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Line Graph Utility
A software module for routing

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Abstract

This project was about building a line graph utility, a software module that should read map data from a PostGIS database and transform that information into a line graph (edge based graph) that the calling software could use to perform routing decisions. This outer calling application is part of a project (by an anonymized company) for flexible public transportation, that is meant to manage and direct a fleet of vehicles to where the customers actually are, instead of idling at bus stops. The software module should take different kinds of restrictions and conditions into account when building the line graph, to reflect the actual traffic situation. That can be turn restrictions, traffic signs, inclination, or conditions such as temporary hindrances, time of day. Some are static, but others vary dynamically and the state is to be found in the database.

This study has found a set of tools that aids in the transformation of OpenStreetMap data into a PostGIS database; for building the topology of the map; querying the database; and data structures for representing the graph and line graph.

The result of the project is a piece of working software that can return a line graph as a Boost graph with some restrictions taken into account, but it has not yet implemented them all, and more specifically, it does not handle conditional restrictions yet. There remains a good deal of work to implement all that complex logic.

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1 Introduction

The work presented in this thesis is about flexible routing of public transportation. The result of the work is a software module that loads map data and converts it into in-memory data structures that can be used for routing decisions by exposing an *API*, (Application Programming Interface). This module is part of a bigger transportation optimization system that is meant to enable flexible public transportation solutions.

The module will be used for finding efficient routes in a dynamic traffic environment, i.e. the complete solution must take turn restriction, traffic lights and road signs into account. The outline of how to do this is by loading map data from *OpenStreetMap*¹ into a database (*PostgreSQL*² extended with *PostGIS*³). Upon a request directed to the API, the module should build (with soft real-time requirements) a data structure suitable for passing to a routing algorithm.

1.1 Background and problem motivation

The company (*anonymized*) aims at developing a solution for managing *flexible* public transportation, meaning no more buses standing idle and empty at bus stops, waiting just in case another bus fills up. The buses can be directed to where they are needed, and part of the solution is finding the best routes and give directions to the drivers where they should go. The public does not need to wait at bus stops, but can ask for pick-up via a mobile app.

There can obviously be huge benefits from such a transportation system. Less vehicles are needed, and better utilization of the vehicles, which should be good both for the environment and the finances of the operation. The public should also benefit from having access to public transportation where needed, and not from fixed locations.

Central for such a system is efficient routing of the vehicles, with almost instant updates on restrictions made available to the drivers needing directions. This project is a small piece in that puzzle.

1.2 Overall aim

This project should result in a working software module, fulfilling the requirements set by the company. There is needed some preliminary studying of graph theory, data structures, and research into what theories and solutions that already might exist, and if so, if they can be adapted and used in this project.

1.3 Scope

The scope of this project is to create the routing data structures representing the map data, not the routing algorithms, although they might affect one another, such that the choice of algorithm might affect what data structures are suitable.

1.4 Detailed problem statement

The software in this project is a module, exposing a function. When the function is called, it should load map data from a database, which has previously been loaded with OpenStreetMap-data, and build a connected graph to be used for routing decisions, and the data structure is returned to the caller so it can be used for routing. The building of the graph should happen in *soft real-time* so that it reflects all known restrictions in the database. For example if one

¹<http://www.openstreetmap.org>

²<http://www.postgresql.org>

³<http://postgis.net>

road gets temporarily closed it should be marked as such, and that should be represented in the graph.

The requirements from the company states that the graph should be represented as a *line graph*, which is a basic technique for representing available turns at junctions. The software module shall be implemented in C++, using the *Boost Graph Library*⁴ for the data structures. The software should be developed using *Behavior Driven Development* (BDD) or *Test Driven Development* (TDD) as methodologies, and otherwise adhere to the company's coding standards.

1.5 Outline

- Chapter 2 will present some background on graph theory, and research in map routing, regarding both theoretical foundations and some available implementations.
- Chapter 3 shows the methods and tools used.
- Chapter 4 is about the design and implementation of the software module.
- Chapter 5 presents the results from testing the implementation.
- Chapter 6 will include some discussion and conclusions made during this project.

1.6 Contributions

The work presented in this report is the sole work of the author.

⁴http://www.boost.org/doc/libs/1_54_0/libs/graph/doc/index.html

2 Related work

One of the first applications of *graph theory* was when *Leonhard Euler* considered the *Königsberg bridge problem*: Is there a way to walk over the seven bridges of Königsberg only once?

It is trivial to see that there is a close correlation between graphs and maps, as you can see in figure 2.1, with the roads and junctions in the map being lines and dots in the graph. A line is mostly called *edge* or *arc* and a connecting dot is called *vertex*, *node* or *point*; in this report it will mostly be *vertex* and *edge*, but to differentiate, another type of graphs called *line graph* will use the names *node* and *line* to distinguish. As one delves deeper into the theoretical material, one will find that there is good to know some *graph theory* and be familiar with some definitions.

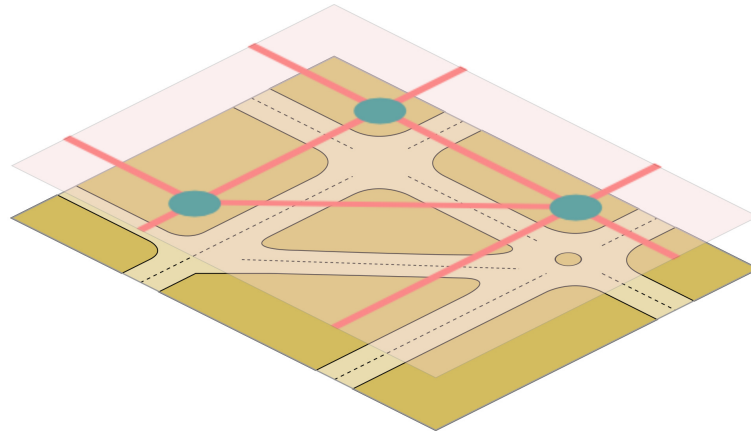


Figure 2.1: Graphs and road maps are a natural match.

