Visualizing Transportation Routes for Data Analysis in Logistics

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***Abstract*—Logistics activities refer to transporting materials and/or storing them in specific warehouse (platforms) for a given period of time. Typical problems are related to route and vehicle load optimization and monitoring of transportation conditions. GPS availability in the vehicles allows transportation companies to remotely check if vehicles are on schedule. Such information is often related to a single shipment. This paper presents a web tool which aims to support analysts through an interactive visualization technique that shows all routes performed by the vehicles in a given period of time on a geographic map. The tool allows analysts to perform explorative analysis in order to obtain information that otherwise is difficult to get. Various filters help them to reduce the visualized data to a manageable quantity. The interface is simple, complex queries can be executed by specifying a few parameters and performing zoom & pan gestures on the map.**

Keywords: route visualization; transportation analysis; logistics

I. INTRODUCTION

A recent project we worked to aimed at providing commercial opportunities to small and medium size enterprises by developing a system that enables all stakeholders involved in logistics to improve the cooperation and the visibility in the market. The project covered industrial processes from the acquisition of raw materials to the delivery of the final product to the client. There is a difference between the products and the materials to be transported. While the products are the result of a production process, transported materials also include intangible goods, such as information flows (orders, invoices, marked data, etc.). The combination of physical and information flows is an added value of the project. The developed system addresses a number of companies with different capability involved in logistics, which offer various goods and services. The system offers multimodal services and use new technologies to perform advanced planning, schedule, tracking, and analysis. This allows the producers, but also transportation companies, to reduce the quantity of unsold products, the storage time, to shorten or speed up the supply chain.

In early 50s the term logistics focused only on the movement of goods. Starting from the mid-1970s, methods to move goods more efficiently were considered. Today logistics includes the logical flow that accompanies the physical flow, which consists in documents and information of the process to pack, load, transport and deliver goods. Company managers that organize their fleets need to know the position of each vehicle, information about the route, transportation conditions and drivers' conditions. Vehicles are equipped with GPS. Sensors are often installed in the containers to constantly monitor the transport conditions. Today, transportation tracking is very common and the carrier can provide the client with the position or the stage in the process where the ordered product is.

On the carrier side, typical problems involve the optimization of vehicle load and routing, which often deal with mathematical models from the operational research field. About twenty years ago, routing was the main issue [1], then further issues related to load optimization and route scheduling occurred [2]. Later, with the goal of improving service quality and reducing costs, research focused on the planning of the entire supply chain [3]. Such methods are now robust and work pretty well. However, operational research algorithms are considered as black boxes, and the analysts do not get a precise understanding of how data are processed and the results are obtained. Moreover, optimization algorithms often take into account a single delivery and provide weak support for long-term analysis.

Common problems in logistics are due to: the high number of actors in the supply chain; the request of a small quantity of products; routing scheduling; load optimization; transportation condition quality; little or no use of intermodality. The developed system provides the involved companies with a time-based strategy [4] that performs appropriate planning and scheduling; allowing them to easily cooperate.

Logistics processes generate huge and dynamic datasets, that analysts find difficult to understand. The tool presented in this paper provides a visualization technique useful for analysts working in transportation, interested in understanding the complex and dynamic spatial interactions among products (either components or finished ones), producers, carriers (e.g. road, rail marine, flight companies, logistic providers), consignees, and clients (those who order goods and trigger transportations). The visualization technique has been developed according to the Shneiderman's Visual Information Seeking Mantra [6], which prescribes to provide a general overview of the data, but also the possibility to filter data in order to allow the user to concentrate on specific data of interest and, finally, to provide details on demand. Thus, the tool first shows an overview of routes of many shipments and provides filters to refine the visualized data in order to support the data analysis process. The user activates filters by modifying the value of

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various attributes, related to tracking (e.g. order date, delivery time, customer code), vehicles (e.g. transportation company, vehicle code, vehicle characteristics), load (e.g. weight, packaging, items no., product type), and delivery (e.g. address and location, date and time). Details of specific item are provided if the user requests them.

Next section briefly reports some related works about visualization of mobility, traffic, space and time, including also time series and process visualization. Section III presents the developed tool. Section IV concludes the paper, also highlighting some future work.

