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Open Street Map for Multi-Modal Freight Transport Planning

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1 ABSTRACT

Route planning for transportation of goods is an essential task. Determining a route for e.g. a truck is simple if the road network including the legal and technical limitations like truck ban or weight restriction are known. Planning of multi-modal routes is a bit more complex. The change of mode of transportation is only possible at specific locations. This change takes time and is often subjet to additional technical or legal restrictions. Thus the different networks, e.g., road and rail, need to be connected.

An obvious approach for multi-modal transport planning would be the use of Open Street Map (OSM) data since it does not only contain information about roads but also about trains and rivers. In this paper we first present some existing solutions for multi-modal transport planning and then discuss the use of OSM data in such a process. We identify missing elements in OSM and show opportunities for further development and interventions.

2 INTRODUCTION

Transport of persons and goods is an important part of current business. Production centres are distributed around the globe and exchange of goods from raw materials to finished products is essential. Within cities the transport of persons between the residential areas and the place of work is equally important. A number of different modes of transportation is available to solve this task. The simplest form from an organizational point of view is individual (motorized) traffic. However, the maximum amount of individual transport is restricted by the capacity of the road network. Thus, especially in cities and other densely populated areas, other forms of transportation are necessary. In case of transport of persons this is mainly public transportation: Busses, trams, subways, trains, ships, airplanes, etc. There are different modes of transport for goods as well. The counterpart for individual traffic is transportation by trucks. Other possibilities include ships, trains, and airplanes. The advantages of individual traffic are flexibility and speed. Other modes of transport are less flexible and take more time but are more energy efficient and thus cheaper.

Transportation is also a basic requirement for modern economy and society. In Europe, 10 million people are directly working in the transport industry and this branch is responsible for 5% of the gross domestic product (EC, 2011). Transportation in general includes both, transportation of people and transportation of goods. Passenger transportation is the process of moving people from one point to another point, while freight transportation moves goods. The major difference between these two types is that passengers are assumed to have cognitive abilities, i.e., if something does not work as planned, passengers will collect information, make a decision, and move on with the trip. This is not the case for freight. In the remainder of the paper we will concentrate on freight transportation, however some of the examples used for illustration deal with passenger transport.

There are numerous factors affecting movement of goods. Ortúzar (2011, p.463) lists the following:

- location factors (dependency on source materials),
- chain of dependencies,
- physical factors of goods (e.g., steel vs. milk),
- operational factors (e.g., company size and internal regulations),
- geographical factors (e.g., population density),
- dynamic factors (e.g., seasonal changes), and
- pricing factors (usually not published like with passenger transport).

Not all of these factors are of importance to this paper. The factors discussed here are geography and dynamic changes. Topology of networks are part of the geographical factors and route planning tools depend

on correct topological relations. Another important aspect is scheduling. Trains, ships and ferries have specific timetables and are not available on a continuous basis. This is one of the dynamic factors of freight transportation. There are numerous others like, e.g., weather (e.g., Litzinger et al., 2012) or traffic (e.g., Partusch et al., 2014) but these are not subjects for considerations in this paper.

There are different modes of transport like roads, railways, airways, and waterways. Nowadays, a large part of transportation is road-based. According to Eurostat (2013), the modal split between roads, railways and inland waterways between 2000 and 2011 has been fairly constant at 5% inland waterways, 20% railways, and 75% roads. Since the total amount of transportation is still growing, the traffic density on the roads is increasing unless the modal split changes or road capacity is increasing. In order to avoid problems with traffic density, adopting other modes of transportation should be promoted.