2.1 Graph theory

There are good lecture notes such those from *Tampere University of Technology* [1] and *University of Turku* [2] (both happen to be Finnish) and a good text book by *Reinhard Diestel* [3] are available to get into this subject. One does not need to understand all the concepts, but be familiar with some basic definitions and notations.

A *graph* is made up by *vertices* and *edges*, see figure 2.2.

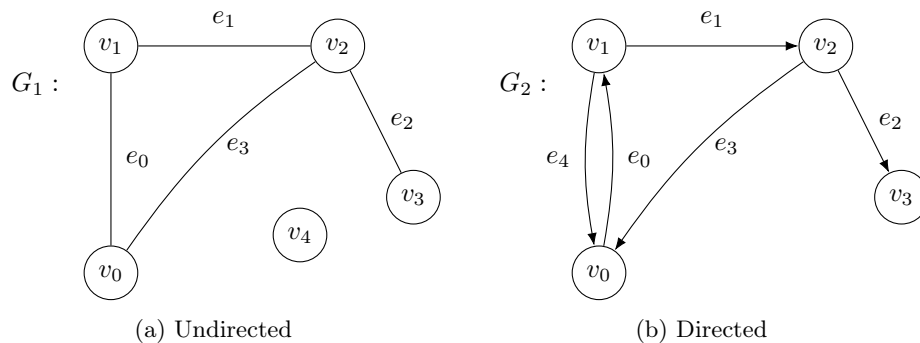


Figure 2.2: A *graph* with *vertices* and *edges*.

So a graph G is a pair of sets, $G = (V, E)$ where $V = \{v_0, \dots\}$ is the set of vertices and $E = \{e_0, \dots\}$ is the set of edges. The edges can have their own labels as in the figure, or they can be denoted by the pair of vertices they connect: e_0 could be also named as (v_0, v_1) or v_0v_1 . A graph can be *undirected* (figure 2.2a) if the edges have no sense of direction, or it can

be *directed* (figure 2.2b) if the direction of travel along an edge matters; e_0 is distinct from e_4 because they have different directions although they connect the same nodes v_0 and v_1 . A directed graph can also be called a *digraph*.

To decide how “big” a graph is, one can count the number of vertices, $|V|$, to get the *order* or *cardinality* of the graph. If one counts the number of edges, $|E|$ one gets the *size* of the graph. In figure 2.2, G_1 has order 5, and size 4; and G_2 has order 4 and size 5.

Edges are *adjacent* if they share a common vertex, and vertices are adjacent if they are connected by an edge, one can also say that v is *incident* with e . In figure 2.2a, v_0 and v_1 are adjacent but not v_1 and v_3 , and e_0 and e_1 are adjacent but not e_0 and e_2 .

The number of edges connecting to a vertex is called the *degree* of the vertex, $d(v)$. In figure 2.2a, $d(v_2) = 3$, $d(v_3) = 1$ and $d(v_4) = 0$. A vertex of degree 1 is called a *pendant* vertex, or *leaf*, and a vertex of degree 0 is called *isolated*. If all *components* of a graph are *connected*, then the graph is a connected graph. In figure 2.2 graph G_2 is connected, but graph G_1 is not because it has an isolated vertex as a component.

A graph is *planar* if it is possible to draw without edges crossing each other. It is *Eulerian* if one can travel over every edge in the graph only once (as in the *Königsberg bridge problem*). A graph is called *Hamiltonian* if one can visit every vertex in the graph only once (as in the *Travelling salesman problem*).

Travels in graphs can be called different names. Ruohonen [1] has the most general name *walk* for travel from vertex to vertex along edges. A walk is *open* if it ends on a different vertex than it started, or *closed* if it ends on the same vertex. If an edge is traversed only once, the walk is called a *trail*. If any vertex is visited only once then the trail is a *path*. If the walk is a path but with the start and ending vertices being the same, then the walk is a *circuit*.

One can partition a graph into *subgraphs* if one places a cut in a vertex (*cut vertex*) or over a set of edges (*cut set*). In figure 2.2a a cut vertex could be v_2 and a cut set could be $\{e_1, e_3\}$.

2.1.1 Graph representation

There are different ways of representing graphs. We have so far used

- Graph diagram
- Set definitions, $V(G) = \{v_0, v_1, v_2, v_3, \dots\}$, $E(G) = \{e_0, e_1, e_2, e_3, \dots\}$

One can also use

- *Adjacency matrix*
- *Incidence matrix*
- *Adjacency list*

An *adjacency matrix* is a matrix that shows if vertices are adjacent or not. A value of 0 indicates that the vertices are not adjacent. For an *unweighted* graph, adjacency can be indicated with a 1, or if it is a *weighted graph*, it can be the value of the weight (e.g. edge length or cost). From figure 2.2a:

$$D = \begin{matrix} & \begin{matrix} v_0 & v_1 & v_2 & v_3 & v_4 \end{matrix} \\ \begin{matrix} v_0 \\ v_1 \\ v_2 \\ v_3 \\ v_4 \end{matrix} & \begin{pmatrix} 0 & 1 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{pmatrix} \end{matrix} \quad (2.1)$$

