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A New Open-source System for Strategic Freight Logistics Planning: the SYNCHRO-NET Optimization Tools

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Abstract

Globalization and e-commerce facilities have yielded in the recent years an incredibly huge increment of freight movements. Consequently, the underlying supply chains have become more and more complex to manage for the shipping companies, in terms of costs, distances, times, and environmental sustainability. SYNCHRO-NET, a H2020 European research project, aims to de-stress the international supply chains by fostering cost-effective and greener transportation alternatives. Besides other important actions, the SYNCHRO-NET framework provides an optimization and simulation toolset to support decision-making in freight logistics planning at a strategic level. The synchronized use of different transportation modes and the exploitation of smart steaming strategies for ship movements are the two main aspects considered in this innovative optimization system. In this paper, we present the optimization toolset developed, its contribution with respect to the existing platforms, and the experimental set-up implemented to evaluate its performance, usability, and effectiveness. The system is, in fact, currently under evaluation by several world-wide leading companies in freight logistics and transportation. However, the toolset potentialities go beyond the SYNCHRO-NET context, being the system an open-source project that makes use of open data formats and technologies.

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Keywords: Freight logistics; Synchro-modality; Slow steaming; Decision Support Systems; ICT; Network optimization; Open-source systems.

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1. Introduction

SYNCHRO-NET*, SYNCHRO-modal supply chain eco-NET* (*http://www.synchronet.eu/*), is a Horizon2020 European research project that aims to overcome the stress due to increasing transportation distances, higher complexity, and vulnerability of supply chains, mainly fostered by the modern-age e-commerce facilities and globalization. The SYNCHRO-NET approach incentives coordination across supply chain operators and smart transport modes by emphasizing **slow steaming**, i.e., the practice of operating cargo ships at significantly less than their design speed, reducing fuel costs and greenhouse gas emissions, and **synchro-modality**, i.e., multi-modal transportation in which stakeholders can switch between transportation modes in real-time for higher efficiency.

Differently from other similar projects (see, e.g., e-FREIGHT, 2010, e-MAR, 2012, and CORE, 2015), SYNCHRO-NET combines strategic, operational and real-time aspects with a stakeholder-driven business perspective to achieve a close-to-market solution and more sustainable international supply chains. In fact, through the SYNCHRO-NET actions, many different stakeholders of the supply chain (carriers, freight forwarders, haulers, retailers, shipping companies, and logistics and transportation operators) can quickly analyze and calculate the impacts and benefits of slow steaming and synchro-modality into their planning, enabling the identification of business opportunities and simultaneously enhancing quality, sustainability, and reliability of their activities.

From an ICT perspective, SYNCHRO-NET is based on an integrated optimization and simulation platform in which cost-effective robust solutions are guaranteed by incorporating strategic and real-time synchro-modal logistics optimization, smart steaming ship simulation and control, risk/benefit analysis, stakeholder impact assessment, and all the communications needed for a complete interoperability. All these aspects are managed and tackled by several procedural or software modules that work together in complete integration within the platform and interface with external services using standardized and open APIs. Cloud concepts are also implemented to achieve a high degree of flexibility for platform deployments. For a comprehensive overview see Holfeld et al. (2018).

The purpose of this paper is to present the strategic freight logistics optimization toolset developed within the SYNCHRO-NET project. In this context, *strategic* must be intended as opposite of *real-time*, i.e. only based on static data for planning and simulation purposes, even if the optimized processes are definitely of an operational kind. We focus on all the innovations proposed with respect to the existing platforms that are, in general, limited in some ways. For example, they consider a single transportation mode, a restricted geographical area, a specific issue (traveling optimization, empty container repositioning, berth scheduling in ports), or are driven by over-simplified cost models. Open-source libraries have been used to build up the system and open data have been adopted to support routing and mapping operations. We also remark that the final toolset will remain an open-source project, to foster possible future contributions and improvements from the community. To the best of our knowledge, no other open-source planning systems exist in the field of freight transportation management.

