Standard driven approach for sustainable interoperability of public transport passenger information systems

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Abstract
A large number of passenger information systems for public passenger transport exist in Europe at national level but their trans-national interoperability is very limited. A passenger information system depends on many underlying heterogeneous information systems; ranging from management of transport infrastructure network, public transport infrastructure objects, public passenger transport services and public transport processes and regulations. Public transport service providers have their local information systems that should be vertically interoperable with the national passenger information system. In the future trans-national interoperability of national passenger information systems for journey planning across Europe is expected.

In the paper interoperability of passenger information systems and appropriate ITS standards are explored. An existing information system for management of public passenger transport is described, and implementation of sustainable interoperability requirements is proposed. Finally, a European Passenger Information System – EPIS is proposed as a new solution for sustainable trans-national interoperability of passenger information systems across Europe.

Keywords
Trans-national passenger information system, transportation informatics, sustainable interoperability, ITS standards, public passenger transport
1 Introduction

Public passenger transport (PPT) is a complex and dynamic system where expertise from multiple disciplines is needed. The interdisciplinarity involves dominantly applications from transport geography, mobility planning, transport economics and transport informatics. 

PPT is part of transport systems, which by their nature, consume land and exist in a complex geographical setting. Transport geography is geography of transport systems [1]. From IT point of view transport geographers can help in modelling elements of a public transport network topology and evaluation of transport demands.

Mobility planning involves traffic engineers whose work results in modelling transport route network elements like routes, services, and timing and journey patterns. Good mobility plan results in efficient public transport lines and stimulates use of sustainable modes of transport.

Transport economics, generally, considers public transport system as an enabler for sustained economic prosperity [2], which can be achieved through efficient use of resources and expenditure control in a public transport system. More practically, elements of an economic model in public transport are costs of public transport system and incomes of service operators [3]. Service operators - public passenger transport concessionaries, usually report incomes for a period of time to public transport authorities. Costs are understood as concessionaries’ operating expenses per kilometre driven.

In the last decade information and communication technologies have strong influence on public transport (i.e. creating, collecting and delivering of public transport information). Transport informatics comprises intelligent transportation systems (ITGs) and road transport and traffic telematics (RTTT). An important task for transport informatics now is global harmonization and standardization work that integrates transport geography, mobility and economics, and enables interoperability of passenger information systems (PISs). In the paper the term PIS is used as a super-synonym for a journey planner because of increasing passengers’ demand for quality information beyond journey planning (i.e. real-time, mobile information).

The experts from all of the mentioned disciplines (transport geography, mobility planning, transport economics and transport informatics) have a common task to maximize the utilization of public transport. However, this can only be achieved in collaboration with main actors in the PPT: authorities (PTAs; local, regional, national, trans-national), transport service providers (PTSPs; operators) and passengers. Nowadays, major challenge for PTAs is implementation of best practice solutions for:

- environmental aspects (reduction of congestions, emissions and energy consumption);
- sustainable solutions for the mobility of passengers in urban and inter-urban transport;
- better integration of various modes of PPT (bus and coach services, train services, rail transport, underground trains, air transport, ports and maritime transport, ferries, etc.);
- implementation of a unified ticket system;
- better transport informatics services for journey planning (door-to-door) including various modes of PPT;
- efficient (standardized) exchange of information between information systems in PPT.

In Europe, territorial fragmentation and overlapping of PPT systems is high. Unfortunately, most of the PISs are “isolated” to:

- single mode of transport and not interoperable easily with other modes;
- within national borders but interoperable with other modes.
The challenges of seamless cross-border travel planning are even greater. Therefore vertical (from PTSPs to local/regional/national PTAs) and horizontal (between PTSPs, between PTAs and between cross-border PISs) business-to-business (B2B) interoperability of information systems in public transport becomes one of the most interesting challenges for the transport informatics community. Especially in countries that are situated at the crossroads of public transport corridors there is a huge need for transnational interoperability of passenger information systems.

PISs have been developed in many countries over the past decade. Usually, they are part of ITS architectures on a national or sector specific basis (e.g. rail ITS architectures) [4]. Likewise, the typical use and viewpoint has been that of a sector authority, usually at national level. ITS architectures describe conceptual and functional requirements. These requirements ensure interoperability if implemented in software. In Europe the European ITS Framework Architecture (FRAME, [5]) is maintained by the European Union and many EU member states currently follow FRAME in structure and notation. However, it is hard to implement a universal ITS architecture suitable for all European countries [6].