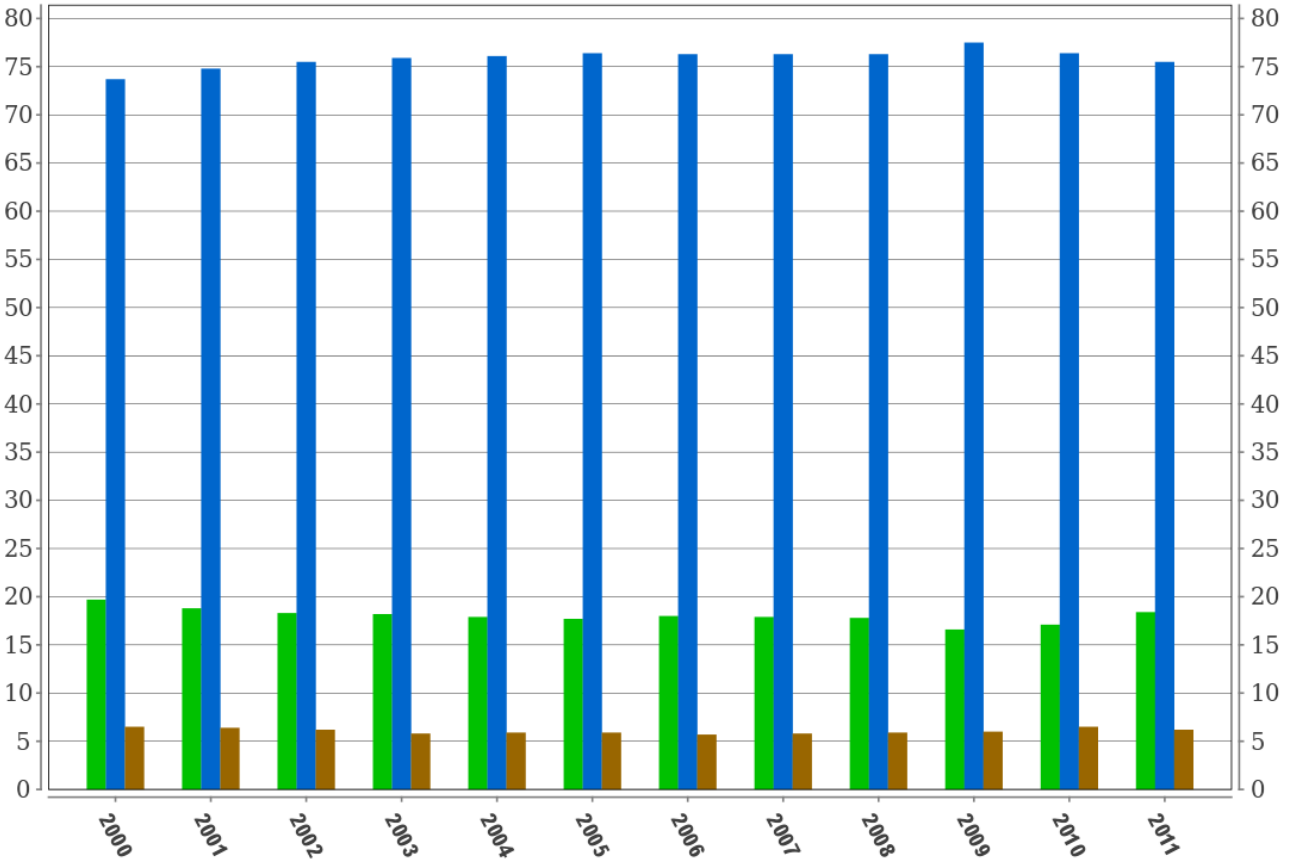

Fig. 1: Modal split of freight transport in the EU27-countries between 2000 and 2011, units display the percentage in total inland freight tonne-km (Source: Eurostat[1])

Literature distinguishes between monomodal transportation and multimodal transportation (Macharis & Bonekoning, 2004). Monomodal transportation denotes the case when only one mode of transportation is used. An example would be the transportation of goods directly from their origin of production to the processing facility without changing the means of transportation along the way. Multimodal transportation combines at least two modes of transport, e.g., by truck to the railway station, then by rail to the port, etc. A variant of multimodal transportation is intermodal transportation where the transportation vehicle itself is transported, e.g., by putting the truck with the freight on a train or vessel. This work deals with multimodal transportation and ignores the difference between multimodal and intermodal transportation.

The paper is structured as follows: In section 2 we discuss the basic properties of multi-modal transportation and the planning thereof. We introduce the concepts of Open Street Map (OSM) in section 3 and show the implementation of multimodal transportation planning in section 4. In section 5 we discuss the problems of this approach. Some remarks then conclude the paper.

[1] http://epp.eurostat.ec.europa.eu/tgm/graph.do?tab=graph&plugin=1&pcode=tsdtr220&language=en&toolbox=data

3 MULTI-MODAL TRANSPORT PLANNING

Transport planning has the goal to find an optimal route of transportation where the optimality criterion can be time, price, security, simplicity, etc. The difference between security and simplicity can be tricky: A simple route consists of a small number of different segments or a small number of turns (compare Duckham and Kulik, 2003). A secure route provides the highest protection against problems like piracy.