The remainder of the paper is organized as follows. In Section 2, we review the scientific literature about freight transportation considering slow steaming and synchro-modality practices and the related existing tools. Section 3 is devoted to describing the developed optimization system for supporting strategic decisions in freight logistics planning, with a particular focus on the customizations introduced in the open-source code libraries used. In Section 4, we discuss how existing open data formats have been customized to better support freight logistics optimization processes. In Section 5, we briefly present the experimental set-up with which the newly developed system is going to be tested and evaluated by some leading companies in the field of logistics and transportation. Finally, conclusions and possible future perspectives are drawn in Section 6.

2. Literature review

Due to their capability of strongly reducing operational costs and environmental externalities, slow steaming and synchro-modality are becoming more and more attractive in long-haul shipments both from a methodological and business-oriented point of view (Perboli et al., 2017). In the following, we briefly review the literature concerning these two main aspects of our optimization system.

The practice of slow steaming for transoceanic container ship movements has massively started in 2007 (in the face of the rapid rising of the fuel oil costs) and nowadays nearly all the international shipping lines are using slow steaming strategies to save money on fuel. In fact, lowering the travel speed lowers the power requirement and thus the fuel consumption. By using slow steaming strategies, carriers can save about 5-7% on their logistics costs (Bonney, 2010) while it has been estimated that just a 10% reduction on the vessel speed can lead to at least 10-15% decrease on emissions of CO_2 and other pollutants (Cariou, 2011). This practice is then both cost-efficient and environmentally friendly. However, apart from the already mentioned direct savings on specific ship routes, we are more interested in the possibility of exploiting slow steaming to optimize and de-stress the entire supply chain of a transportation scenario. In fact, through a *smart steaming* management (that includes the possibility to dynamically change the vessel speed according to real-time state of the sea, weather conditions, and congestion at ports), it is possible to optimize overall costs, durations, emissions, and risk measures while maintaining schedule adherence and reliability of the shipments (see, e.g., Armstrong, 2013 and Lee et al., 2015).

To this aim, the synchronization of operations and the possibility to switch among different modes of transportation, the so-called synchro-modality, become even more critical to be considered. Contrarily to the conspicuous literature concerning optimization in multi-modal/inter-modal networks (see Steadie Seifi et al., 2014 or Crainic and Kim, 2007), the study of synchro-modal settings and the relative optimization methodologies seem still at an early stage and very few contributions going beyond conceptual issues can be found (Pfoser et al., 2016). Fan (2013) approaches the design of synchro-modal freight transport systems to improve the performance of the existing inter-modal ones, whereas Li et al. (2017) investigate cooperative synchro-modal freight transport planning among multiple intermodal freight transport operators in different and interconnected service networks.

Consequently, there is also a lack of applicative solutions/tools able to exploit the potentialities of synchro-modal transportation in realistic (in terms of size and complexity) commercial contexts. Only very recently, Kapetanis et al. (2016) propose and test a decision support system enabling the assessment of different transport modes, in terms of time, cost, and emission for commercial routes through the terminal of Piraeus (Greece). However, the proposed tool seems just a cost calculator than an optimization platform. Mes and Iacob (2016) present an applicative tool based on a multi-objective k-Shortest Path Problem to deal with efficient synchro-modal transportation switch in a real-time environment. Other existing platforms, that can be found as online commercial services (e.g., *https://www.inttra.com*, *https://www.searates*.com, or *https://www.skyspacecargo.com/skyspace/*), are in general oriented entirely to pricing and booking details and cannot support companies in strategically improving their business through the use of better solutions in terms of cost, time, distance, reliability, flexibility, and emissions.

The SYNCHRO-NET optimization toolset, instead, provides freight forwarders and transportation companies with an open-source strategic Decision Support System that enables more efficient, sustainable, and de-stressed supply chains also exploiting the potentialities of slow steaming and synchro-modality strategies.

3. Optimization toolset for strategic freight logistics planning

The SYNCHRO-NET optimization toolset provides strategic-level decision support regarding routes and schedules for synchro-modal freight transportation. It finds the best possible solutions according to users' objectives and constraints by using optimization techniques and algorithms over a logical network created by elaborating a well-defined database of geospatial and commercial information.