The paper is organized in the following way: in the first part of section two the basis for the paper is presented by defining the concept of interoperability. Second part of section two presents current research in the fields of intelligent transportation systems and road transport and traffic telematics where enablers for interoperability in passenger information systems are identified and described. Section three describes an information system for the management of the public bus transport with ambition for extension towards integration with other European passenger information systems. Section four presents requirements, architecture and behaviour of a system that would enable sustainable interoperability within a European passenger information system. Conclusions are given at the end.

2 Interoperability in passenger information systems
Interoperability of PISs requires understanding of the interoperability concept.

2.1 The interoperability concept
Although different interpretations for interoperability exist and as public transport is under governmental supervision an appropriate definition (as suggested in the information systems interoperability study [7]) can be found in the document European Interoperability Framework for pan-European e-Government Services (EIF) [8]. Interoperability therein is defined as "the ability of information and communication technology (ICT) systems and of the business processes they support to exchange data and to enable the sharing of information and knowledge". This definition has been revised in final document of the European Interoperability Framework, published in 2011 [9]. In this document interoperability is defined as "the ability of disparate and diverse organisations to interact towards mutually beneficial and agreed common goals, involving the sharing of information and knowledge between the organisations, through the business processes they support, by means of the exchange of data between their respective ICT systems". This new definition further refines the previous one by stressing that the organizations in interaction are heterogeneous, that their interaction has a common goal, and that they will all benefit from it.

The above definition introduces a necessary and sufficient but abstract concept which todays PISs implementations does not yet follow. Existing PISs are not overall interoperable because they use proprietary data models and message sets for B2B communication.
Interoperability can be unregulated or standard-based [10]. Industry consortia and standards development organizations, such as CEN/TC 278 (ITS standardisation; http://www.itsstandards.eu), have responded to this problem by publishing standards for interoperable B2B data exchange. In the following section most influential industry standards, CEN (European Committee for Standardization, http://www.cen.eu) standard candidates and published standards in relation to PPT are explored. The standards are then used as part of proposal for sustainable interoperability solution for an information system SIJPRIS developed for Ministry of Transport in Slovenia (http://www.mzp.gov.si/en).

2.2 Standards that support interoperability of PISs

In European countries adoption of international standards for public transport is an ongoing process. ITS standards, published at CEN and adopted by SIST (Slovenian Institute for standardization, http://www.sist.si) are results of SIST/TC ITC (information technology and communication) in SIST/TC MOC (mobile communications). SIST/TC ITC adopted 246 European standards of which 102 (41%) are for ITS. Currently SIST/TC ITC works on 58 standard candidates of which 26 (45%) are for ITS. A subset of the ITS standards is appropriate for use in PPT. Figure 1 shows national data models (TransXChange, NPTG, NaPTAN) and industry initiatives (Google Transit) that influenced published European technical specifications (SIRI, IFOPT) and recent developments (NeTEx). TransModel, a European standard, has been fundamental to the mentioned developments since its first version in 2004.
TransModel version 5.1 [11], the European reference data model for public transport information, was formally adopted by CEN as a European standard (EN12896). It describes public transport concepts and establishes precise technical vocabulary for PIS, transport network infrastructure, public transport schedules, fares, real-time passenger information and control operations. Technically, it enables creation of a standard database for easier connectivity between software systems in public transport.

IFOPT (identification of fixed objects in public transport [12]) is a technical specification (CEN/TS 28701) that defines a model containing major concepts for fixed objects associated with access to public transportation (stop places, stop points, access points, connecting paths, etc.) in a multi-modal, multi-operator context. The model primarily addresses the physical infrastructure and equipment for information services and includes the explicit description of objects by their main characteristics. It describes how to locate these objects in space through coordinates and through the link to topographic objects with a clear separation between the
public transport layer and the topographic layer. It also enables assignment of responsibility for data maintenance of each fixed object. Geospatial location referencing techniques of PT objects (e.g. use of satellites, roadside equipment for positioning) or representation techniques on maps (projections) are outside the scope of this standard. IFOPT is based on national data models from UK, Sweden, Germany and France.

SIRI (Standard Interface for Real-Time Information [13]) is an interface specification for collecting and exchanging of real-time operating information in public transport. Real-time operating information contributes to better understanding of public transport's overall operation and more informed passengers (e.g. information boards). Information can be exchanged between vehicles, fixed network infrastructure objects, public transport control centres and information centres for passengers (to ensure the integrity of publicly available information).

