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Linking Multimodal Traveller Information Services for Transnational Journey Planning

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Abstract

There is a huge cross-border travel demand within the EU leading to hundred millions of cross-border trips every year. Notwithstanding the information demand for seamless journey planning and accurate and timely information on public transport, the provided traveller information is often limited in terms of the provided modes and in terms of its geographical coverage. The above mentioned deficiency is tackled by an international consortium of journey planner- and transport operators in the frame of the INTERREG project "LinkingDanube". The goal is the brining information together from several existing regional services in order to enable journey planning that goes beyond the territory covered by the single systems and offers travellers seamless travel information provided in one integrated journey plan. In particular the objective is to develop a system architecture that enables that combination of services, which is addressed as "distributed journey planning" and an integration of the results. By developing and establishing a common interface (Open API) at each of the involved systems, the exchange of requests and results (not data) will be facilitated. The paper elaborates the service architecture and outlines the technical implementation.

Keywords: Public transport, traveller information systems; journey planner, Open API; linking services

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1. Introduction

The purpose of multimodal travel information services is to inform travellers about the details of their journey as well as about the best mode of transport. Gentile and Nökel (2016) provided a good definition of multimodal travel planners: These systems are front-end-back-end computer systems, which provide a traveller the best itinerary according to several parameters characterising an intermodal passenger transport journey. Multimodal travel planners provide better modal integration and more sustainability by enabling travellers to select the most suitable combination of transport modes for the journey and could lead to an increase use of public transport, cycling or walking in urban environment (Gentile and Nökel, 2016).

There are a huge number of multimodal information systems across Europe, but they are limited in regard of the geographical scope and cross-border information is hardly integrated. There is a need for seamless journey planners for public transport, which are going beyond the local or regional system boundaries. This deficiency must be viewed against the huge cross-border travel demand within the European Union leading to hundred millions of cross-border trips every year by EU residents and further several hundred million trips by international tourists. Understandably, the lack of information on public transport for door-to-door routing affects the mobility behaviour of all kinds of transnational travellers, especially of cross-border commuters who abandon public transport options and use their car instead. Hence there is a need for cross-border information on public and multimodal transport solutions.

The LinkingDanube project addresses this problem by linking so far isolated systems with the objective to extend their geographical scope also across borders. LinkingDanube stands for "Linking transnational, multimodal traveller information and journey planners for environmentally-friendly mobility in the Danube region". The project is co-funded by the INTERREG Danube Transnational Program of the EU. While setting up a common system is as well an issue of cooperation and organisation, the present paper introduces the technical concept for implementation of a distributed journey planning system within dedicated Danube Region countries. The paper describes the service architecture for such a system, called Danube Region Journey Planner (DJP) and outlines the premises and necessities for technical implementation. It describes a particular deployment case for distributed journey planning system that makes use of a single Open Journey Planning API (Application Programme Interface).

This work is not only relevant in a technical sense, but significantly contributes to the goals and objectives of the European Directive 2010/40/EC on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport, issues by the European Commission (2010). In priority action a) of the Directive 2010/40/EC the European Commission specifies the requirements for making "EU-wide travel information services accurate and available across the border to ITS users." A Delegated Regulation for the priority action a) is currently in preparation and is expected to be published in 2017. New regulations will be issued on how to provide access to and exchange data as well as on re-using static travel and traffic data (i.e. graphs, timetables, ticketing information, etc.). The linking of services via Open API for transnational routing is regarded as promising solution to enhance the geographical coverage of travel information services. Therefore the work done in the project can be considered as an early implementation of priority action a), thereby serving as a proof-of-concept for linking services. Also from a long-term strategic perspective the topic of the this work is significant, as multimodal journey planning has been a key part of the European Commission's strategy to support the future of transportation, as described in the White Paper (2011).

A thorough study by Rapp et al. (2011) has been reported within the policy framework of the European ITS Action Plan. This study aims to support a future development for European multi-modal journey planner by recommending functional, technical and organisational specifications as required by the ITS Directive. The study identifies major obstacles, mainly arising from organisational deficiencies, lacking business models and hence limited access to data. In all, it reveals that stakeholders prefer distributed solutions because these correspond better to existing organisational structures, facilitate adequate allocation of responsibility for data quality, and accommodate issues related to data ownership (Rapp et al 2011). LinkingDanube is exactly this principle of a distributed journey planning system.