It is obvious that freight transport planning is more complex than individual trip planning because there are more variable parameters. Goods need to be declared and depending on the route, different goods may not be allowed. Also, some modes of transportation may not be feasible for some types of goods. Finally, quantitative differences in freight transportation are much more relevant than in passenger transportation.

The basis for any route planning application is

- a routable graph,
- a routing engine, and
- additional (real-time) data.

The routable graph defines the available connections and their static properties. If there are different graphs, it is important that connections between these graphs are modelled. This is necessary, for example, if national data sets are used because the connections at the national boundaries are essential for transnational routing. The same is true for multimodal routing. The additional data then models the variable properties of the graph. Some links may operate on a specific schedule. A ferry, for example, is only available at specific times. Other information may include winter closure, restrictions due to maintenance work, or temporary unnavigable river segments.

There are several routing algorithms to find an optimal path in a graph. Sanders & Schultes (2007) explore some of them and also give some estimates on strengths and weaknesses in special scenarios. One of these scenarios is transportation with time-dependent edge weights that becomes relevant when dealing with scheduled multimodal transport systems. Algorithms that, e.g., use a bidirectional search for optimization become unusable when there are time dependencies in the graph.

According to Rodrigues et al. (2013, ch. 3), modes of transportation include

- road,
- rail,
- pipeline,
- maritime,
- air,
- intermodal, and
- telecommunication.

Not all modes are relevant in the context of this paper. Telecommunication is a special case because several copies of the same data could be sent on different paths to determine the fastest connection. This is not easily feasable for freight transportation. Pipelines are special cases as well, because they only work with specific types of goods. The other modes may be relevant.

All modes except two are restricted to graphs These exceptions are air and maritime. Maritime transportation is only bound to a pre-defined network if it occures on rivers and air traffic is (at least theoretically) not restricted to a graph at all. Theoretically, air traffic, from a logistic point of view, is defined by airports and there is a possible connection by air between any two airports. This is not necessarily true for the other modes of transport, since, e.g., two railway stations may not be connected by rails if they lie on different continents.

4 OPEN STREET MAP

The OpenStreetMap project was started in 2004 by Steve Coast and is commonly described as the wikipedia of maps (Ramm et al., 2010). A superficial but sufficient introduction to the way data is stored in OpenStreetMap is the following: Real world entities can be entered into a publicly accessible database.

These entities are assigned attributes by a number of loosely defined key-value pairs, so-called “tags”. A street, for example, is identified by a tag called “highway” which is also the key to a possible value of “primary”. This would denote a main road. Any entity can have as many tags as necessary to sufficiently describe it.

In addition to simple geometric objects it is also possible to group single entities to “relations”. These are ordered lists of entities which can themselves have tags assigned to them. It is therefore possible to describe the route of a bus by a sequence of single streets. Relations are widely used when dealing with non-physical entities like bus lines which are composed of many single roads and stops.

4.1 Street Network

While the origins of OpenStreetMap lie within mapping the network of streets, no bias towards an intended purpose is given. This explains the dominance of streets besides buildings and the commonly applied “source” tag (which denotes the source a mapper has collected the information entered into the map, e.g. an aerial photography or GPS device) in contrast to the variety of other information that can be found in the OpenStreetMap database (see figure 2).