An *incidence matrix* describes which vertices that are incident with which edges. In a directed graph it is *positive* if it is the *start* vertex of the edge, or *negative* if it is the *ending* vertex of

the edge. From figure 2.2b:

$$A = \begin{matrix} & \begin{matrix} e_0 & e_1 & e_2 & e_3 & e_4 \end{matrix} \\ \begin{matrix} v_0 \\ v_1 \\ v_2 \\ v_3 \end{matrix} & \begin{pmatrix} 1 & 0 & 0 & -1 & -1 \\ -1 & 1 & 0 & 0 & 1 \\ 0 & -1 & 1 & 1 & 0 \\ 0 & 0 & -1 & 0 & 0 \end{pmatrix} \end{matrix} \quad (2.2)$$

A *dense* graph has almost all vertices connected to each other, i.e. there are few 0s in the adjacency matrix. In a *sparse* graph there are a lot fewer edges than there could be, so the adjacency matrix has a lot of 0s. To be space efficient, especially in computing, it can therefore be better to represent a graph as an *adjacency list*, which simply lists for each vertex which other vertices it is adjacent to. No 0s needs to be included. From figure 2.2a:

$$v_0 : (v_1, v_2), \quad v_1 : (v_0, v_2), \quad v_2 : (v_0, v_1, v_3), \quad v_3 : (v_2) \quad (2.3)$$

2.2 Map routing

For graphs as those described above, there exists basic algorithms such as *Dijkstra* and *bidi-rectional search*, or more goal directed such as A^* , that tries to find the shortest path from vertex s (source) to vertex t (target). To do that, each edge needs to be associated with a length. That is, the *metric* is *distance*.

However, when it comes to map routing there can be other metrics that are more important than the shortest path. For example *time* (we want the shortest driving time); *road category* or *land use* (we don't want to route through a residential area with low speed limits, or avoid having to go by ferry); *turn cost* (turning slows driving down so prefer straight routes); *multimodal* (when going by public transport we want to minimize waiting and the number of exchanges); *via* (we want to travel via a specific road or city); and so on.

A really basic ingredient in map routing is of course also the fact that roads are directed, i.e. there can be one-way roads. It is also important to take into account that there can be turn restrictions, so that a turn is not allowed at a junction, although it looks like it on the map (and the graph). Even more complicating is the fact that different restrictions on roads might be permanent, or just temporary due to road work, accidents, etc, so there is a difference between *static routing*, where the metric costs are static, and *dynamic* routing where the costs fluctuate over time.

2.2.1 Overview

In an overview of route planning techniques from 2009 [4], it is stated that the starting point for a “horse race” in developing speed-up techniques started in 2005 (p.124), when continental sized road networks of Europe and USA were made publicly available. Before that, large map data had been proprietary and it was hard to compare different approaches. The last decade since then has seen a quick development in the area, so a new overview in a tech report in 2014 from researchers in German universities and Microsoft [5] stated that the previous report was now outdated. This last report is a great overview of route planning techniques from the basic *Dijkstra*, continuing to different families of techniques: *goal directed*, *separator based*, *hierarchical*, *bounded hop*. The report also describes combinations of different techniques and notes on *path retrieval* (getting a description of the shortest path, not just the cost), *dynamic networks* and *time dependence*.

The motivation for the speed-up techniques is to enable “instant” route planning in large networks. The Dijkstra algorithm might need some seconds to complete a query, while one with some preprocessing might be able to perform a query in milli- or even microseconds. This is done by dividing the work into two distinct phases: the *preprocessing* phase, and the *query* phase. The preprocessing phase takes the original graph and performs transformations and builds new data structures. This is a process that can take a lot of time, from seconds

to hours and even days depending on algorithm, and the data the size of the data structures might multiply several times. The gain is that the query phase executes almost instantly.

A lot of the research has been conducted on simple models without turn restrictions, so it is easy to compare the speed gain to Dijkstra’s algorithm, and one have thought that adding turn costs or restriction on top will not be so hard. However, it turns out that most algorithms with large gains in speed are quite inflexible and have trouble to incorporate changing restrictions and metrics without the need for running the preprocessing phase again [6, p.2]. A more flexible way would be to have a separation of *topology*, i.e. how the graph “looks” with vertices and edges, from the *metrics*, i.e. the cost for travel in the graph.

Those techniques with preprocessing can be characterized as *offline* techniques, while techniques that perform all processing in the query phase can be called *online*. As said before, a lot of the research has been done on continental scale maps. But if one restricts one self to a metropolitan map with a graph of a smaller size, then perhaps the queries perform fast enough without preprocessing, or the preprocessing phase is so fast that can be run online?

2.2.2 Map representation

To have a real-world application that performs route planning, it also needs to seriously take turn restrictions into account, and to be more useful also be able to handle *turn costs*. There exists several techniques for that, see figure 2.3. The most straight-forward technique might be to introduce some new vertices so that edges have a *head* and a *tail* vertex, and turns are modeled by connecting head and tail vertices; this is called a *full-blown* representation (figure 2.3b). One of the most used representations is by converting the original *vertex-based graph* to an *edge-based graph* (also called *arc-based graph* or *line graph*). It can be viewed as connecting tails to tails, see figure 2.3c. These techniques introduces several new edges and vertices, inflating the space needed for the data structures. A more compact representation is keeping a table for each junction with the associated turn and turn costs, see figure 2.3d.

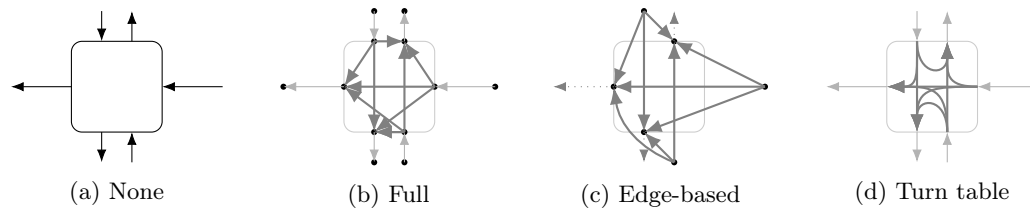


Figure 2.3: A closer look at a junction with two bidirectional and two unidirectional roads with different turn representations. (After [6, p.8].)