2. State-of-the-art and gaps

Several EU funded projects were devoted to multimodal journey planning. The Easyway project promoted the development of travel information services, especially emphasising the need of creating a multimodal journey planner and information portal. Nuzzolo and Comi (2014) described in the i-TOUR project topics of adaptive, personalised multimodal routing with the combination of external information (e.g. road conditions, weather), locations based service and personalised preferences. Spitadakis and Fostieri (2012) presented the WISETRIP application, which uses personalised information for multimodal journey planning. The passengers may set their preferences, receive alerts and may reschedule their trip and choose a alternative routes. A current application of Sierpinski et al. (2016) is GTPlanner, which takes into account personal preferences when planning routes for the users and also provides information about their trips. The METPEX (2015) project aimed to develop and evaluate a standardised tool to measure passenger experience and service quality across whole journeys.

During the past decade three European systems have been introduced in order to cover wider geographical areas for distributed multi-modal journey planning: JourneyWeb, DELFI and EU-Spirit. Some ideas of these systems have been included to develop an Open API based standard, on an extension of the German TRIAS schema. As a result the Open Journey Planner API specification (OPJ) has been published for distributed journey planning of public transport by the Technical Committee CEN/TC 278 (2017), which opens the way for unified and standardised solutions in Europe. This specification is applied in LinkingDanube to develop a seamless journey planning solution.

As a consequence there are a huge number of such multimodal information systems across Europe, mostly have started with an urban or regional focus depending on the public transport operators involved in the information provision. Hence these systems are mainly serving relatively local journeys. Also cross-border information is hardly integrated due to organisational, administrative and interoperability hurdles in setting up transnational cooperation. In contrast to the local and regional services, those for longer-distance journeys are mainly mono-modal information systems from the rail and airline industries. Currently these facts result into a lack of seamless journey planners for public transport, which are going beyond the own system boundaries.

Beside of there are technical obstacles like lacking interoperability of data and systems. In fact, plenty of different journey and route planners are available on the internet and many advanced information systems exist for transportation management and supervision. They provide a range of solutions, but in most cases they are limited concerning the functions of multimodal and/or international journey planning due to the reasons outlined above. In many cases a holistic approach is lacking and the information provision of public and private transportation systems is very diverse. Considering this requested paradigm shift to seamless information provision, smart systems are to be created, which provide comprehensive solutions through different aspects of transportation.

3. Methods

3.1. The LinkingDanube Concept for distributed journey planning

While data access and exchange has been in the focus of past research initiatives, LinkingDanube goes one step further towards the actual linking of services. One main output will be a publicly available Concept on Transnational, Multimodal Journey Planning Services for environmentally friendly modes in the Danube Region. The Concept shall serve both as input for the technical development work within LinkingDanube as well as for subsequent uptake by project externals. The LinkingDanube Concept will make a conception for distributed journey planning for the Danube Region by building on existing decentralised journey planners in the Member States. The developed Danube Region Journey Planner (DJP) will integrate operative journey planners from six different countries, namely Austria, Hungary, Czech Republic, Slovakia, Slovenia and Romania that will cooperate and link their services in the pilot action.

One major pre-condition for the development work was that journey planning is facilitated in a decentralised way ensuring that each country remains responsible of its routing logic, data quality and maintenance. As it is currently the case with most existing services, two systems with different languages or requesting methods cannot communicate directly. So a translator is needed to guarantee successful exchange of requests. All participating journey planners will implement a common open application programming interface (API) that facilitates a common understanding of the request information exchanged between the systems.

On the one side implementation work is required on the side of the participating systems to implement the common interface and, if necessary, develop proper translation tools. On the other side the development work in the project focuses on a sophisticated central journey planning system, the Danube Region Journey Planner (DJP) that offers capability and functionality to respond to an end-user's enquiry, to orchestrate the requests to and from the participating systems and to provide the appropriate logic and intelligence to combine multiple responses in a reasonable manner. In particular the system must be able to work out what enquiry to send to one or more other information systems and how to merge the responses with data from its own repositories in order to create one or more seamless journey plans for the enquirer. In the end this means that decentralised local and regional services will be interoperable and will be able to "plug into" the Danube Region Journey Planner (DJP) System that provides seamless information from multiple systems. Another major aspect in the development work is, that the participating systems will receive back the final results, so that it can be shown in their own brand, if whished.