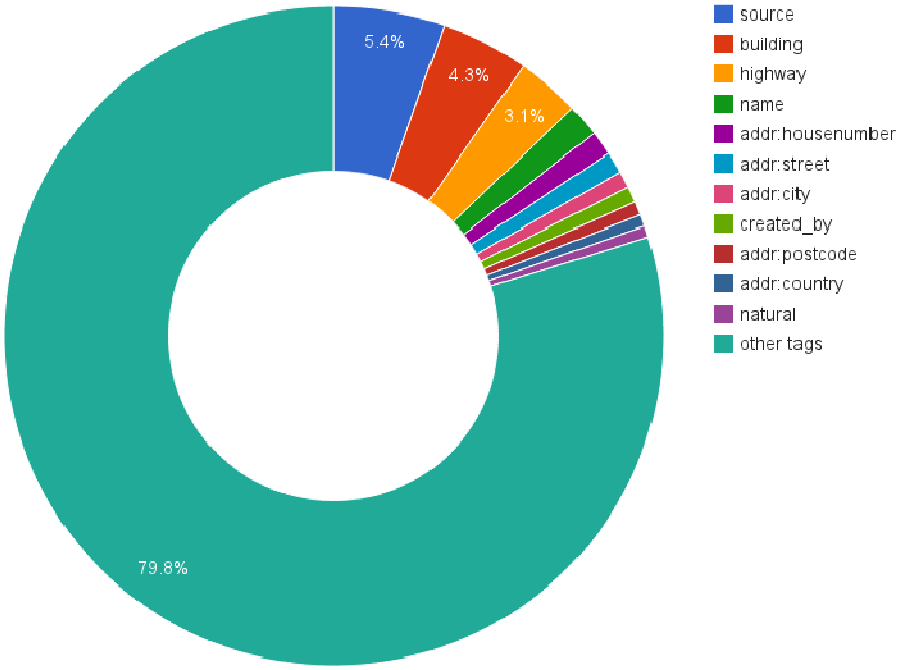

Fig. 2: The most often used tags in the worldwide database of OSM (Source: Topf, 2012)

Following this, there have already been done several analyses of the quality of the street network. These attest a good quality of the mapped streets. Ludwig (2010) shows that main-roads correlate up to 90% with her comparative dataset in German cities while this correlation drops rapidly when moving to more rural regions. Haklay (2010) was able to detect an overlap with administrative data of up to 100% of high ranked roads in five areas in London. Graser et al. (2013) did an analysis of the street network around the city of Vienna. Their findings include that when dealing with streets of high order there are less errors in OSM as well as in her comparative administrative dataset.

It is usually possible to generate a routing graph from OpenStreetMap road data with little effort (e.g. by using the pgRouting tool (pgRouting Community, 2014)). While it is more difficult to include more advanced rules like turning restrictions into a routing engine it has already been done by several services (e.g. a routing application for Android Smartphones (OsmAnd Community, 2014)).

4.2 Relevant Elements of OpenStreetMap

4.2.1 Railways

Railways are easily mapped since they do not occur as often as streets and feature a more constant linehaul. Stops and stations along the tracks can be mapped but usually do not contain additional information about whether it is possible to transfer goods at this location or not