II. Related Work

To the best of our knowledge, logistics companies do not use advanced visualization to analyze data. They often use software systems whose outputs show icons overlaid on geographic maps, in order to indicate the position of a vehicle and provide information such as the status of vehicles (stopped, moving, broken, …).

Many works in the literature focus on mobility data, which refers to objects that change position during time. Movements can be represented as continuous paths in space that are also movement in time. Such continuous paths can also be seen as a composition of various spatial events [7]. A given path can also be enriched with additional data, such as the carrier and the cost for the shipment.

About traffic data visualizations, Chen et al. presented a survey that illustrates basic concepts and focuses on methods that address temporal, spatial, numerical and categorical properties [8]. In the survey, data are classified as location-based (where an object is detected), activity-based (what the object is doing), device-based (what is generating the data). The survey focuses on trajectories and incident visualization.

Time dependent data can be visualized in different ways, according to analysis goals and data characteristics. For instance, a visualization can be appropriate if the periodicity is relevant (in case anthropic activities or seasonal factors are important), while a completely different visualization is needed if time is considered as a continuous entity. Several proposals consider the periodicity, identified with radial [9] or spiral [10] visualizations. Many others visualize time linearly, often using line charts, which, however, are not very good in dealing with multivariate data. A survey on the most well-known visualization techniques for time-dependent data has been performed in [11]. The problem with multivariate visualization has been addressed in various ways. As an example, TimeSearcher adopts multiple panels, stacked and aligned according to a timeline in order to highlight correlations of the studied phenomena [12].

Abstract representations are well suited for visualizing process; the technique in [13] uses block diagrams to visualize supply chain data.

Many visualizations proposed in the literature have some issues that prevent utilization by potential users. Russell performed a study on a company that uses big data every day in order to improve its service [14]. The goal was to understand how such proposed visualizations are used today for analytical purposes. This study showed that new Information Visualization techniques are perceived useful in the investigation phase of research, but they appear to be peripheral to everyday work in companies. Among the reasons of such low adoption in working practice, there is the difficulty of preparing data for the visualization. This suggests that designers and developers should produce visualizations that, rather than being appealing, first and foremost are easy to understand and easy to use by the intended users. Even with simple representations, it is possible to perform good analyses. The example of the data table presented in [14] is very simple but it is well suited for the analysis it has to support.

III. The visualization tool

The goal of the work reported in this paper is to produce a simple, easy and immediate analytical tool that can display transportation information very quickly in order to support data analyst in their daily work. According to the Shneiderman's mantra [6], the tool provides an overview of available transportation routes on a geographic map, a set of filters to reduce the dataset to the item of interest and details of the visualized data, if required. As a case study, this paper presents data about shipments of a company in South Italy in 2014.

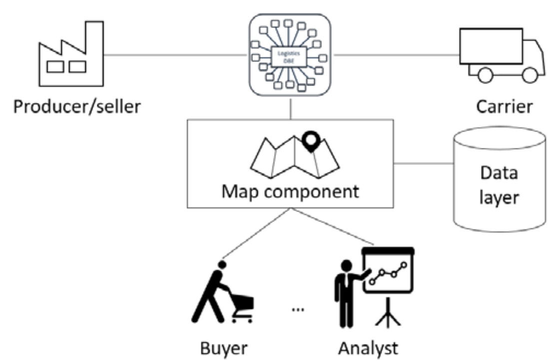

Figure 1. Simplified schema of the tool architectural organization.

Figure 1 shows a simplified schema of the tool architectural organization. Stakeholders interacting with the tool are represented at the bottom part of the schema, for example, a customer that buys a product and wants to keep track of the order, or an analyst who wants to find information about deliveries. *Map component,* a module that is part of *Logistic DBE*, allows the users to interact with the map and data represented on it. The map is visualized using OpenLayers libraries [5]. The *Logistic DBE (Digital Business Ecosystem)*, represented in the middle at the top of the schema of Figure 1, is the overall logistics system developed in the project, which stores information about logistics stakeholders, such as customers, carriers, producers, and service providers, for various activities. The DBE consists of many modules; its complete description is out of the scope of this paper. One of the core components is the EDI (Electronic Data Interchange) that allows various components to communicate in different formats, means, and modalities.