3.2. Use Cases for the LinkingDanube pilot

The developed LinkingDanube Concept will be subject to a "proof-of-concept", a pilot action that will demonstrate linking of services building on existing decentralised systems in the Member States. The LinkingDanube pilot will create a transnationally overlapping operative environment where the feasibility of specific use cases for long-distance, multimodal traveller information and demand transport integration will demonstrated. Naturally the Pilot action will not be able to cover the whole system landscape, which will also not be its purpose. Rather it will focus on selected use case which are of major importance and suitable for achieving convincing and upscalable results. In this way the demonstrations will be the basis for further large-scale implementation. The general scope of the use cases is on multimodal routing requests however due to the heterogeneous structure of operators and features of the respective home systems, cross-border rail routing will be the minimum requirement towards the LinkingDanube system environment.

The use cases have been clustered into two main categories depending on the area covered by each of the services:

- *Remote use case* – in this use case two services which have neither a common border nor an overlapping area of action are linked
- *Adjacent use case* – in this use case two services with neighboring or overlapping areas are linked

In this matter it is important to differentiate between geographic borders and the coverage of the participating journey planners. While two Member States participating in the project (i.e. Austria and Slovenia) might be geographic neighbours, the Slovenian system might only cover the greater Ljubljana area and therefore neither adjoin nor overlap with the Austrian system. Consequently the linking of these two services would actually be of the remote use case category.

In case of linking two remote journey planners the routing between the system boundaries (i.e. exchange points as described in chapter 3.2.2) must be handled by a separate entity, which is called International Routing Service (IRS).

3.3. Public Transport - Open API for distributed journey planning

If different routing systems between Member States are to be connected for transnational request handling and routing, the API needs to know all modes of transport that are supported, all information about lines and stops as well as the minimum requests to be processed by each of the different home systems, including the (possibly dynamic) hubs for transnational handover of the request.

The system architecture to be followed in LinkingDanube closely relates to the concept of a central-distributed journey planner that is described in the final draft version of the Technical Specification for Public Transport – Open API for Distributed Journey Planning, which has been prepared by the Technical Committee CEN/TC 278

(2017) “Intelligent transport systems”, the secretariat held by NEN (Netherlands Standardization Institute).It consists of one central entity containing the major part of the intelligence and a set of national (i.e. decentralised) journey planners.

The applied Open API is a technical specification defining a schema for establishing an Open API for distributed journey planning that can be implemented by any local, regional or national journey planning system in order to exchange journey planning information with any other participating local, regional or national journey planning system. Open API is underpinned by the main existing standards for public transport operations, i.e. IFOPT (Identification of Fixed Objects in Public Transport), NeTEx (Network and Timetable Exchange), SIRI (Service Interface for Real-time Information), Transmodel (Pubic Transport Reference Data Model).

The open journey planning (OJP) schema defines four key "actors" or "roles" in the distributed journey planning process, which is also applicable for LinkingDanube project:

- *enquirer* - representing the user asking for information
- *home system* of the enquirer - which represent the journey planning system to which the enquirer is connected;
- *distributing system* - that represent the system that distributes journey planning enquiries to other systems; this component will be realised by Danube Region Journey Planner (DJP) web service
- *responding systems* – that represents the system responding to questions from the distributing system

Based on the Open API specification the main features of the proposed services are defined and explained. The open journey planner interface services are defined as XML schemas. Table 1 shows the relevant subset of Open API services for the use cases that form the minimum requests that will be used in the pilot.

Table 1: Relevant Open API services selected from the list of all services of OJP by Technical Committee CEN/TC 278 (2017)

Service	Name of request element	Schema file
Location information	LocationInformationRequest	OJP_Locations.xsd
Exchange points	ExchangePointsRequest	OJP_Locations.xsd
Trip request	TripRequest	OJP_Trips.xsd
Distributed journey planning	MultiPointTripRequest	OJP_Trips.xsd

3.3.1. Location information

The *location information service provides* matching text input of possible origin and destination locations and names of locations near a given coordinate. It also provides *geographical context service*, *reverse address resolution service* (delivers the nearest address for a given coordinate), *stop assignment service* (finding the nearest stops/stations for a given coordinate). The XML schema file OJP_Locations.xsd defines data types and structures for use in the Location Information service.

3.3.2. Exchange points

Exchange points (hubs) are boundary points of two neighbouring home systems, where the trip calculation process is handed over. If they are not known in advance the exchange points can be requested by using the exchange points service.

3.3.3. Trip request

This service provides intermodal trip information from an origin location to a destination taking user preferences into account. This service element can used by the home systems, when they require a public transport based journey plan from another system. At the same time, the journey planning can be split into several subtasks. This approach is called distributed journey planning and detailed in the next section.