The system has been built upon an open-source package of Java libraries called *Open Trip Planner* (OTP, *http://www.opentripplanner.org/*) that uses a client-server architecture and provides a map-based web interface. Originally, OTP was conceived for multi-modal/multi-agency journey planning and urban people mobility. It basically provides alternative multi-modal solutions with respect to the users' intended departure/arrival location and time. For the SYNCHRO-NET project, the OTP has been extensively customized to be used as a synchro-modal multi-agency container-based freight transportation planner (as a stand-alone simulator or by third-party applications through specific APIs). In particular, advanced optimization procedures, new searching options and the calculation of additional outputs have been implemented, together with the relative graphical tools in the web interface. Moreover, specific exchanging messages and data formats have been customized to support the data management and the new functionalities. In the following subsections, we will describe the basic optimization process of the proposed system and all the developed improvements/customizations that characterized the SYNCHRO-NET strategic optimization toolset with respect to the standard OTP.

3.1. Basic optimization process

The basic functionality of the system allows the user to select an origin and a destination location for the shipment under interest and some basic constraints on the departure and arrival dates and times. The locations can be selected from a list of cities, harbors, rail stations, and inter-modal inland ports already included in the database (see Section 4.1) or picked interactively on a map. In the first case, while the user is writing the name of the desired place, the system proposes a list of available locations with a similar spelling in an auto-filling fashion. In the second case, the system proposes the list of the nearest available locations to the coordinates picked on the map.

Once received the location coordinates and the desired time constraints on the shipment (the release time, i.e. the time at which the freight is ready to depart, must be compulsorily specified while the arrival time specification is just optional), the system applies its optimization routines to find the best possible synchro-modal solutions. The internal optimization is based on some well-known exact or heuristic algorithms, such as the *Dijkstra* and *A**, for the Shortest Path Problem (Festa, 2006, Hart et al., 1968), but further adapted to consider:

- an inter-modal network and the synchronization of the schedules among the different itinerary legs, taking into account alighting, boarding, and transit times at each vehicle change (Section 3.1.1);
- an objective function depending on several, possibly conflicting, attributes (Section 3.1.2);
- additional constraints on the use of ports and routes, and restrictions on the transportation modes (Section 3.1.3).

Eventually, the system returns to the user a list of feasible and reliable synchro-modal itineraries. Results are shown primarily in a summary table where several Key Performance Indicators (KPIs) can be assessed (see Section 3.1.4). Chosen a specific solution from there, the user can explore detailed information and visualize the route on the map as shown in Fig. 1 through an example. Fig. 2 shows the summary results panel of the same example.

