to a locality and municipality according to the topographical database and its location (X, Y or LAT, LON).

### 3.2 Bus line segment

The user selects the station points and the road segments that are displayed on the map in different colour and line weight according to their category. Identification is based on the selected sequence of station points along the road segment. Based on this input, the application writes the station points and road segment identification data into the database. Along with defining line segments the user can also edit the station point database or add new station point to it.

Since many road segments are used by more than one line segment and bus line, the initial step involves joining bus station points with road segments, creating a directional
network of line segments, pointing from one station point along the digital infrastructure to the adjacent one. This way the work multiplication in assigning line segments to road segments can be avoided.

In the second step, itinerary and line creation, the line segments are connected into bus itineraries according to known bus line time schedules with the detailed road geometry between the bus station points already known.

The user can import bus station points and bus lines in KML (Keyhole Markup Language) format in order to speed up the bus station point, line segment and bus line manipulation (Figure 4).

![Figure 4: An example of adding new bus line sections with the help of an imported KML line supplied by a transport operator](image)

An information background and a user interface has been developed to provide the user with the means of manually entering the road geometry, which might for any reason be missing from a road network database. The geometry is entered with a pointing device directly onto a map with active orthophoto underlay.

The entry is based on a visual determination of geometry points (as X-Y pairs in the D48 coordinate frame) over the features visible on the orthophoto underlay. Together with coordinates the user has an option to enter other information such as road section name, length and an arbitrary remark. The length of the entered road section can be computed automatically (using different algorithms, also taking into account the data from Digital Elevation Model) or assigned to it directly by the user. A road section entered this way is stored into the DTD, where it is available to all users of the application for bus line data entry.

The application also supports import of roads axis geometry measured by a GPS receiver or a GPS-aided inertial measurement system as described later on.
3.3 The GPS module

A GPS device can be connected to the mobile computer used for bus station point cataloguing and road axis acquisition. The GPS module enables the user to control the connected GPS device and to connect to a DGPS network SIGNAL (the Slovenian network of DGPS stations).

A DGPS receiver is used to determine the current location. In ideal conditions this provides sub-metre accuracy for coordinates. The GPS module takes care of communication between the application and the GPS receiver. The DGPS signal from the SIGNAL network is taken into consideration automatically via NTRIP protocol. In case of DGPS signal unavailability the regular GPS signal (with correspondingly lower accuracy) is used and logged into the database accordingly. In principle any DGPS-enabled GPS receiver can be used. The communication to the GPS receiver is performed in form of standard NMEA sentences. The module also supports recording of road axis geometry, which can be displayed, stored and later imported into the map module. Due to modularity and true multithreaded nature of the software application, other tasks can be done simultaneously while recording.

3.4 Bus station point cataloguing

The bus station point cataloguing module (Figure 5) has been developed in order to facilitate the on–the–spot field cataloguing of bus station points. It is based on the paper cataloguing form, which has been prepared by the traffic safety authorities, and contains all the relevant data about a bus station point in order to determine its safety status. The bus station point cataloguing module is linked to the map module in order to display the chosen bus station point on the map underlays or to open the module for a particular bus station point directly by clicking it on the map. A link to the GPS module is also provided so that the bus station point location can be entered based on the current GPS coordinates.

![Figure 5: The bus station point cataloguing module as filled in on the spot by bus station cataloguers](image-url)
3.5 The Queries module

The queries module can be used to perform searches over the data, stored in the DTD and partly over the data stored in the road infrastructure database that have been included into DTD as help with bus station point cataloguing.

The application includes a group of search tools that provide the user with an overview of the data and means for its management. Any meaningful data can be passed to the map module, which displays it on the map in the suitable scale or on the orthophoto underlay. Application also provides an option of exporting the retrieved dataset into an MS Excel worksheet. The provided search tools include search for bus station points, for bus line segments, for roads of different categories, and for political entities (localities and municipalities).

3.6 Bus itineraries, lines and regions management

The user interface for bus itinerary, line and regions setup includes tools for overviewing, adding and editing of bus itineraries, lines and regions.

To set up a new bus itinerary, the user transfers the bus line segment data into the bus line module and enters the bus line's name and its identification number. Upon entry the application automatically calculates the newly entered bus line's length from the lengths of the corresponding bus line segments. When editing an existing bus line the user can change its name or identification number. The existing bus lines can be displayed on a map at any time (Figure 6).

The variations of bus itineraries (added or removed points at the beginning or end) can then be joined together into bus lines, which are further joined together into regions. These regions are the basis for distribution of work among transport operators.