3.3.4. Distributed journey planning

The Open API supports distributed journey planning, when more than one home system is used to create a transnational route. Practically the planning procedure is distributed into several planning processes. First the client system sends a TripRequest message to its enquirer home system. The home system forwards this request to the Distributed Journey Planner (DJP) system. The DJP has the ability to split the journey planning request into pieces and to find the relevant home systems (local journey planning engine). The responding home systems may get more than one request before the total trip is completely calculated.

4. Results

4.1. System architecture for the Danube Region Journey Planner (DJP)

According to the CEN/TC 278 Technical Specification there are two different system architectures possible to facilitate distributed journey planning, depending on the location where the supporting metadata, like gazetters are held. There is a decentralised and a centralised approach for distributed journey planning. In a decentralised approach each participating system needs to hold gazetteer data for all the participating systems' areas and the enquiry process could then work on a peer-to-peer decentralised basis. In order to get an efficient approach it is necessary to consider all required support data – not only the gazetteers, but also how access to the timetable data for long-distance public transport services (notably trains, coaches, ferries and flights) can be achieved in a way that allows it to be used in the creation of the effective journey plans. This has been considered as a drawback in the project in regard to the high development efforts on the side of the all participating systems that would go beyond the scope of the project. Therefore, the central distributed journey planning approach was chosen. In this approach, the route calculation is still decentralised, but the supporting data are held in an central entity, the Danube Region Journey Planner (DJP). The DJP will recognise in which system(s) will be able to provide journey planning answers for the requested origin and destination. This will be facilitated by sharing a central repository of gazetteers (indexes of geographical entities – localities, addresses, stops & stations, etc) for a network of distributed journey planning systems to identify the relevant journey planner. Then the central DJP will make the necessary enquiries of the relevant journey planning systems and handle back the information to the originating system. This is an centralised model for handling journey enquiries that required the distributed service.

The basic system architecture for transnational and multimodal journey planner is presented in Figure 1. The Danube Region Journey Planner (DJP) aims to become a link between existing national journey planners and to rely on the information these provide in order to offer extended trip planning solutions that are not limited by the scope of any local planner. The Danube Region Journey Planner (DJP) is connected to a web service with the Open API interface, which allows sending back the combined routing result to the linked home journey planners. It is possible to implement the common Open API interface on their national journey planners (home systems) in order to exploit the functionality of DJP.
The main entities or roles within the system are the Danube Region Journey Planner Central Node (CN), which provides the necessary logic to manage the request, the Local Journey Planner (LJ) and the International Routing Services (IRS), which is needed to generate routes between journey planners that are remote and not adjacent. In the following the system components are described more in detail.

- *Danube Region Journey Planner Central Node (CN)* is the main component of the system. It provides the necessary logic to query the local journey planners and the International Routing Service (IRS), using a common communication API and concatenates the received information to obtain the planned trip solutions. The Central Node offers a web portal that implements a unified graphical interface for transnational journey planning. An open standards map is used to visualise the final results of the multimodal trip alternatives. In addition, the central node offers a web service that implements the common API, which can be used by any other local journey planner for transnational and multimodal planning.

- *Local Journey Planners* (LJP) are the journey planners from different countries with trip planning ability limited in space, i.e. typically they calculate within a country/region. In the Open API logic they are fulfilling the functions of the home system and the responding system. In LinkingDanube project these are the existing systems that will be upgraded to be able to be interlinked with Danube Region Journey Planner Central Node (CN) via a common interface.

- *International Routing Service (IRS)* is a particular service that holds transport connection of the Trans-European Transport Network (TEN-T) and other relevant cross-border connections. The general goal of TEN-T concept is to provide integrated and intermodal long-distance, high-speed routes. Accordingly, for the transnational multimodal journey planner the TEN-T remote routing is applied to generate routes between international hubs (typically railway/bus stations) which are stored by the exchange points' database (see next point). Also transnational bus services and other major connections between exchange points are implemented. This component will be developed by the project consortium.