NeTEx (Network Timetable and Exchanges [14]) is supporting action to complete SIRI services on network and timetable exchanges in public transport. It contains comprehensive set of conceptual UML models and XML schemas for implementation of multi-modal public transport services. It consists of three parts: schemas for exchange of PT network topology, schemas for exchange of timetables and schemas for exchange of information about fares.

Implementation of standards is labour-intensive work. Prototype examples exist which are focused around single mode of transport (e.g. bus) and are geographically limited to national PPT. However the main promise of the standards is to achieve technical interoperability in international and multi-modal passenger transport. Optimally, national PISs can then be integrated to provide an overall system that is capable of providing data and information better than the individual PISs operating in geographically isolated area. Until now, working examples are known from fields motivated by closed interest groups with strong economical interest like international logistic chains [15] or international rail alliances using single PIS (like DB, http://reiseauskunft.bahn.de, based on HAFAS, http://www.hacon.de/hafas). These systems use centralized (global) technical solution. Only few prototype PISs, based on interoperability between loosely coupled ISs, exist [16].

Some promising cross-border project initiatives also exist, e.g. System for integration of information about public transport in cross-border regions of Slovenia and Hungary [17].

In the next section an information system SIJPRIS is described. The system supports governance and operation of national bus transport in Slovenia. The SIJPRIS’ data model supports cross-border interoperability and is a good candidate for approach that ensures sustainable interoperability through standards. We believe that the approach that SIJPRIS will use towards sustainable trans-national interoperability is a good solution that can be applied to other comparable PISs.

3 SIJPRIS: case for sustainable interoperability approach

SIJPRIS is a distributed information system, made to the order of the Slovenian Roads Agency (http://www.drsc.si, PT authority in Slovenia, part of Ministry of Transport) primarily for the management of the public inter-urban (long distance) bus transport. The system supports implementation of PTA’s tasks and of concessioners’ tasks stipulated by the law. PTA’s tasks, supported in SIJPRIS are: management (registration) of public transport stop place model, infrastructure model and scheduled services model. A support to running business with concessionaires (economic model; periodical reporting about financial figures, number of passengers transported, etc.) is also included.

Concessioners’ tasks, supported in SIJPRIS are: creation and maintenance of proposals for new scheduled services, modification and cancelation of scheduled services.

Additionally, the system supports the tasks for planning and analysing of PPT. Data model supports also other types of public transport (rail, urban/city).
3.1 System components
SIJPRIS is designed in such a way that in the future it will be possible to include other forms of PPT in it as well. It is a three-layer software architecture (Figure 2), which includes following mutually connected subsystems:

- Public transport database (BPP, Oracle and ESRI ArcSDE) is a shared database server for PPT used by SIJPRIS.VozniRedi, SIJPRIS.WebGIS, BUSO and SIJPRIS.Centrala.
- SIJPRIS.VozniRedi is a software (desktop application, Java) for management of public transport infrastructure network, timetables, journey planner and economic model. It uses local database (Apache Derby), synchronized with BPP.
- SIJPRIS.WebGIS (Figure 3) is a software (on-line GIS, Geoserver) for GIS based presentation of public transport data (topology of road network infrastructure, public transport infrastructure, itineraries, routes) that eases the decision-making tasks like registration of lines.
- BUSO is a software (ArcGIS with a local database MSSQL) for maintenance of topology for public transport infrastructure network. It maintains geolocations of stop point locations and links between them.
- SIJPRIS.Centrala is an application server (Oracle WebLogic) that implements services (web service, Java EE) for data exchange (in XML format) among the subsystems. It enables interoperability within SIJPRIS.

3.2 Public transport database
The scheme of the BPP database consists of approximate 80 entities and has the following characteristics:

- Contains entities for stop places and stop points (Site frame);
- Groups entities for road network: roads, and road elements (Infrastructure frame);
- Groups transportation network entities: lines, routes, route links, route points, and scheduled stop points (Service frame);
- Processes support: the database scheme supports workflows for public transport authority (proposal, decision, registration, rejection, deletion);
- History trail: the database keeps track of processes and records for any date in history.