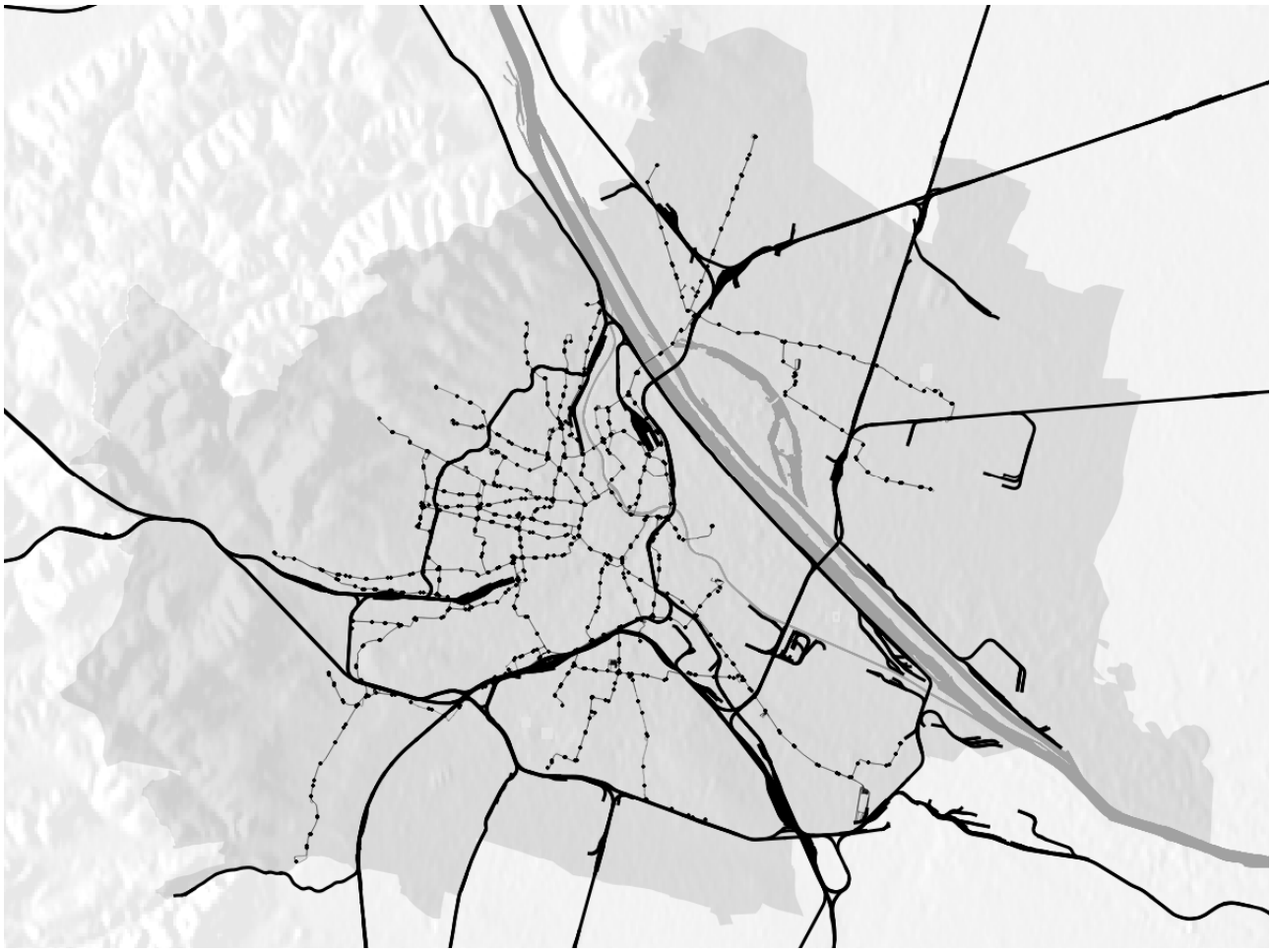

Fig. 3: Railways (thick black lines), Trams (thin black lines) with their stops (black dots) and the river Danube (thick grey lines) mapped in OSM in the area of the city of Vienna (grey area)

4.2.2 Aircraft

Whilst aircraft routes are not mapped, the infrastructure supporting airborne transportation is. These are airports, terminals, storage buildings and runways, to name only a few. A special case is the airport of Vienna where the OpenStreetMap community was provided with official, highly detailed maps of the airport to map it as accurately as possible (Schweikert, 2013).

4.2.3 Water/Ferries

There are many ways to describe water in OpenStreetMap. When dealing with a water surface one uses the tag “natural=water” while flows are mapped with the key “waterway”. The accompanying value describes the extent and size of the the flow (e.g. “river”, “stream”, …). Additionally to that it is possible (but not used very often) to give details about the maximum allowed draught, size and speed of ships and other official information like the European river classification for navigable waterways (European Conference of Ministers of Transport, 1992).

Ship lines, when they do not represent ferries, are not mapped explicitly since they can be easily deferred from waterways.

Ferries are mapped as lines along which a ferry operates. Also, the entry and exit points of a ferry can be mapped and may have attached more information about what is allowed to be transported.

4.2.4 Connections

Connections between single lines of travel are important when dealing with navigation. They symbolize situations where a traveller can switch to a different path.

When two lines share a common node in OSM, they intersect. Non-material entities like tram routes are represented by relations as was explained before. When it comes to more complicated scenarios like turning

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restrictions so-called “turn restriction relations” are used. This is a special kind of relation that lists the street from where to where and via which point or street a vehicle is or is not allowed to go. These kinds of relations are well proven and pose no problem with monomodal routing information.

When it comes to multimodal route planning, locations of intersection of different modes of transportation where goods or persons can be interchanged need to be mapped. Stops of various means of transportation are designated by a single tag named “public_transport=platform”, usually assigned to an area. This tag is common to multiple different types of transportation. They also may be part of a relation (tagged as “public_transport=station”) containing elements describing different modes of transportation. By utilizing this relations, an intersection between different modes of transportation can be constructed. It is even possible to specify details on whether a certain means of transportation supports freight transfer at this location or not.

A simpler variant which is in use quite commonly is to just connect the end-points (or intersecting points) of ways from different modes of transportation to one another. But this poses some difficulties when e.g. there is no direct connection between two modes of transportation and the line connecting these is mapped by a footway. Where to put additional information about the intersection like e.g. weight of goods to be transported? Also, a simple footway may beneficial to the structural integrity of the graph but not to its cartographic representation.