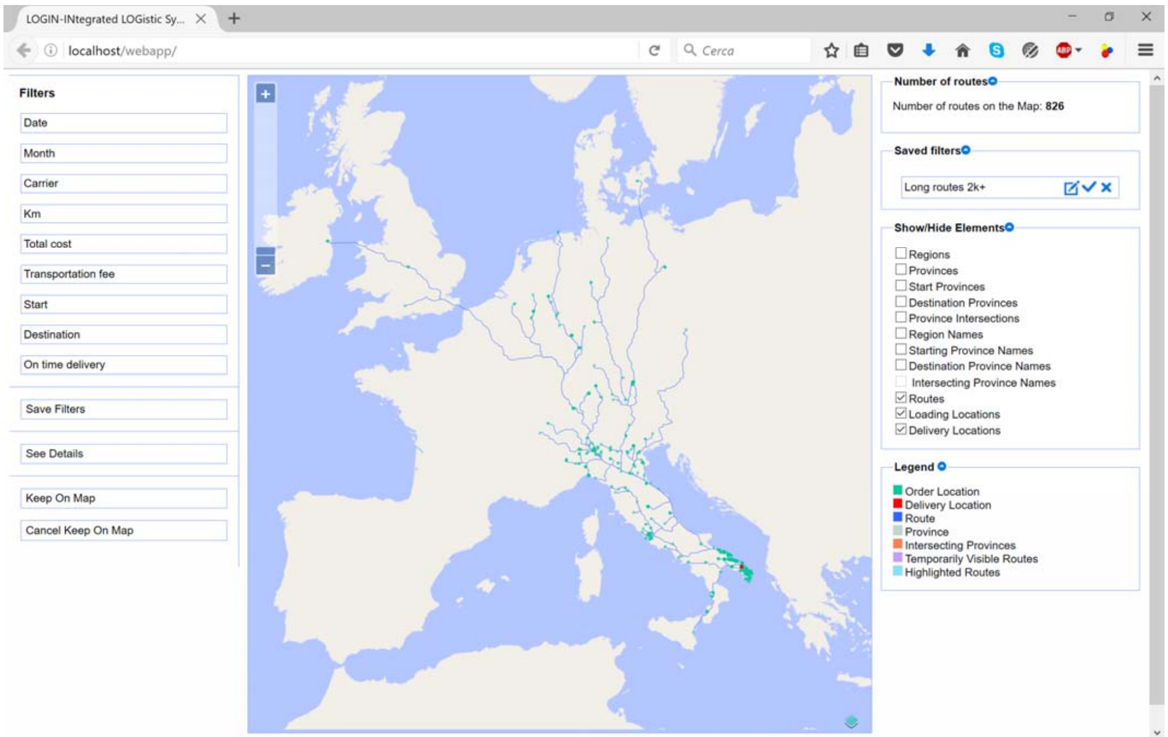

Figure 2. Overview of the transportation paths. A number of filters allow the analyst to select needed information.

Carrier (Figure 1) indicates companies that provide the service of shipping goods from the producer to the customer. Each vehicle sends information about the position and metadata of the transportation, in order to allow vehicle and good tracking. Vehicles send to the *Logistics DBE* data such as vehicle ID, timestamp, geographic coordinates, and data related to the sensors on board of the vehicle. Such sensor measurements can be related to temperature, solar radiation, humidity and other parameters relevant for the transported goods.

Producer/seller are the companies that offer products to the market and ask logistics solutions to the Digital Business Ecosystem.

One of the goals of Information Visualization is to help users forming their mental model about data. When dealing with geographic data and routing, it is quite obvious to show data through maps. Maps are used in transportation companies to have a clear idea about the position of their vehicles. During the project, we made on-site visit to transportation companies. We found that they use different tools for monitoring real-time conditions and traditional visual techniques are used to analyze historical data. An example is the use of histograms to visualize the time spent by a given driver on a vehicle. The analysis of the routes taken by the companies, however, were performed through specific queries to their database, with no support of any visual tool. The goal of the tool described in this paper is to help analysts to amplify their knowledge on data. Route data and layers for the representation of countries, borders, cities and other geographic information are stored in the *Data layer* (Figure 1).