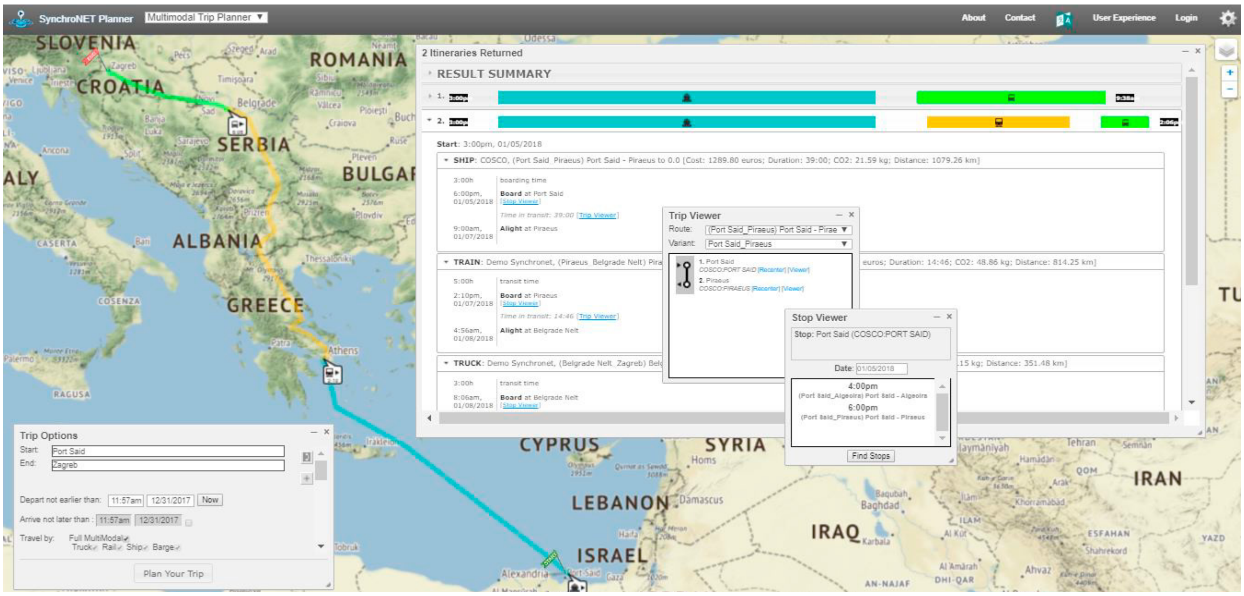

Fig. 1 The SYCHRO-NET optimization toolset is used to simulate a shipment from Port Said (Egypt) to the city of Zagreb (Croatia). In this example, the system proposes two possible multi-modal itineraries. The second one, involving a ship, a train, and a truck leg, is visualized on the map. As shown, several details about the routes, the stops, the agencies and the schedules can be explored by using the graphical interface.

3.1.1. Transportation modes

Synchro-modality is a key aspect of our optimization process. Three main modes are considered for freight transportation in the SYNCHRO-NET project: truck, train, and ship (sea vessel and river barge). For each mode, specific parameters (such as average speed, costs, and emissions rates) can be specified.

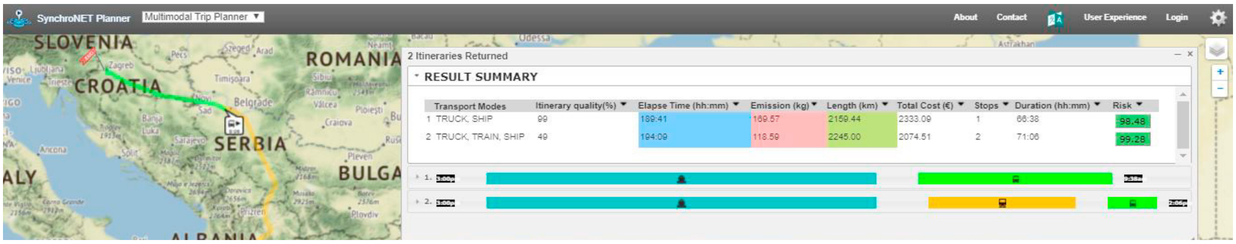

Fig. 2 Result summary panel of the previous example.

Concerning the ship routes, different steaming models, vessel types, and boarding options (*roll-on/roll-off* and *lift-on/lift-off*) are considered. These aspects may affect the operating costs, the schedule, or the capacity of a ship on a given sea route. The modeling for other modes, instead, has resulted simpler. For example, we have assumed that a truck has not a specific schedule but can start traveling when needed after the time necessary for loading the cargo.

3.1.2. Multi-attribute optimization

The original basic OTP elaborates solutions by optimizing only with respect to the length of the itineraries or to the relative proportional time duration. To encourage the use of alternatives de-stressing the supply chain, the new optimization strategies aim at minimizing several attributes of a solution such as distance, actual trip duration, total elapsed time since the booking time, CO_2 emissions, and monetary costs. Note that the considered attributes may be conflicting (e.g., choosing a slow steaming ship route lowers the emissions but, in general, increases the traveling time). Moreover, times, emissions, and monetary costs of an itinerary are not collinear with distances due to the presence of both proportional and fixed factors for their evaluation (cargo alighting, boarding, and transit times must be considered beyond the travelling ones, while emissions and contracts costs may depend on the vehicle type or the agency). These aspects make the optimization even more complicated. However, to guarantee a response of the system within a reasonable time, we do not perform a real multi-objective optimization. Instead, following a common practice for multi-attribute problems (Gendreau et al., 2016, Manerba et al., 2017), we minimize a single objective function in which the contribution of each different attribute is weighted by a factor. The relative importance of each attribute can be configured by the user, thus possibly affecting the results of the optimization.