Edge-based graph

An *edge-based/arc-based/line graph* is a pretty straight forward transformation, where the edges of the original graph is turned into vertices in the transformed graph, and two vertices in the transformed graph is connected by an edge if a turn is allowed in the original graph. To make it simpler to distinguish between the vertex-based original graph and the new edge-based graph, we can call the new vertices *nodes*, and the new edges *lines*, i.e. “road = node”, with nodes connected by lines, if a travel is allowed. This gives us a graph $G' = G_{\text{edge-based}} = (N, L)$ where N is the set of nodes, $N = \{n_0, n_1, \dots\}$, $N = E$ and L is the set of lines, $L = \{l_0, l_1, \dots\}$ connecting the nodes, see figure 2.4.

As one can see, the complexity and size of the graph grows in the transformation, what was $|V| = 4$ vertices and $|E| = 7$ edges became $|N| = 7$ nodes and $|L| = 13$ lines. The increase in size of the data structures is one drawback with this simple transformation, but on the positive side is the fact that one can apply ordinary algorithms such as Dijkstra to the edge-based graph just as easily as on the original graph. Another disadvantage might be that it lets the topology represent metrics, i.e. a turn restriction is hard coded into the topology, so how does one handle temporary restrictions?

Volker [7] has written a study on “Route Planning with Turn Costs” and uses edge-based

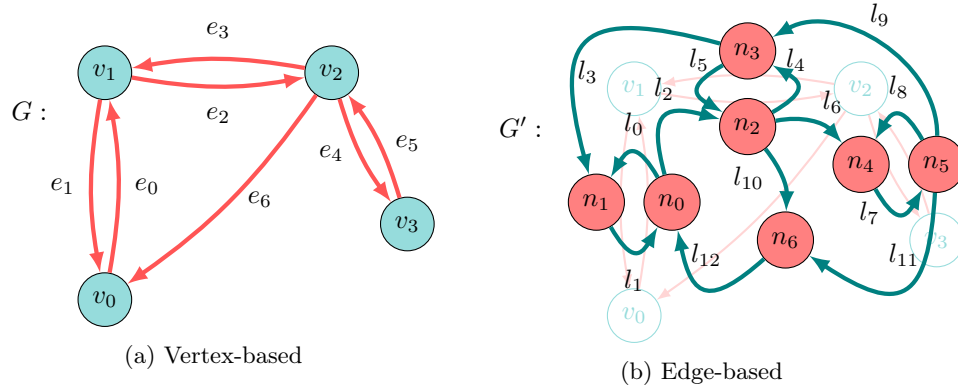


Figure 2.4: Transformation of a graph G to an *edge-based* graph G' .

graphs as the foundation. He also introduces an *interface graph* as a link between a vertex-based and an edge-based graph. This new graph builds on an elaboration on what a turn and a junction actually is, with an incoming and an outgoing edge being adjacent on the junction vertex. One can thus see a turn T as either $T = (e_{in}, e_{out})$, i.e. an incoming and an outgoing edge, or as $T = (s, t, u)$ as going from vertex s to vertex u , *via* vertex t . This kind of finer look at what a turn is, is also used by others to build a more compact representation, see below, section 2.2.2.

Turn tables

One way of dealing with a more compact representation of turns and restrictions and costs associated with them is presented in “Efficient Routing in Road Networks with Turn Costs” [8], where they use a standard vertex-based graph (where roads are edges and junctions are vertices) on which they use speed-up techniques such as *Contraction Hierarchies*, but they associate each junction with a table that describes the costs of turns there, essentially describing all possible turns and restrictions. It turns out that a lot of junctions in a road map share the same characteristics and therefore can share the same *turn table*, so that on a map over Europe on average 18 vertices could share the same turn table. Thereby they managed to reduce preprocessing time by a factor 3.4 and space by a factor 2.4 with the same query times.

Another solution which uses the vertex-based graph with a turn table at the junctions is described in “Customizable Route Planning in Road Networks” [6, p.6]. Their solution uses a *separator-based* speed-up technique, which has been viewed as slower than hierarchical techniques, but they argue that this is the most flexible solution with a clean separation of *topology* and *metrics*, with two preprocessing stages before the query stage; one slow *metric-independent* that works on the topology, and a faster *metric customization* stage that can be run for each metric (takes about a second). This solution also uses the fact that many junctions share the same characteristics and therefore turn tables can be shared.

Bidirectional edges

So far we have thought of the directed original graph as having an edge for each direction of travel between two vertices, as with edges e_0 and e_1 in figure 2.4a. But this can be more compactly represented with one edge having a couple of flags indicating directions, meaning that for most roads we need not have two complete edge structures, but only one with two extra bits indicating the direction. This is however not something that can be done in an edge-based graph as the *lines* in it are not bidirectional.

2.3 Map data

One needs to have good map data as the source for building these data structures and apply smart algorithms on. With poor data it does not matter if one has smart algorithms. As said earlier, a race in route planning started with the public release of previously proprietary data. About the same time *OpenStreetMap* also began, which is an *crowd-sourced* project, meaning that anyone interested can be a cartographer and contribute with map data. Over the years the project has grown to an impressive size, and is used as the base for many applications. However, it turns out that the map data actually lacks a lot of turn restrictions. They might be hard to enter, and they are impossible to spot when comparing aerial photos with maps. Efentakis et al. states that for Athens with 277 thousand vertices only 214 restrictions were entered. They propose an automated remedy by comparing GPS-traces to the maps and deducing that turns seldom made are actually banned and could be marked as restricted in the map data [9].