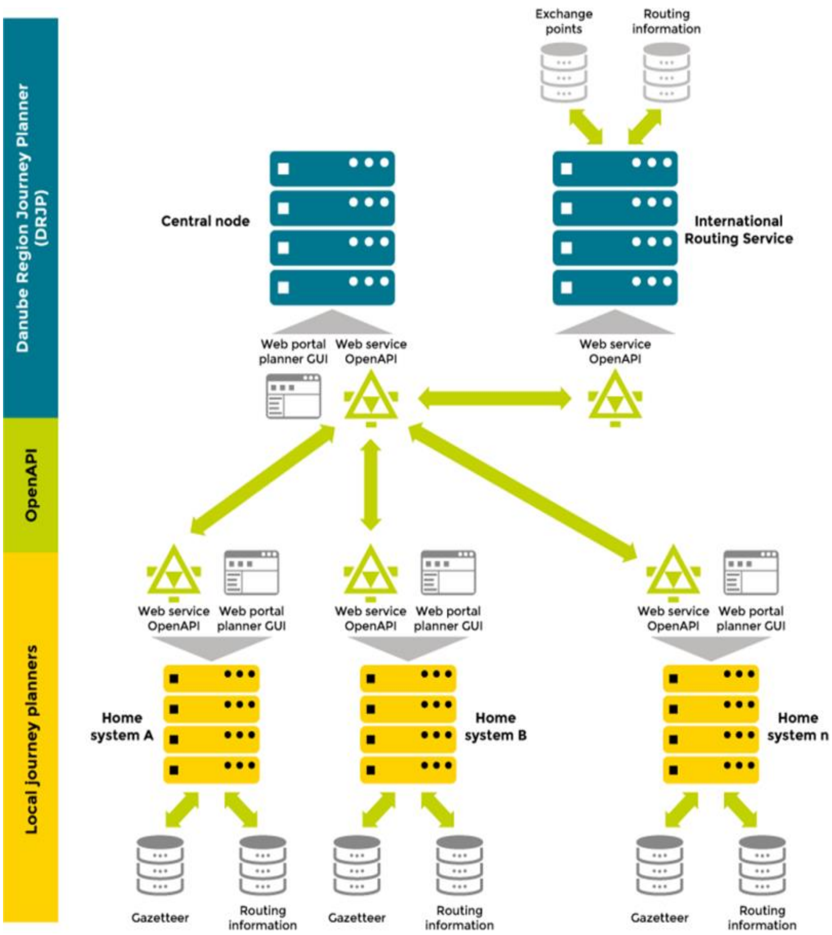

Figure 1: Basic system architecture of the Danube Region Journey Planner (DJP) showing its main compontents

Beside of the above mentioned entities or roles (also shown in Figure 1), there are other main components that need to be defined and set within the system architecture, which is the interface itself, the Open API, but also the exchange points and the gazetters. The components are defined as follows within the system.

- *Open API interface* - this API is the key element in the transnational, multimodal route planning concept. This component is responsible to ensure the connection and interoperability of the local route planners (home systems). It will be implement according to the CEN/TC 278 Technical Specification for Public Transport – Open API for distributed journey planning.

- *Exchange points (hubs)* - multimodal and transnational journey planning requires several journey planning systems (home systems). The planned parts of the whole trip must be then assembled between the relevant hubs. The first home system plans from the origin of the trip to international hubs. From these hubs the International Routing Service (IRS) calculates the possible routes until to the next possible international exchange points. Then, the next home system searches for routes from these hubs to the next relevant hubs of adjacent home systems. This process is repeated until the last home system finds the route to the destination of the user's trip. The hubs of the home systems are called exchange points where the trip calculation is handed over from one system to another.

- *Gazetteer* - digital gazetteer is a structured dictionary of geographical places. It will be used by Danube Region Journey Planner (DJP). Different name types from different languages need to be tackled as well.

Particular focus in the development needs to be given to the request flow within the distributed journey planning system. The main steps in the request flow when user asks for a multimodal and transnational journey plan from central Danube Region Journey Planner (DJP) are given below:

- *User provides the origin and destination points* on Danube Region Journey Planner (DJP) GUI (typing into the textbox or GPS coordinates or clicking on OSM map).
- *Danube Region Journey Planner (DJP) queries gazetteer* in order to get valid (existing) points.
- *Gazetteer sends back valid origin and destination points*.
- Based on the origin and destination points, *Danube Region Journey Planner (DJP) queries the exchange points'* database in order to get all relevant hubs. A hub will be assigned as relevant if it is a mutual hub for both the origin's and destination's home system, i.e. an international railway/bus station with direct transport between the countries of the origin and destination points.
- *Danube Region Journey Planner (DJP) gets the relevant hub list* from Exchange point's database for both home systems.
- *Danube Region Journey Planner (DJP) asks the origin's home system to plan trips* from origin to all exchange points of the hub list. Danube Region Journey Planner (DJP) also asks the destination's home system to provide all trip variations from the points of the relevant hub list to the destination point.
- *Danube Region Journey Planner (DJP) requests trip* planning between adjacent hubs from International Routing Service (IRS).
- *Danube Region Journey Planner (DJP) considers the trips* provided by the home systems from origin to hub and from hub to destination as well as the planned route variations between hubs given by the International Routing Service (IRS). The best trips will be assembled. The criteria for "best" trip are given by the user, e.g. shortest travel time, mode choice, fare.
- Finally, *Danube Region Journey Planner (DJP) visualizes the route options* on OSM map layer in the web/mobile application.