3.1.3. Advanced searching options

Several advanced options are made available to simulate more complex transportation scenarios. While the full multi-modality is set by default, the desired subset of allowed transportation modes can be specified by the user. Moreover, specific routes and locations can be either banned or forced to be in a solution itinerary. Banning options can be useful to avoid passing through a particularly congested port or high-risk corridor. Instead, forcing options reflect the need to visit a location because it represents a specific facility (e.g., an intermediate depot) or it belongs to routes managed by an agency with which the shipper has a long-term contract.

3.1.4. Outputs and post-optimization functionalities

The summary panel (see Fig. 2) has been enhanced by including, for each returned itinerary, several quantitative and qualitative KPIs information such as the length, the duration, the emissions, and the total cost of the trip, as well as the types of vehicles involved, the number of stops, and the associated risk indicator (see Section 3.3). Sorting options for each KPI are particularly useful to compare and evaluate the alternatives. Moreover, even if the optimization toolset is more oriented to simulate transportation scenarios for strategic planning, specific buttons have been predisposed for expressing interest and booking activities on specific itineraries.

3.2. User authentication and configuration

An accounting, authentication, and configuration management system has been developed upon the optimization toolset for a robust, possibly concurrent, user-oriented interaction and confidentiality of the information. Each user, in fact, can fully customize the system in terms of configuration parameters and data available for the optimization.

Concerning the parameterization, a MySQL database has been created and integrated to store and manage user configurations and preferences. A configuration is a set of customized global parameters (average speed, proportional costs per km, per traveling hour, or per kg of CO_2 for each type of vehicle) and a specific proportion of importance of the different attributes for the optimization. A user can create and save several configurations and load them when necessary to evaluate the same transportation scenario under different conditions.

Concerning data, the system allows different visibility of the available commercial routes over which to optimize. This means that each user may have a customized, possibly private, set of alternative transportation options beyond those provided by default into the system. These data can also be updated interactively by the user (see Section 4.2).

3.3. Risk Analysis

Our optimization system works under the assumption that all the information is deterministically known in advance. However, in real environments, data uncertainty and unforeseen events (delays, congestions, accidents) may destroy the effectiveness of a planned solution, in particular concerning routing and scheduling problems (Beraldi et al., 2017). To deal with this issue, we put beside the optimization routines also the calculation of additional Key Risk Indicators (KRIs) that allow assessing the reliability of the returned itineraries. Methods and software for this calculation have been developed by *Fraunhofer IVI* of Dresden (Germany), partner of the project.

A simulation-based risk analysis, which relies on a historical storage including existing knowledge and experience on the use of ports and routes, is incorporated into the system. As exposed in Simroth et al. (2016), the analysis is based on the so-called *Monte-Carlo Rollout* approach that generates random disturbances and invokes the basic optimization process iteratively to simulate future scenarios and their outcomes. More precisely, for each itinerary, the system calculates its *safety* (robustness against loss/damage along the shipment), *flexibility* with respect to modes changing, and the expected *time and cost deviation* when a re-optimization is needed. All these calculations are returned to the user as normalized percentage values and as a more intuitive histogram (Fig. 3a).

Similar to what explained for the multi-attribute optimization, also the relative importance of the above four KRIs can be set by the user to build the overall risk degree of choosing an itinerary. Another interesting aspect to highlight is the possibility to interact with the system to describe what did indeed happen to an ongoing shipment (the relative form appears in Fig. 3a), to refine the historical database over time and improve the KRIs calculation.

3.4. Advanced simulation modalities

Two complete new simulation modalities, the so-called *multi-destination search* and the *multi-container management*, have been developed to support other common freight transportation scenarios. We remark that all the already explained features also apply in both modalities and that the two modalities can be used simultaneously to simulate multi-container shipments to several destinations. The two modalities are detailed in the following:

- **multi-destination search**: this simulation modality allows the user to optimize freight movements from a single origin location to many different destinations. For each destination, arrival date and time can be specified. Basically, the system runs a plain optimization process for each destination, stores several possible feasible alternatives for each, and then combines them by merging common parts in a smart way. In this case, the result of the search is not a list of alternative itineraries but a list of complete plans to reach all the destinations within the same shipment. As shown in Fig. 3b, a plan is represented by a tree of itineraries with possible common parts. The multi-destination search is particularly useful for the assessment of freight shipments consolidation;
- **multi-container management**: while the basic optimization process does not consider the volume of the cargo and focuses on traveling and scheduling aspects, in this simulation modality the user can specify the number of containers to deliver for each destination. The search works as described in Section 3.1, but the optimization algorithms must also consider the possible restricted capacity of the used vehicles and evaluate, in the objective function, the trade-off between using a fleet of similar vehicles over the same route and changing the transportation mode. Since in general trucks are the less capable vehicles (e.g., they can transport one container each), this modality is of high interest for evaluating the impact of truck routes within more complex itineraries.