All the same, a lot of high quality applications exists built on *OSM* (OpenStreetMap) data and this project aims at that to.

2.3.1 Projections

Generally speaking, the globe is spherical, but a map is flat. That means that one somehow needs to *project* the spherical data on a flat surface. There exists a lot of different *projections* that tries to do it best. To keep track of which projection one is working in, one can identify it by its *SRID* – *Spatial Reference System Identifier* that uniquely identifies which projection and which kind of coordinate system one works with.

2.3.2 Topology

The *topology* is about the relationship between objects in a map [10]. If one only thinks of a map as a collection of lines, it is hard to make something out of that information. It becomes useful when we understand the topology, that “this line is connected to that line at this point”. Then we have a relationship between the lines and can understand how to travel on the map.

Analyzing the topology also makes it possible to correct errors made while adding items to the map data, such as if two lines don’t actually meet. Then there is a gap and there is no connection. When analyzing, one can opt to connect lines that are within a small distance of one another, thereby correcting mapping errors.

2.4 Available applications

Some of the research described earlier in this chapter is used actual working applications. For example *CRP* (*Customizable Route Planning*) [6] is used in Bing Maps, and *CH* (*Contraction Hierarchies*) are used in for example GraphHopper¹ and OSRM², and they are open source routing applications. So the source code is available so one can study how the data structures are implemented and how the algorithms work. There exists a lot of other solutions built on OSM as well³, using Contraction Hierarchies or other speed-up techniques.

2.5 Memory or database

All research referred to so far has been about building data structures to be held *in memory* so algorithms can operate on them. But as we speak of *queries*, one might think that databases and query languages might be useful as well. There is some research, and a technique called *HLDB* is interesting [11], [12]. It is fast enough, and very flexible, permitting to query for *alternative routes* and *points of interest*.

¹<https://graphhopper.com/>

²<http://project-osrm.org/>

³http://wiki.openstreetmap.org/wiki/Applications_of_OpenStreetMap

pgRouting is an open source database extension to *PostgreSQL*, often used for holding OpenStreetMap-data. It has a function called `pgr_trsp`⁴ that looks for the shortest path with turn restrictions, so obviously standard relational databases can be part of a solution.

⁴<http://docs.pgRouting.org/2.0/en/src/trsp/doc/index.html>

3 Methodology

The overall methodology for the development is a combination a of *Behaviour Driven Development*, *BDD* and *Test Driven Development*, *TDD*, meaning all features of the module have either a *scenario* (BDD) or a *test case* (TDD) written.

As for tools, some are given in the specifications (see Appendix A), while others have been chosen during a selection process. Below is presented the tools chosen, and in some cases what alternatives that were also considered and tested. The categories are:

- Behaviour and Test Driven Development.
- Database.
 - Database and extensions.
 - Loading OpenStreetMap into database.
 - Build topology.
 - Examining map data.
 - Connecting to database from application.
- Reading configurations from json-file.
- Building graph.

3.1 Behaviour and Test Driven Development

Behaviour Driven Development tests usually have the structure: *Scenario* → *Given* → *When* → *Then*, written with words to describe the steps. An example in the *Gherkin* language is shown in listing 3.1.

```
Scenario: vectors can be sized and resized
  Given: A vector with some items
  When: the size is increased
  Then: the size and capacity change
```

Listing 3.1: Example of a BDD scenario in *Gherkin*.

So when developing BDD style one has to think through different scenarios and write them down, which can be helpful when thinking about what one tries to accomplish.

3.1.1 Tools, installation and usage

The testing library for this project is [Catch](http://www.catch-lib.net)¹, which is a small library for both BDD and TDD, where the BDD “*scenario*” corresponds to a TDD “*test-case*”, and “*given*”, “*when*”, “*then*” corresponds to “*section*”, meaning one can choose the development style one wishes. *Catch* was chosen because it is header only, and there is no need for complicated building of libraries and setting up paths; one can just include the header in the project and go.

Simply download the file `catch.hpp` and put it either in your project tree or in your path for includes.

Include the header in the source for your test, and get *Catch* to provide a `main`-method. See listing 3.2 for an example of how to implement the above stated “feature”.

¹<http://www.catch-lib.net>

```
1 #define CATCH_CONFIG_MAIN
2 #include "catch.hpp"
3 #include <vector>
4
5 SCENARIO ("Vectors can be sized and resized", "[vector]") {
6     GIVEN ("A vector with some items") {
7         std::vector<int> v(5);
8
9         REQUIRE (v.size() == 5);
10        REQUIRE (v.capacity() >= 5);
11
12        WHEN ("the size is increased") {
13            v.resize(10);
14
15            THEN ("the size and capacity change") {
16                REQUIRE (v.size() == 10);
17                REQUIRE (v.capacity() >= 10);
18            }
19        }
20    }
21 }
```

Listing 3.2: A basic BDD scenario with Catch

3.1.2 Alternatives

The BDD style of developing seems not to have caught on in c++ so much. There are a few libraries. [Cucumber-Cpp](#)² was investigated as it is an implementation for c++ of the Cucumber tool, which is widespread in many programming languages, so one could write the test for features in the ordinary `.feature`-files in the *Gherkin* language, that are common for writing features for tests. But I could not get Cucumber-Cpp to build correctly with CMake and the dependencies.

3.1.3 Remarks

It should not be a very difficult task to write a script that reads a `.feature`-file and outputs a template in c++, using the Catch syntax.

If one were to *not* go for BDD-style of testing, then one could go for TDD testing using Boost Test, if one would want to keep using Boost for most parts of the project.