The example reported in Figure 2 relates to the routes of different transportation companies that operated for a company that sold wine in the year 2014. Areas served by such company are immediately visible; in fact, the wine company works very much in South Italy, more specifically in the Apulia region. Many shipments go to Rome, Milan and other cities of Italy. The company has clients also in Europe and the routes mostly spread vertically leading to North. It is immediate to see that Spain and France are not part of the sale market of the company. The company does not even sell products to Sardinia and Corsica islands and performed just one single delivery to Sicily, namely to Catania.

On purpose, the map has a light solid colour, in order to avoid distracting the analyst with useless details. Region names and other details are shown on demand.

As visible in Figure 2, the user interface is divided in three main parts: the left panel contains a list of filters and operations to perform on selected data; in the middle, the map is shown; the right panel contains visualization options and the legend.

Available filters depend on the attributes in the company dataset (see left side of Figure 2). In particular, *Date* allows the user to select an interval of dates of interest. If the user wants to see all shipments that occurred, for instance, in March and in September, he or she should use the *Month* filter that allows him/her to select noncontiguous months. *Carrier* is a searchable list of companies that provide the transportation service. Once selected, the user types a few character of the company name and the list narrows down, according to the typed characters. More than one transportation company can be selected. Figure 3 shows the selection of *Mail Boxes* and *BRT SpA*; consequently, all routes performed by other companies are removed from the visualization.

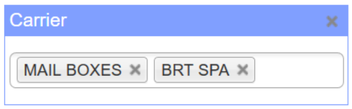

Figure 3. The Carrier filter shows the selection of two companies

Km filters all routes that satisfy the specified minimum and maximum distance between departure and destination. To set such values, the double slider shown in Figure 4. A double slider component filters all routes whose lengths are between 400 and 1320 Km. is used; in the shown example, the user selected all routes whose length is between 400 Km and 1320 Km. The extremes of the interval depend on the available dataset. In the case reported in Figure 4, the maximum distance is the destination to the Dublin area (Ireland), which is 2840 Km long. The use of a double slider is also appropriate for *Total cost* and *Transportation fees*, since they allow visualizing only routes whose total cost and transportation fees, respectively, are between minimum and maximum values specified by the user.

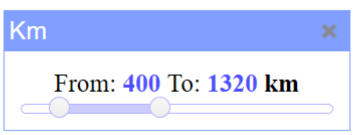

Figure 4. A double slider component filters all routes whose lengths are between 400 and 1320 Km.

Start and *Destination* filters are similar to the structure of *Carrier* filter, and are used to specify starting and destination locations. *On time delivery* filters only deliveries that are on time.

Save Filters saves the current filter combination for later use. Once selected, the user can leave the default value or he/she can assign a different name to easily remember it. In the example of Figure 2 there is one saved filter, available in the box *Saved Filters* on the right column and named by the user as "Long routes 2k+", meaning that the filter shows only routes longer than 2000 Km. When the filter is selected the visualization changes according to the parameters specified in the saved filter. The user may modify and delete the saved filters.

See Details is not a filter but once pressed, it shows the data in a tabular format. This is a common request made by the users, which do not completely believe in visualizations and want to see their data. It is also mentioned in the Shnederman's Mantra (details on demand) [6].

The user may also want to keep routes to make comparisons with other filter combination. *Keep on Map keeps* the current filter combination and shows the routes with another color in order to compare this with another selection. For instance, one may want to compare the routes made in the month of January with those of June. The button *Cancel Keep on Map* removes such temporary selection.

The *Number of Routes* box at the top of the right column in Figure 2 indicates the number of displayed routes.

As stated before, in order to avoid user overloading, the visualization initially shows the routes on the map with few details (see Figure 2). The user, depending on his/her needs, can operate on the parameters in order to see details of interest.

The *Show/hide Elements* panel on the right of the screen in Figure 2 contains buttons that give the possibility to visualize/hide elements on the map.