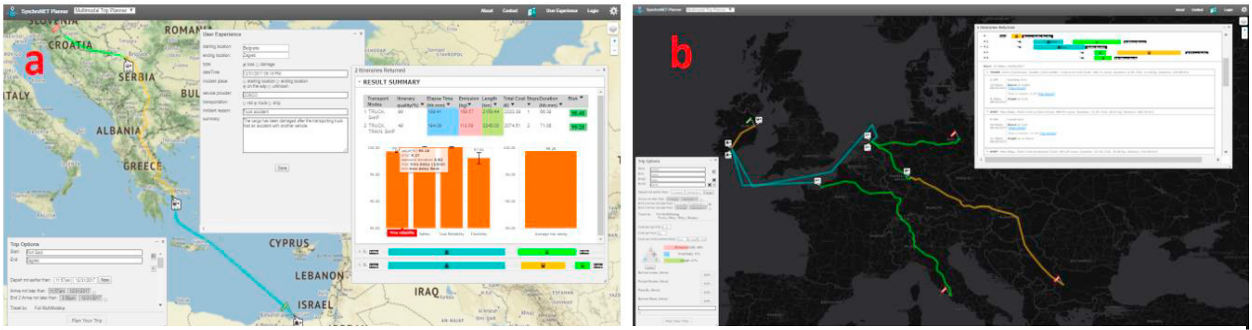

Fig. 3 a) Key Risk Indicators are visualized in detail for the example presented in Section 3.1. The histogram shows KPIs expected values and its standard deviation. b) A multi-modal multi-destination plan from Dublin (Ireland) to Sofia (Bulgaria), Rome (Italy), and Berlin (Germany).

4. Open data format for strategic freight logistics

The OTP originally relies on consolidated open data standards such as *Open Street Map* (OSM)[†] for the definition of geospatial information about the motorway and the railway networks and General Transit Feed Specification (GTFS)[‡] for transits and schedules. OTP merges the information coming from the two sources to create the network underlying the optimization procedures.

To simplify the information management and speed up the system response, the construction of the supporting network in the new system avoids any dependency from OSM data while it is totally based on GTFS. Note that the original GTFS format is conceived to deal with public transportation schedules and agencies, mainly at an urban or regional level. Hence, it does not match the needs of our system. However, given some natural similarities with people transportation, we propose duly enhanced GTFS feeds as a stand-alone format to support strategic planning for freight transportation at an international level. In particular, the GTFS format has been extended to include all the geospatial information needed (length and shape of a route, country and typology of a location), commercial and operational information about the routes (monetary contract costs, vehicle type, loading type, times for boarding, alighting and movement of containers). The new open specifications that will be released at the end of the project have been created by starting from to the original GTFS format, so to simplify adaptation of existing GTFS tools.

To facilitate the creation and the updating of GTFS data (in the new format), we have also developed a *GTFS data generator* and a *GTFS data editor*. These two facilities are detailed described in the two following sections.

4.1. GTFS data generator

The **GTFS data generator** is a batch procedure that, given a list of locations, automatically generates a database of GTFS routes by combining OSM information and standard commercial features. More precisely, for each pair of locations, the tool returns (if they exist) unimodal truck and train routes corresponding to the shortest path in terms of geographical distance, generates the corresponding GTFS data, and stores them into the system database.

Since the set of generated routes grows quadratically with the locations number, we have implemented a *clustering algorithm* and a *two-tier generation* of the routes to reduce the GTFS database size. More precisely, we cluster around the biggest locations (centroids) all those ones (satellites) located within a given radius. Then, only centroids are used for the above complete generation, while each satellite is linked with similar routes only to its own centroid.