We can conclude that:

- The physical schema for BPP corresponds to the early version of conceptual model described in TransModel;
- The database schema supports management of the economic public service of the public inter-urban bus transport in Slovenia;
- It has potential to include other important features like creation and maintenance of fare scales.
Data exchange within SIJPRIS is realized through a web service, using XML documents formatted according to own XML schema called TransportXML.org. The schema (Figure 4) was developed for SIJPRIS and contains proprietary elements. Schema elements are generic and follow the hierarchy and CRUD operations (Create/Insert, Update, Delete) of the relational database BPP.

A typical TransportXML.org document has the following hierarchical structure:

- Svezenj (=Envelope): is used to group all Documents in the schema
- Dokument (=Document): is used to group all Tables in the schema
• Tabela (=Table): is used to group Table's structure (attributes) and Table's lines (records)
• Struktura (=Structure): is a sequence of table's attributes (including primary keys)
• Zapis (=Record): contains an attribute Ukaz (Command = Insert, Update or Delete) and a sequence of pairs (name, value) which are database column names and values that needs to be manipulated.
Comparison of 18 features (as defined in [18]) between the SIJPRIS TransportXML.org schema, TransXChange, Google Transit Feed Specification (GTFS) and NeTEx shows (Table 1) high number (13) of features that are covered in TransportXML.org. We can conclude that further development path of TransportXML.org should merge with the technical specification NeTEx.
Feature | TransXChange | NaPTAN | GTFS | NeTEx | IFOPT | SIJPRIS | TransportXML.org
--- | --- | --- | --- | --- | --- | --- | ---
Transport operators | YES | YES | YES | YES | YES | YES | YES
Stop points/stop places | Points | Points | Full interchange | YES | YES | YES | YES
Routes | YES | YES | YES | YES | YES | YES | YES
Tracks | YES | YES | YES | NO | YES | YES | YES
Lines | YES | YES | YES | YES | YES | YES | YES
Journey patterns | YES | NO | YES | YES | YES | YES | YES
Real-time timing info | YES | NO | YES | NO | YES | YES | YES
Timetabled journeys | YES | YES | YES | YES | YES | YES | YES
Journey interchange | YES | NO | YES | YES | YES | YES | YES
Availability conditions | YES | Limited | YES | NO | YES | YES | YES
Operational days | Proposed | NO | YES | YES | YES | YES | YES
Full rail support | NO | NO | YES | NO | YES | YES | YES
Fares | Stages only | Basic zones | Basic model | NO | YES | YES | YES
Distributed administration | YES | NO | YES | YES | YES | YES | YES
Peer-to-peer exchange | YES | NO | YES | YES | YES | YES | YES
Model based | YES | NO | YES | YES | YES | YES | YES
Reusable elements | YES | NO | YES | YES | YES | YES | YES
Loosely coupled | YES | NO | YES | YES | YES | YES | YES

Table 1: Comparison of features between SIJPRIS and other standards in development

4 A concept for sustainable interoperability of PISs in Europe

PTAs at national level invest money in software and hardware for PISs. Between 2005 and 2009 Slovenian Roads Agency spent close to 500,000 EUR on different projects for development of an information system for operations management and control of inter-urban public transport data within the country. In 2011 two tenders were issued: a 150,000 EUR worth tender for a first PIS in Slovenia and a 100,000 EUR tender for a national register of public transport network topology (only stop places and stop points for buses). Obviously, external driving forces for national PTAs in Europe to offer online PISs exist: (1) ambitious public transport development policies which expect to double public transport market share worldwide by 2025 [19], (2) increasing expectations for quality of passenger information for scheduled transit service, and (3) the ubiquitous access of online IT services.

In Slovenia there are 48 public bus transport operators (small to medium sized companies) and one national passenger train operator. Table 2 shows the number of online PISs offered by public transport operators in Slovenia. Bus transport operators publish timetables for their own scheduled bus services on company portals. Also the Slovenian national rail company (Slovenske železnice, http://www.slo-zeleznice.si) publishes only their own national train timetable for passengers. The cross-border train timetables are covered by a web link to German PIS (DB, http://reiseauskunft.bahn.de). International scheduled bus services are not published online.

<table>
<thead>
<tr>
<th>Type of transport</th>
<th>Num. of operators</th>
<th>Num. of online timetable information systems</th>
</tr>
</thead>
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<tr>
<td>Bus</td>
<td>48</td>
<td>20</td>
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<tr>
<td>Train</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2: Timetable information systems offered by public transport operators in Slovenia (source: Slovenian Roads Agency)
As part of our research 41 PISs from Europe have been identified (Table 3). The PISs can integrate multiple types of public transport.