4.3 About Vienna

To give a better understanding of the quantity of information one is dealing with when looking at Vienna, some numbers are presented here. These data was computed from an OpenStreetMap extract of the Vienna region from Migurski (2014) after it was clipped to the exact extent of the city of Vienna.

On the 18.02.2014 there were 139 railway halts, 270 railway stations, one airport, two ferries and one harbour mapped in Vienna. Waterbound transportation routes other than ferries are not mapped explicitly but can be deferred from rivers.

5 MULTIMODAL TRIP PLANNING APPLICATIONS

There are a number of products for multimodal transportation planning. The most important systems used by Austrian companies are:

- FLAVIA (Raicu et al., 2011)
- LAMBIT
- European Intermodal Route Finder
- AnachB (Heimbuchner K., 2011)

Some of these systems, like FLAVIA, have been developed by universities, others, like AnachB are developments of public service providers. Basic graph data from various sources are used for all mentioned systems: TeleAtlas, NAVTEQ, public administration, and OSM. One of the typical bottlenecks is real-time information. Although FLAVIA, for example, is an online system, it does not connect to data sources providing information on aspects like traffic congestions. This needs to be dealt with in the future. One of the emerging problems is the availability and harmonization of these data.

AnachB is currently the only system that can incorporate these data. However, it is currently restricted to the eastern part of Austria. Data integration is based on the graph integration platform (Kollartis S., 2010), a common nationwide road graph. Since it was designed as an Austrian system, it is questionable if it can be opened for other countries without significant adaptation.

An OSM-based multimodal system is Open Trip Planner. It was developed by the National Center for Transit Research of the University of South Florida. The open trip planner is a tool enabling multimodal trip planning only for individuals (Hillsman & Barbeau, 2011) and is displayed in figure 4. There have been performed extensive analysis of how to integrate OSM into the tool (Hillsman & Barbeau, 2011; McHugh, 2011). While it is optimized for personal transport, it is still possible to identify various points in their study that are also valid for multimodal freight transport planning.

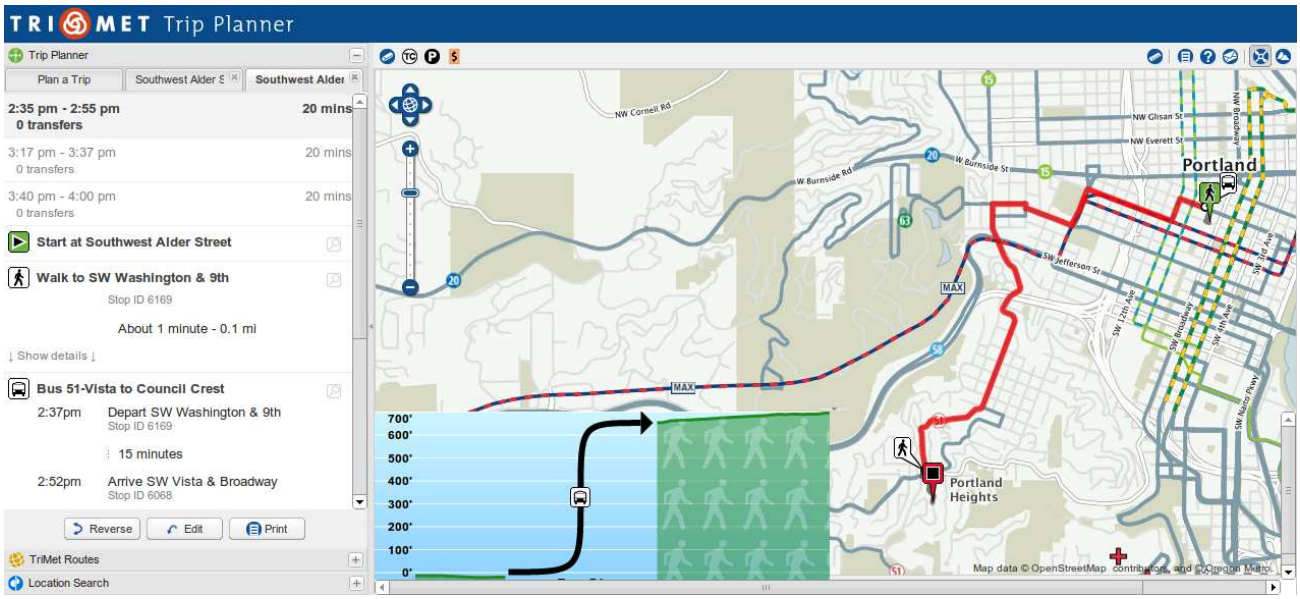

Fig. 4: An instance of Open Trip Planner (source: TriMet)