[†] OpenStreetMap official website: *http://www.openstreetmap.org* (accessed on January 03, 2018).

[‡] GTFS static overview: *http://developers.google.com/transit/gtfs/* (accessed on January 03, 2018).

4.2. GTFS data editor

The **GTFS data editor** (see Fig. 4) consists in a series of interactive and map-based interfaces that allow the user to add and modify locations of interest and all the connecting routes (together with their schedules, geospatial, and commercial information) into the system database. The editor can correctly handle writing operations on GTFS data according to the different users and, therefore, a user can operate only on its own GTFS data without damaging the entire database consistency. The editor is obviously designed to reflect the GTFS data structure and to include the new features described above. It consists of the following three main parts:

- the **stop editor** allows the user to modify the existing locations and define the desired ones if they are not yet available in the database by giving names and coordinates or selecting them directly on the map. Extra information, including country, type of the location, role in the network (centroid or satellite) can be assigned to the stop as well;
- the **route editor** manages the creation of the new routes and the modification of the existing ones. Many fields can be specified, i.e., the mode of the route, the service dates where the route is valid, departure and arrival time, the number of days between the departure and arrival dates (in case of long period routes that exceed one-day duration), and the frequency, if any, with which the route is repeated after a time interval (e.g., every two hours). Finally, a specific interactive editor is devoted to the waypoints indicating the shape of the route;
- the **service editor** is devoted to arranging the schedules. A schedule is composed of a periodic weekly calendar and a set of separate dates that represent exceptions to the calendar. The calendar is created by selecting the days of the week where the service operates repetitively. Two types of exceptions can be defined, i.e., including a date that does not appear in the periodic weekly calendar or excluding a date that is active.

5. Experimental set-up

The testing phase of the strategic optimization toolset presented is implemented in the SYNCHRO-NET project through three different case studies (called *demonstrators*), mainly involving European zones and related corridors, but also Asia-Europe freight movements. The first case study (*Pan-European* demonstrator) aims at optimizing the freight flows between the Piraeus hub (Greece) and the rest of Europe, whereas the second one (*Regional* demonstrator) focuses on the logistics overseas movements from the port of Cork (Ireland's south coast). The third case study (*East-West* demonstrator) considers import/export operations of some common oceanic trade lanes from the Far East (Shanghai, Hong Kong) to the main Mediterranean harbors (Algeciras, Valencia, Genova, Piraeus).

The case studies have been proposed by some world-wide leading companies in the field of logistics and transportation (*COSCO Shipping Lines Spain S.A.*, *DHL-Spain*, and *Kuehne&Nagel-Ireland*), partners of the project. In this context, the proposed toolset will support shipping companies in some general activities such as:

- in-land transport planning optimization by integrating maritime route information;
- benefits evaluation of the smart steaming strategies for sea routes and of synchro-modal planning and scheduling in terms of supply-chains de-stressing, costs and emissions decreasing;
- optimization of the vehicle capacity and minimization of the empty container movements;
- assessment of transport options and quotations in terms of KPIs and KRIs to better fulfill client order requirements and explore new business opportunities;
- planning of long-term consolidation processes over a defined time horizon to optimize the volumes of each movement and possibly reduce the number of shipments per year;
- benchmarking in terms of costs and emissions of the modal shift between different ship boarding modalities, e.g., how much it is convenient to move from the currently predominant *roll-on/roll-off* operations (in which wheeled cargo is directly loaded onto a ship) to *lift-on/lift-off* ones (containerized movements through the port).