<table>
<thead>
<tr>
<th>PIS</th>
<th>Provider/Operator</th>
<th>Country</th>
<th>Train</th>
<th>Ferry</th>
<th>Air</th>
<th>Bus</th>
<th>Urban</th>
<th>Walkway</th>
<th>Cross-Border</th>
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<td>In-Time</td>
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<td>SCOTTY</td>
<td>ÖBB PersonenverkehrAG</td>
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<td>VERKEHRSPilot</td>
<td>Austrian Federal Railways, ASFINAG and Austrovcontrol</td>
<td>Austria</td>
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<td>VOR</td>
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<td>developed by SIJPRO consortium</td>
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<td>Door2Door</td>
<td>Amadeus IT Group SA</td>
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Most of the PISs operate within national borders, while 19 of them already demonstrate cross-border coverage with different level of details. SIJPRIS has also been developed with support for cross-border functionality.

The PISs in Slovenia are capable to offer only limited city and regional (national) public transport information. There is also limited online information available for the needs of the cross-border traveller. Door-to-door travel information for Slovenia is not available.

Further analysis of PISs from Table 3 has identified two significant interoperability patterns: (1) distributed data model with interoperation between distributed and heterogeneous PISs (example: EU Spirit) and (2) centralized integrated data model with a PIS (“super PIS”) as a centralized global service (example: DB). A central data integration system usually has a global schema, which provides the user with a uniform interface to access information stored in the data sources. Alternatively, in a distributed data integration system, there are no global points of control on the data sources and any PIS can accept user queries for the information distributed in the whole system.

Discussion [20] between Google Transit and SCOTTY (ÖBB-Personenverkehr) revealed practical differences between (1) and (2) that are important for a future PIS that will cover all European countries and all types of public transport:

- Regional (national) PISs want to preserve their autonomy;
- PISs use different search algorithms which can result in different journey itineraries (one possible itinerary versus more alternative itineraries);
- A global PIS may not handle real-time exceptions (delays, cancellations, disruptions in network, time progress report) as good as regional PIS;
- A global PIS should follow an internationally accepted standard that easies interoperability (like NeTEx);
- A global PIS should guarantee quality data from all European countries.

The above experience show that a centralized and global PIS hits barriers as it grows. Obviously, a trade-off between efficiency and autonomy has to be made. Our proposed system EPIS is a decentralized (distributed) peer-to-peer system, connecting autonomous PISs across Europe through open web service interface.

Conclusion is that there is no single PIS capable of providing a complete door-to-door public transport journey information for whole Europe. Vast majority of cross-border journey plans must be collected manually from available short-distance and long-distance scheduled services.

| PIS Name         | Provider/Developer                                      | Country       | Rating
|------------------|---------------------------------------------------------|---------------|
| RESROBOT         | Samtrafiken                                             | Sweden        | ● ● ● ● ●
| routeRANK        | routeRANK Ltd                                           | Switzerland   | ● ● ● ● ●
| SBB Online Fahrplan | SBB/CFF                                                | Switzerland   | ● ● ● ● ●
| INTEGRA          | Ecole d'Ingénieurs La Rochelle (EIGSI) with input of START project partners | United Kingdom | ● ● ● ● ●
| Transport Direct | Atos Origin (for UK Department for Transport, Welsh Assembly Government and Scottish Government) | United Kingdom | ● ● ● ● ●
| Traveline south east | Traveline south east                                   | United Kingdom | ● ● ● ● ●

Table 3: Comparison of PISs in Europe
4.1 Towards sustainable interoperability: European Passenger Information System

In this subsection a conceptual solution for EPIS that enables journey planning across Europe is proposed. The IS assumes PIS-to-PIS (PIS2PIS) data integration where global data interoperability between PISs is achieved through common API (SOAP web service based on a XSD/WSDL specification). To avoid problems related to syntactic, schematic and semantic heterogeneity, technical standard IFOPT and NeTEx is used for data exchange.

Requirements for sustainable interoperability

The EPIS addresses following sustainable interoperability requirements [10]:

• Modularity: new PIS can be freely added to and removed from the EPIS architecture. The only requirement is to utilize common EPIS metadata with mapping tables to store location-PIS correspondences, which we believe results in easier construction of itineraries.