The most important finding was that they call “Implementing a multimodal trip planner using open-source software and open sources of data is very feasible” on page IX. The creators also denote that OSM alone is not capable of storing all relevant information in its database because this would be too impractical. Instead, they propose the use of the open GTFS (“General Transit Feed Specification”) (Google Developers, 2012) to synchronize existing data from OSM with schedule information. The Open Trip Planner goes even a step further by using GTFS files as its primary data source which means that a certain amount of OSM information has to be converted.

6 WHAT IS MISSING IN OSM

Looking back at the previously defined prerequisites for and implementations of a working multimodal (transport) planning system it is now possible to identify components of the OpenStreetMap project that prevent the exclusive use of OSM data for a multimodal freight transport routing system.

6.1 Concerning the graph

While it is an easy task to operate on graphs from different modes of transportation from the OSM database, it is more difficult to connect these graphs with one another. The existence of a tag describing areas of access to public transport facilities (“public_transport=station”) may serve as a blueprint for a more general scheme describing intersection points. Information about how long to wait with a certain amount of goods for a specific connection can be added to this areas.

Hillsman and Barbeau (2011) observe that certain data is too difficult or even hazardous to collect for non-professionals. This includes data on volumes of vehicle traffic, width of lanes, operating characteristics of signals to just name a few. This is a point reached where OSM data alone is not sufficient enough by quality.

Another important point made by Hillsman and Barbeau (2011) is that OpenStreetMap is not mapped with equal detail in every location. It is necessary to motivate users to map essential features and explain the requirements for multimodal routing to the community.

6.2 Concerning real-time data/schedules

There are ongoing discussions on community mailing lists of the OpenStreetMap project about how much attributive information should be inserted into its database. Leaving this very subjective matter aside, it is simply impractical to a point of impossibility to store extremely short-dated real-time information inside the OSM database. OSM is not suited to hold all information of this kind because of the quantity and frequency of real-time data.

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6.3 Concerning route-planning

The OpenStreetMap project itself does not provide any routing algorithm, but there exist multiple OpenSource projects that take over this part. These ranges from implementations as web services to stand-alone solutions which are integrated in desktop GIS (e.g. Corti et al., 2014, chapter 6; Furieri, 2011).

Little is left to say about this cornerstone of multimodal transport planning in this context since routing is not a problem OpenStreetMap is intended to or is able to solve on its own.

7 CONCLUSION

In this paper it became clear that the OpenStreetMap project alone can not solve the problems arising from multi modal transport planning on its own. While OSM is a valuable contributor, its database lacks functions and descriptive powers necessary for state-of-the-art multimodal transport planning. Table 1 gives an overview of the aspects missing in OSM.

Type	Description of missing information	Example
Quality	missing information that can not be gathered	volume of traffic, storehouse capacity
Frequency	information that is changing too often	real-time data on usage
Quantity	information that is too specific in relation to its size and geometric reference	train schedules
Availability	service that is not provided	routing algorithm

Table 1: Four points why OSM alone is not sufficient for multimodal transport planning

Hillsman and Barbeau (2011) have proven that it is possible to synchronize OSM data with databases from other sources to compensate for the information missing which would account for missing information of the type frequency and quantity (according to table 1).

Crucial elements relevant for multimodal route planning are locations where two or more different modes of transportation intersect each other. This can be mapped but users have to do so. Information too difficult or impossible for private individuals to collect may be entered by experts or has to be provided by a specialized database. This accounts for problems about quality.

What can be seen is that the problems identified are not unique to OpenStreetMap but are also valid for commercial datasets. The solution most general to most of the problems is about combining different datasets to receive all the information needed. The challenges of this synthesis are a chance for OpenStreetMap to prove its flexibility and openness. Theses two attributes turn OSM into an ideal candidate for research and development in the field of multimodal transport planning.

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