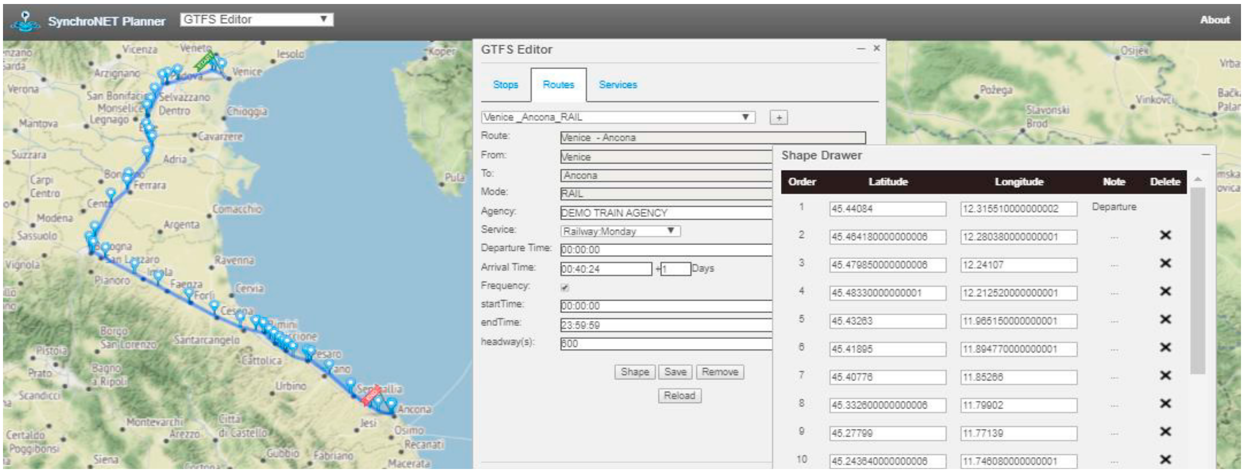

Fig. 4 A rail route from Venice to Ancona (Italy) in editing mode into the GTFS editor. In the left panel, general information about the route and its schedules can be inputted. In the right panel, the geographical shape of the route can be defined by using coordinates of its way points.

Moreover, relevant decisions that relates to a specific case study can be also addressed. E.g., in the Regional demonstrator, the tool will support the evaluation of the Brexit consequences for the Irish supply-chains and the exploitation of new cost-effective corridors.

To this aim, the system has been initially fed with a large set of realistic routes and schedules for different types of vehicles over geographical areas corresponding to the case studies. The GTFS data generator and editor presented in Section 4 have resulted to be essential. Data have been extracted from open *Geographic Information Systems* and private commercial archives of the companies. About 130,000 realistic (truck, rail, and ship) routes linking more than 1200 terminals (main cities, harbors, train stations, intermodal ports) have been stored along with their commercial properties, schedules, and frequencies.

A beta-testing is in place at the current time being by the above companies. Their first objective is to evaluate the overall performance, usability, and effectiveness of the developed system and the suitability of its future full integration into their business. However, the case studies must eventually demonstrate how the strategic tool contributes to the general SYNCHRO-NET results, which are expected to be very impressive:

- a 25-30% increase in modal shift to rail and a consequent 12-15% reduction in truck kilometers;
- a 12-18% reduction in hinterland transportation costs and fewer empty movements;
- a 20-25% decrease in fuel emissions, especially for ships;
- a 20-30% decrease in turnaround times, thanks to reduced congestion and waiting times at ports.

Moreover, even if only long-haul transportation is directly optimized within the project, it is expected a consequent 5-8% average saving in the cost (estimated around 5 billion Euros per year) of inland *last-mile* truck movements.

6. Conclusions and future perspective

A new optimization toolset supporting strategic decisions for synchro-modal freight logistics has been developed within the SYNCHRO-NET European project. Multi-attribute optimization procedures, advanced searching options and simulation modalities, and the calculation of additional outputs (including risk indicators) have been implemented, together with the relative graphical tools in the web interface. Moreover, specific tools to configure the optimization algorithms and manage the data are also provided. The system is, and will remain, an open-source project based on open data formats and libraries. Some world-wide leading companies in the field of logistics and transportation are currently testing the developed system on simulation scenarios interesting for their business. A working demo version of such a system is freely available at *http://icesrv.polito.it:3333/*, while a video tutorial can be found at *https://www.synchronet.eu/multimedia/video/webinar-the-synchro-net-simulator/*.

Given the enormous complexity of real transportation settings, we believe there is room for improvements of the system and its potentialities. However, we sketch here just a couple of possible enhancements. First, exploiting some possible integration with existing maritime systems/databases would have a great value for achieving an automatic generation also for ship routes. Second, in the perspective of an integration of the optimization toolset into a complete logistic process, there will be the need to implement interfaces with existing freight logistics platforms for booking operations by using standard communication protocols (González-Rodríguez et al., 2015).

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