3.2 Database

The database of choice, and in the requirements of the project, is [PostgreSQL](#)³, with the extension [PostGIS](#)⁴ which gives the database *spatial* and *geographic* capabilities, which are needed to simplify working with maps and such, for example when needing to measure distances in different projections. How to set up the database with users and passwords and such are not given in this report, but it is not so hard. When setting up databases one can interact via either the commandline or a *graphical user interface*, *GUI* such as *pgAdmin3*.

3.2.1 Tools, installation and usage

The tool set was given in the requirements, as mentioned before. On my Debian/Ubuntu system they can be installed as shown in listing 3.3.

²<https://github.com/cucumber/cucumber-cpp>

³<http://www.postgresql.org/>

⁴<http://postgis.net/>


```
$ sudo apt-get install postgresql postgresql-contrib-9.3 postgis postgresql-9.3-postgis-2.1 pgadmin3  
↪ osm2pgsql
```

Listing 3.3: Installation of database tools

Listing 3.4 shows how to create a new database called `mikh_db` with a user “jonas” (that is already set up as a user with rights to create databases), and enabling the needed spatial extensions to work with map data.

```
$ createdb mikh_db -U jonas  
$ psql -U jonas -d mikh_db -c "CREATE extension postgis;"  
$ psql -U jonas -d mikh_db -c "CREATE extension postgis_topology;"  
$ psql -U jonas -d mikh_db -c "CREATE extension hstore;"  
$ psql -U jonas -d mikh_db -c "SET search_path=topology, public;"
```

Listing 3.4: Create database and enable spatial extensions.

3.2.2 Loading map data

To get the `.osm`-file, which is actually in `xml`, into the database one needs a conversion tool to parse the file and populate some tables with data.

Tools, installation and usage

There exists several tools for importing OSM data into a database. It was hard to know which one to pick and different options were tried, but the chosen tool is [osm2pgsql](#)⁵. It was installed in listing 3.3.

```
$ osm2pgsql -U jonas -d mikh_db -k -s mikhailovsk.osm
```

Listing 3.5: Usage of `osm2pgsql`.

Listing 3.5 reads an `.osm`-file in the current directory and populates the database `mikh_db`. The flags `-k` tells to use “hstore” for tags and, `-s` to make a “slim” conversion. Two different `.osm`-files have been provided for testing, “mikhailovsk.osm” and “partille.osm”, hence the usage of “mikhailovsk.osm”.

One might specify other flags as well. Among the options is to chose a different projection than the default 900913. It is also possible to specify a `.style`-file which is a configuration over which tags to import. It is possible to use this file to decide which tags to import into the database and which tags to discard.

Alternatives

There exists a bunch of other tools that can convert OpenStreetMap files into database tables, such as *Osmosis*, *Imposm*, *osm2po*, *osm2pgrouting*, and others; all with different strengths and weaknesses, such as being good and free, but not open source.

3.2.3 Building topology

With the data in the database, it is time to build a topology of the map data, saying how the vertices and edges are connected, to make it possible to build a routable graph. A lot of the “nodes” in the `osm`-data are only useful for describing the geometry, while what is interesting when routing are the nodes that connects edges; that is the junctions at which roads meet. Therefore it is essential to analyze the data and build tables that contain information about the topology.

⁵<http://wiki.openstreetmap.org/wiki/Osm2pgsql>

One can have different thoughts of when to do this. It would be possible to do this at the preliminary step when loading the data into the database. That would be good if one was certain of that the topology is stable. If the network is more volatile, it would be better to build the topology on every query, to be certain that one always has the most up-to-date information. On the other hand; the topology for a road network should be stable, and temporary closures and other changing conditions will be better reflected in tags that can be queried when calculating costs for routing. That is the path taken in this project.

Tools, installation and usage

The choice for this project is PostGIS' topology extension. It is a part of PostGIS, which is already installed.

The `osm-data` from `osm2pgsql` has a table for all the lines in the map, called `planet_osm_line`, but in addition to roads it contains lines for railways, waterways, borders, buildings etc. So to build routing data we need to extract the lines only representing the roads, and put it in a new table. Listing 3.6 shows that.

```
$ psql -U jonas -d mikh_db -c "CREATE TABLE roads AS SELECT * FROM planet_osm_line WHERE highway IS  
↪ NOT NULL;"
```

Listing 3.6: Creating a table with only roads in it.

Then one can build a topology of the roads, as shown in listing 3.7. The first line creates a new schema called `roads_topo` which will hold the topology data in the projection 900913 (the projection used when loading the database). The second line adds a column called `topo_geom` to the table `roads` in the public schema. The third line connects that column with the newly built corresponding topology in the `roads_topo` schema. The topology is built with a tolerance of 1.0 units. The unit for this projection is meters, so it means that if there are several nodes within 1.0 meters or a node within 1.0 meters from a road, they are joined. This can be essential to building a routable network. When running the validation tool in JOSM on the `mikhailovsk.osm`-file, it reported 16 suspect cases with nodes close but not connected, see figure 3.1.

```
$ psql -U jonas -d mikh_db -c "SELECT topology.CreateTopology('roads_topo', 900913);"
$ psql -U jonas -d mikh_db -c "SELECT topology.AddTopoGeometryColumn('roads_topo', 'public',  
↪ 'roads', 'topo_geom', 'LINESTRING');"
$ psql -U jonas -d mikh_db -c "UPDATE roads SET topo_geom = topology.toTopoGeom(way, 'roads_topo',  
↪ 1, 1.0);"
```

Listing 3.7: Building a topology with PostGIS.

Alternatives

One might load the database, and build a topology with [osm2pgrouting](http://pgrouting.org/docs/tools/osm2pgrouting.html)⁶, and the PostgreSQL extension [pgRouting](http://pgrouting.org/index.html)⁷. That solution is pretty smooth, and might heal the topology with a tolerance, but it seems it only builds the topology and does not give access to tags and other information usable when calculating costs.