The most important part of the bus line composition is the multi-level search tool that enables the user to search all the possible connections from the starting bus station point to the ending one, thereby allowing the user to specify the upper limit to the number of bus station points along the way. The information about the starting and the ending bus station point is supplied by the user by specifying them on the map.

Another important part, which is built on top of the multi-level search tool, is the bus line over stations, to bus line over station points translator. The existing bus line database is based on bus stations with locations based on the arithmetic mean of its bus station points and does not take in to account that station points can be many meters apart. In some longer lines distance travelled to and from differs for some kilometres. This tool enables the user to translate existing itineraries in to new ones using bus station points automatically.

Figure 6: Bus itinerary, line and region module with multi-level search tool and itinerary translator
3.7 DTD management module

The DTD management module, the bus station section provides the following functionality: locating and editing bus stations that are located too close together or even overlapping, locating and editing of discontinued bus stations, locating and editing of bus stations with inappropriate purpose designation, location and editing of bus stations with filled-in cataloguing form and deletion of bus station records that contain errors.

The DTD management module, the line segment section provides functionality for automated discovery of line segment cycles (line segments that lead from a bus station to the same bus station), for discovery of similar or equal bus segments and their deletion or correction.

3.8 Economic data

The economic data module enables the user to import, view and export the economic data associated with transport operators and itineraries, lines and regions. The module has a filtering system to ease the way of retrieving data and is connected to the map module for data selection.

All the data received from transport operators via concession report forms is fragmented, analysed and put in to special XLS forms for import into DTD. The import of these special forms takes place through economic data module.

![Economic data viewer with a few rules set for filtering](image)

3.9 Data synchronisation

The synchronisation module takes care of synchronisation of the data between the database maintainer/manager, the bus line segment cataloguer and the on-the-spot bus station cataloguers. In order to protect the data, the module also provides mechanisms of encryption of data for transfer. As it is usually not possible for the on-the-spot cataloguing teams to be permanently connected to the central database, they have their own databases installed locally. The synchronisation module is used to synchronise the data between the cataloguers' local databases and the central database. The data transfers are divided into export and import packages. In case of data export, the data that have not yet been synchronised are first collected from the database and written into an XML scheme that corresponds to the database record format. The data are then encrypted and sent as synchronisation packets to the corresponding users by means of standard data transfer protocols (SOAP XML, FTP, HTTP, E-Mail). The synchronisation packets always contain the data about bus stations and bus line segments - other data are not transferred.

Apart from these, the synchronisation packet contains the auxiliary data about the packet origin, the synchronisation type and the user agent data. The bus line cataloguer can
provide data about new bus line segments and new bus stations and can edit the type or remarks of the existing bus stations. The bus station cataloguer can only provide the bus station data. This way any errors in the data can be avoided. The database maintainer/manager can edit and add any kind of data that are part of the synchronisation packet. If need be, they can also send an entire tables of bus stations and road network data.

For security reasons all the transferred data is encrypted. Until the data is encrypted it is stored only in computer volatile memory and is not written to any permanent storage media. An RSA encryption algorithm with asymmetrical 2048-bit keys is used, which provides a strong enough security for an adequate further period. The keys are included in the application and can be changed by the user with suitable privileges. Since the keys are asymmetrical, the public key can be used only for data decryption, whilst the private keys can be used for decryption as well as encryption. This way it is possible to control the user rights of encrypting and decrypting data. To reduce the amount of data transferred during synchronisation, the synchronisation packets are compressed using standard GZIP compression with CRC error control. In case of data import, the procedure is carried out in the opposite direction. The synchronisation packet is first read-in, then decompressed and at last decrypted. According to the received XML record and the determined user rights, the data is written into the corresponding table in the database.

4 CONCLUSION

The system for public transport management described in this paper is a major step towards reorganisation of the public passenger transport in the Republic of Slovenia. By utilising the system, the authorities will have a means to overcome the shortcomings and limitation of the current system of public passenger transport management. This will bring benefits to the users of public transport in Slovenia and in turn make it a business opportunity for the operators.

The modular structure of the information system for public transport management provides the flexibility, necessary for easy upgrades and feature additions in the future. Once the economic model of the unified public transport ticket is agreed and set out, the required functionality will be added to the system. This will include the information background in the DTD framework and a new module for management in the client application. Further on, the application may include the module for real time vehicle tracking, which will, together with the required equipment on the vehicles, provide data about their trajectories and passenger flow in real time.

REFERENCES