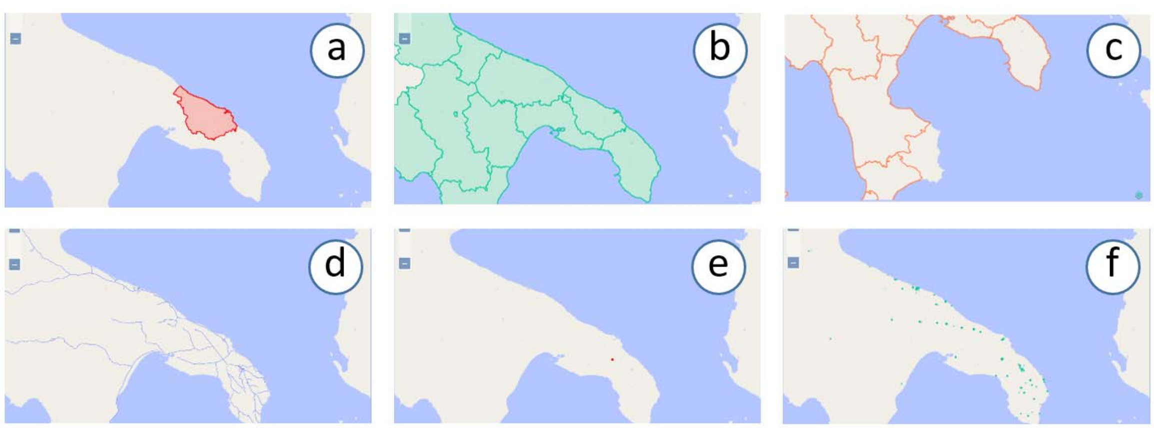

Figure 5. Different layers displayed on screen: a) province of the route starting point; b) provinces of destinations; c) provinces intersected by at least one route (routes are not visible); d) routes; e) route starting point (only one in this example) and destination cities.

Figure 5 shows some outputs generated after clicking on buttons in the *Show/Hide elements* panel: selecting the checkbox *Start Provinces* generates the output in Figure 5a, in which the starting locations (only one in this case) are shown; selecting the checkbox *Destination Provinces* generates the output in Figure 5b, in which the delivery locations are shown. selecting the checkbox *Province Intersections* generates the output in Figure 5c, in which the locations intersected by routes; selecting the checkbox *Routes* (selected by default) generates the output in Figure 5d, in which routes are shown; selecting the checkbox *Loading Locations* generates the output in Figure 5e, in which starting locations (only one in this case) of the routes are shown; selecting the checkbox *Delivery Locations* generates the output in Figure 5f, in which delivery locations of the routes are shown.

Figure 6 shows the visualizations of Figure 2 in which it is applied a zoom on Italy. With respect to Figure 2, several details are shown, including the borders of Provinces. The user can easily see that many provinces in Italy contain destinations with at least one delivery. Thirteen provinces that do not include destinations are crossed by routes. These areas should be further investigated in order to understand why there are no clients in such provinces. The dataset used for this example refers to a company that produces wine in the South Italy; it is evident that most of the clients are Italians. This company also sells products in Europe, even if there are very few delivery destinations (about 30, see Figure 2).

IV. Conclusions and Future Work

This paper presented a tool whose goal is to provide visualizations that help analysts of logistics data in understanding such data in order to provide a support for making decisions. The tool has been developed as part of a bigger system, composed by many modules, which aims to support companies in improving their product offer for their potential clients. In the design of the tool, Shneiderman's mantra [6] as well as suggestions to provide simple representations [14] were the guiding principles for generating a visualization that can be useful for its users.

The described tool could be enriched with other visualization techniques, which can reveal different aspects of data in order to increase user knowledge. One possibility can consider abstract routes instead of positioning them on the map. This could open to more possibilities for comparison, ordering and visualizing according to various attributes.

The tool has been developed on the basis of a User-Centred Design [15]. Informal tests with a few users were performed to evaluate the various tool prototypes. More formal user tests are planned in the future, involving domain experts; we expect to find indications in order to fine tune the present features and identify further useful feature to be implemented.

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Figure 6. Various elements visualized on the Italy map

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