• Adaptability: after new PIS is registered with EPIS its metadata needs to be propagated throughout the PISs in the EPIS and metadata mappings from other PISs to the PIS are registered in the metadata held by the PIS. Therefore, metadata mappings can be added to and removed from the systems, and these modifications are smoothly propagated in the whole system.

• Mediation: implementation of the intermediation function through common API based on standard data modeling formalism (ITS standards). Potential absence of ITS standards may include use of semantic technologies (i.e. local PIS’ ontology, mediation between PISs through ontology matching) in further development of EPIS.

Requirements for standards uptake

Public transport databases behind national PISs in the future distributed pan-European PIS (=EPIS) will have to store all data related to public transport in their country. Theoretically this means that every European country will have its own national PIS. It is expected that most of the PISs from Table 3 will have to adapt their data models to be able to exchange (a) public transport network topology, (b) timetables and (c) information about fares. Appropriate technical standards to achieve that are IFOPT and NeTEx (Figure 5). The PISs participating in EPIS can preserve their legacy database schemas but will have to be able to interoperate with other PISs in order to contribute to final journey plan. Exchange documents will have to validate against IFOPT and NeTEx schema that comprise of:

1. Administrative model (IFOPT)
   a. Provides an organisational model for assigning responsibility to create and maintain data as a collaborative process involving distributed PTAs and public transport operators. Includes namespace management to manage the decentralised issuing of unique identifiers.

2. Stop place model (IFOPT)
   a. Detailed description of stop places in public transport: stop place (or station or area) with stop points (or stops or stop positions or quays), their name and geographical location for all kinds of stops: bus, tram, train, subway, aircraft, boats, ferries, etc.. Includes physical points of access to vehicles and the paths between the points (including accessibility). Stop place identifiers should be unique within each country. A country prefix should be used to ensure global uniqueness.

3. Topographical model (IFOPT)
a. Provides a topographical representation of the settlements between which passengers travel. It is used to associate Stop and Station elements with the appropriate topographic names and concepts to support the functions of journey planning, stop finding, etc.

4. Point of interest model (IFOPT)
   a. Describes the structure of Point of interest including physical point of access, i.e. entrances. Also provides a model for a standardized Point of interest classification hierarchy - a means of providing a taxonomy of different types of Point of interest relevant for journey planning.

5. Scheduled services model (NeTEx)
   a. Scheduled stop points, service links between scheduled stop points;
   b. Service patterns: stop assignments, routes, timing patterns, journey patterns, time demand types;
   c. Lines;
   d. Timetables, service calendar.
Figure 5: NeTEx and IFOPT submodels
Figure 6 shows a typical case for EPIS where a passenger searches for a journey plan from address in Maribor (Slovenia) to address in Prague (Czech Republic). The chosen itinerary (blue color) is composed of:

- Short distance urban bus itinerary from starting address in Maribor to the main train station in Maribor (not visible on the figure);
- Long distance itinerary from the main train station Maribor to the main train station Ljubljana;
- Short distance inter urban bus itinerary from the main train station Ljubljana to the airport Ljubljana/Brnik;
- Long distance airline itinerary from the airport Ljubljana/Brnik to the airport Prague;
- Short distance inter-urban bus itinerary from the airport Prague to destination address in Prague (not visible on the figure).

The two remaining itineraries on the figure are not optimal for search criteria based on total fare price and travel time. The second one (red) is too expensive (over 1000 EUR) and the third one (magenta) takes too long (over 12 hours). The first itinerary (blue) is an acceptable compromise of fare price (under 500 EUR) and travel time (under 9 hours).

Crucial part of the EPIS is the itinerary search algorithm in PIS. The search algorithm in SIJPRIS uses the concept of hierarchical search. The concept was described in [21] and was tested on public bus transport data in Slovenia. Main benefits of the hierarchical search are (a) decreased time complexity of search algorithm in comparison to algorithms like A*, and (b) content aware and informed search versus navigation based search. Content aware search finds fastest possible long distance itinerary between origin and destination (default order is airline, train and bus). The remaining task is to find two short distance itineraries (a) between origin and its closest long distance stop place, and (b) between destination and its closest long distance stop place.
Proposed architecture (see SIJPRIS extended as part of EPIS on Figure 7) of the EPIS operates in the following way:

- Each European country maintains an online PIS with a web interface for journey plan search where a passenger can narrow down a “from” (fromLocation) and “to” location (toLocation) for a journey and configure (i.e. preferences for type of transport, time, price, number of interchanges) the search.
- Search is a request for local web service response (in SIJPRIS this is SIJPRIS.Centrala).
- SIJPRIS.Centrala calls EPIS.ItineraryFinder, which then searches for additional data about fromLocation and toLocation in the EPIS metadata base. Metadata base contains topographic data for all Europe (all cities, towns, POIs). Each data in the metadata base has administration data attached. Administration data are country and web service address of the responsible PIS. Result of the metadata search is the reference to PIS1 and PIS2.
- If fromLocation and toLocation are in the same country:
  - PIS1 is equal to PIS2 and both are equal to local PIS then fromLocation and toLocation are obviously in the same country and EPIS.ItineraryFinder starts local search for journey plan in BPP (public transport database). Local search is a hierarchical search where local itinerary (localItinerary1) is found from fromLocation to the closest long distance stop place (closestLongDistanceStopPlace1). The closestLongDistanceStopPlace1 is searched according to passengers preferred type of transport (default is airline, train, bus, bicycle, walkway, etc.). After the closestLongDistanceStopPlace1 is found, the closest long distance stop place (closestLongDistanceStopPlace2) near the toLocation is found. Local itinerary (localItinerary2) is then found between toLocation and closestLongDistanceStopPlace2.
  - Now the EPIS.ItineraryFinder has the two itineraries, localItinerary1 and localItinerary2.
  - The last step is to search for a long distance itinerary (longDistanceItinerary) between closestLongDistanceStopPlace1 and closestLongDistanceStopPlace2.
  - Finally, EPIS.ItineraryFinder merges localItinerary1, longDistanceItinerary and localItinerary2.
• **EPIS.ItineraryFinder** returns journey plan back to **SIJPRIS.Centrala** and to web interface.

- **If** **fromLocation** and **toLocation** are in different countries:
  - **PIS1** is not equal to **PIS2** and if **PIS2** is not equal to **PIS** then **toLocation** is in another country. **EPIS.ItineraryFinder** starts local search (in the same way as in the previous scenario “**fromLocation** and **toLocation** are in the same country”) to get the **closestLongDistanceStopPlace1** and **localItinerary1**. To obtain the **longDistanceItinerary**, the **EPIS.ItineraryFinder** sends the request to local **EPIS.Link**, which in turn requests **closestLongDistanceStopPlace2** and **localItinerary2** from **PIS2** (in another country).

- Now the **EPIS.ItineraryFinder** has the two itineraries, **localItinerary1** and **localItinerary2**.

- The last step is to search for a long distance itinerary (**longDistanceItinerary**) between **closestLongDistanceStopPlace1** and **closestLongDistanceStopPlace2**. This **longDistanceItinerary** must be obtained from an existing long distance PIS. A question remains whether this should be a single global “super service” for all Europe (one for train, airline and ferry services) or otherwise data are duplicated in each PIS which weakens interoperability concept.

- Finally, **EPIS.ItineraryFinder** merges **localItinerary1**, **longDistanceItinerary** and **localItinerary2**.

- **EPIS.ItineraryFinder** returns journey plan back to **SIJPRIS.Centrala** and to web interface.

### 5 Conclusions

In the paper the interoperability of PISs was systematically approached. Clear understanding of interoperability concepts on one side, and rich R&D experience of our group in the field of PPT on the other side, resulted in the concept of EPIS. EPIS is a decentralized peer-to-peer system, connecting autonomous PISs across Europe through open web service interface. Knowing that there is no single PIS capable of providing complete door-to-door public transport journey information for whole Europe, we strongly believe that the proposed system EPIS is the right solution.

Contributions of the EPIS have multidisciplinary context:

- Maintenance and preservation of wide variety of PIS on the market (loosely coupled EPIS architecture);
- To enable well informed cross-border journeys for public transport passengers;
- Use of emerging technical standards for ITS, like IFOPT and NeTEx;
- Application of requirements for sustainable interoperability, like modularity, adaptability and mediation so that PISs can be seamlessly added to and removed from the EPIS architecture;
- Further improvement of algorithms for hierarchical search of journey plans;
- Inclusion of PISs for airline and ferry.

One of the remaining questions that the paper didn’t answer is the organisational effort needed to integrate European PISs into EPIS. A large European project consortium will most likely answer that question in the near future.

### References