Another attempt, was to run a topology building SQL function (as in <http://blog.loudhush.ro/2011/10/using-pgrouting-on-osm-database.html>), and then run another function to remove all nodes without topological meaning. But that lead to the problem shown in figure 3.1, as there had been no “healing” of nodes first. One solution could of course to write another function for that, or to fix the `.osm`-file manually in JOSM before loading it into the database. But the solution with the PostGIS topology seems like a better way to go.

⁶<http://pgrouting.org/docs/tools/osm2pgrouting.html>

⁷<http://pgrouting.org/index.html>

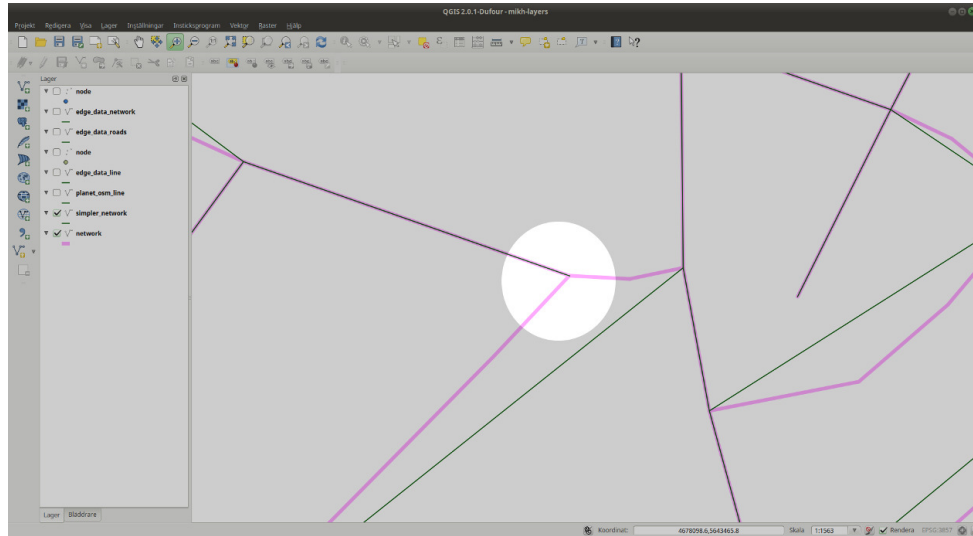


Figure 3.1: Error building topology with a node close but not connected.

3.2.4 Examining map data

Map data lends itself to visualization. And it is also useful to build a mental model of what one is working on, and to see the results.

JOSM

[JOSM](https://josm.openstreetmap.de/)⁸ is an editor for OpenStreetMap. It can open .osm-files and display them, inspect elements of the map, and it has tools for editing and validation, meaning one might be able to fix files that has problems. See figure 3.2.

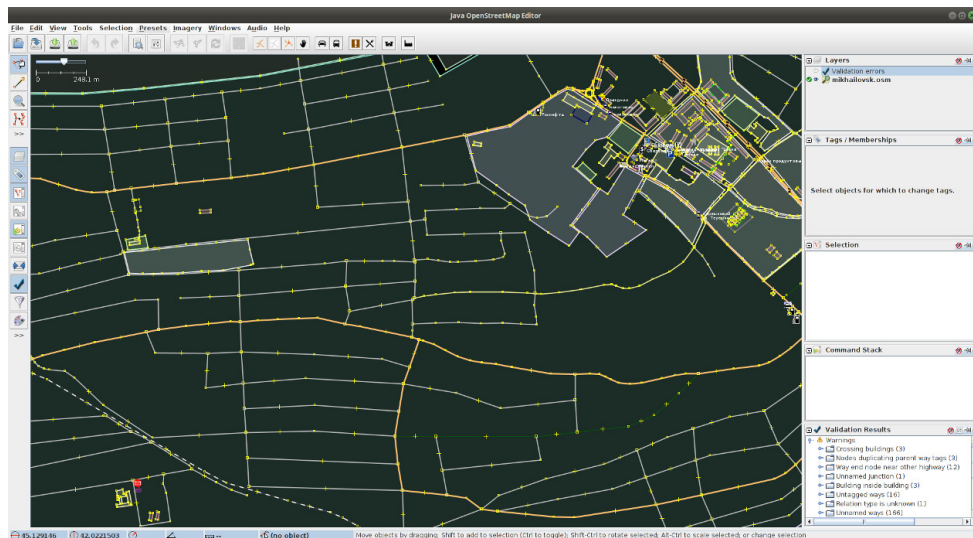


Figure 3.2: JOSM editor with Mikhailovsk map.

⁸<https://josm.openstreetmap.de/>

QGIS

[QGIS](#)⁹ is a tool that can load spatial data from databases and display, as well as load for example .osm-files. It makes it good to visualize for example query results or transformations you have made in the database. See figure 3.3 for an example with layers of PostGIS-data of “Mikhailovsk” on top of each other.