4.2 Technical Development

On the one side development work is required on the side of the Local Journey Planners (LJP) to implement the common interface. That means that they will be upgraded in order to accommodate the common agreed Open API Interface, in order to interconnect with the Central Node. This includes the development of proper translation tools to provide the requests in the common format. In the end this means that decentralised local and regional services will be interoperable and will be able to "plug into" the Danube Region Journey Planner (DJP) System that provides seamless information from multiple systems.

On the other side the development work in the project focuses on a sophisticated central journey planning system, the Danube Region Journey Planner (DJP) that offers capability and functionality to respond to an end-user's enquiry, to orchestrate the requests to and from the participating systems and to provide the appropriate logic and intelligence to combine multiple responses in a reasonable manner, as outlined above. In particular the system must be able to work out what enquiry to send to one or more other information systems and how to merge the responses with data from its own repositories in order to create one or more seamless journey plans for the enquirer. Based on the system architecture and the common Technical Specifications that are developed within the frame of the LinkingDanube Concept, the Danube Region Journey Planner (DJP) Central Node will be developed fitting the mentioned requirements and put in operation.

Another major requirement in the development work is, that the Local Journey Planners shall have the possibility to receive back the final results, so that the journey plan can be shown in their own system and brand to their end-users, if whished. This is an aspect that highly related to the business model and the mutual benefit of a distributed journey planning system.

The international routing service (TEN-T or Similar Service) will be also developed within the project in order to provide information about relevant international hubs between the origin and destination of a planned trip and routing solutions between these hubs. For the scope of this project, the service will be developed internally, using existing TEN-T predefined sets of transport networks in the European Union. In the future, as the TEN-T initiative evolves, other services could be used with the same purpose.

The developed system will be tested in two stages. First, the interconnection and data exchange between Danube Region Journey Planner (DJP) Central Node and Local Journey Planners will be tested. This should meet the requirements and the Technical Specifications defined previously in the project for the common agreed Open API Interface. As the second stage of testing, the entire system will be tested from the user point of view. All the specific use cases for multimodal traveller information and demand transport defined in the first part of the project will be thoroughly tested.

5. Conclusions

The LinkingDanube Pilot action will demonstrate the feasibility and functionality of distributed journey planning by Open API. With the twofold advantage of not having to integrate all data of each local or regional journey planner vice-versa and not having to set up new services every few years with differing GUIs and ever-changing system architectures, the linking of services holds major potential for improving travelling throughout the whole European Union. By using a system like this existing traveller information services can provide end users – especially daily commuters in cross-border regions – with seamless information for their trip and thus facilitate the transition towards public transport by showing alternatives to private car use.

LinkingDanube project has an ambitious goal to create a functional distributed journey planning system, based on local and regional journey planners already existing in different countries. There are three critical processes for a successful implementation identified: First critical process is the correct implementation of the common Open API interface on both sides, in all the Local Journey Planners on one hand and on the newly developed Danube Region Journey Planner (DJP) Central Node on the other hand. The entire functionality of the system depends on the correct and consistent implementation of data exchange between the systems. The second critical process is the correct and unambiguous definition and selection of the hubs, as the transfer points between the Local Journey Planner and the International Routing Service. A suitable algorithm for selecting this hubs is crucial in building consistent international routes from origin to destination. A third critical process is the specific routing algorithm that will be developed and implemented in order to concatenate routes from Local Journey Planners and from International (TEN-T) Journey Planner and selection of feasible and best routes based on different parameters. All these three areas will be treated with great care by the project partners and thoroughly tested within the project in order to obtain a functional international distributed journey planner with coherent results.

For long-term durability of the results, a strategy for the implementation of transnational environmentally-friendly journey planners in the Danube Region will be developed in cooperation with the EUSDR priority area 1B working group.

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