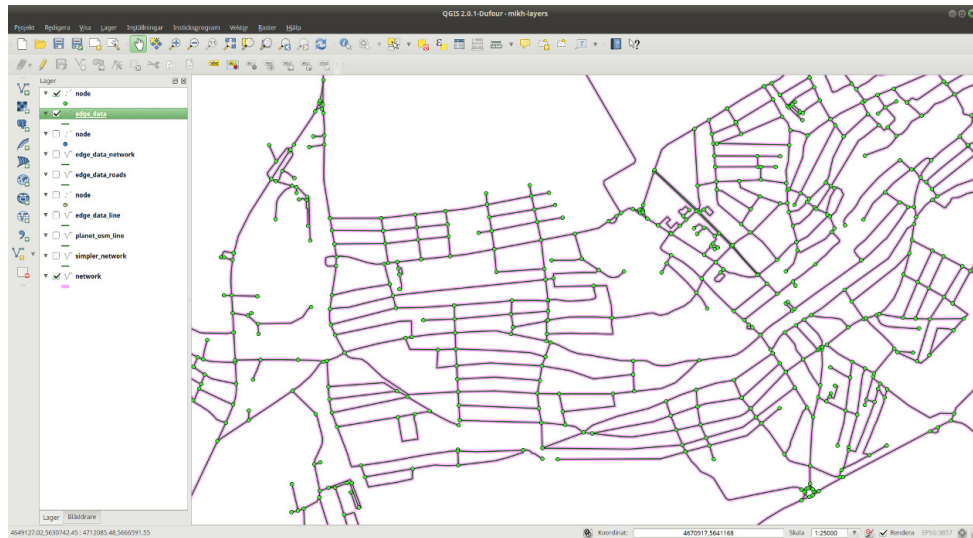


Figure 3.3: QGIS editor with Mikhailovsk map from PostGIS tables.

When loading data from PostGIS one might have to specify which projection to use for display. The default projection when loading .osm-files into the database using `osm2pgsql` is SRID 900913, and to display that correctly in QGIS one needs to use the projection EPSG:3857.

3.2.5 Connecting to database

After the module has read in the configuration, the next step is to connect to the database and perform some work on the map data before extracting relevant information.

The connection to the PostgreSQL database is handled by the library `libpqxx`¹⁰, and while there exists a few alternatives, it is natural to go for the official alternative.

Tool, installation and usage

Installation of `libpqxx` is shown in listing 3.8.

```
$ sudo apt-get install libpqxx-4.0
```

Listing 3.8: Installing `libpqxx` on a Debian/Ubuntu system.

It is pretty straightforward to use: include the header, make connections and transactions. A snippet is shown in listing 3.9.

```
1 #include <pqxx/pqxx>
2 ...
3 pqxx::connection conn("dbname=testdb user=tester password=tester hostaddr=127.0.0.1 port=5432");
```

Listing 3.9: Include header and make a connection to the database.

When compiling, one must link with the libraries `pqxx` and `pq`, as shown in listing 3.10.

⁹<http://www.qgis.org/>

¹⁰<http://pqxx.org/development/libpqxx/>

```
$ g++ mytest.cpp -lpqxx -lpq -o mytest
```

Listing 3.10: Linking libpqxx at compile time.

3.3 Configuration

The module should be configured by a settings file, written as *json*. Settings can be related to the database such as host address, table names etc; or it can be configuration of costs for the routing such as speed limits, traffic lights, turn restrictions.

3.3.1 Tools, installation and usage

There is no meaning in writing a json-parser for this module as there exists lots of good libraries. The one chosen is [Boost Property Tree](http://www.boost.org/doc/libs/1_54_0/doc/html/property_tree.html)¹¹, as the project uses other Boost libraries, and it simple enough to get started with.

As several Boost packages will be used in this project, it is just as good installing all of them (for a Debian/Ubuntu based system), see listing 3.11.

```
$ sudo apt-get install libboost-all-dev
```

Listing 3.11: Installation of Boost libraries.

An example to see how simple it is to parse a json-file is shown in listing 3.12.

```
1 #include <string>
2 #include <iostream>
3 #include <boost/property_tree/ptree.hpp>
4 #include <boost/property_tree/json_parser.hpp>
5
6 void readJsonFile(const std::string& filename) {
7     boost::property_tree::ptree pt;
8     boost::property_tree::read_json(filename, pt);
9     std::string host = pt.get<std::string>("host");
10    int port = pt.get<int>("port");
11    std::cout << "Host: " << host << ", port: " << port << std::endl;
12 }
```

Listing 3.12: Parsing a json-file.

3.3.2 Alternatives

One could go for a header-only solution here as well, such as [jsoncons](https://github.com/danielaparker/jsoncons)¹², which was also tested, but *Boost Property Tree* seemed nice and easy to get working if one already has the Boost libraries installed.

3.4 Build Graph

The requirements said that the “*Boost Graph Library (BGL)*” should be used for representing the graph and for returning the *line graph* structure for routing back to the calling application.

As discussed in section 2.1.1, the most space efficient way of representing a sparse graph is an *adjacency list*, and the *BGL* has such a data structure. Using template arguments one can configure what kind of data structures to use for the lists of *edges* and *vertices*, and the data structures to use for *edges* and *vertices*, and if the graph is *directed* or *undirected*.

If one has some properties of the edges and vertices that one wishes to keep in the graph (like the “cost” or some identifier of an edge), it is possible in several ways, either as “*interior*”

¹¹http://www.boost.org/doc/libs/1_54_0/doc/html/property_tree.html

¹²<https://github.com/danielaparker/jsoncons>

or “*exterior*” properties, and `adjacency_lists` can use *interior* properties either as “*bundled properties*” or as “*property lists*”.

The *property lists* are external structures for some property that gets mapped to e.g. an edge in the graph.

The *bundled properties* are more intuitive, by using data structures as the *descriptors* of the *edges* and *vertices*, and with the properties as fields.

An example from the documentation for *bundled properties* [13] shows the difference clearly, in terms of how easy or hard it is to read or understand the code in the different approaches. See listing 3.13 showing the *bundled* approach and listing 3.14 showing the *property list* way.

```
1 // Vertices = Cities
2 struct City
3 {
4     string name;
5     int population;
6     vector<int> zipcodes;
7 };
8
9 // Edges = Highways
10 struct Highway
11 {
12     string name;
13     double miles;
14     int speed_limit;
15     int lanes;
16     bool divided;
17 };
18
19 // Map using `City` as vertex descriptor and `Highway` as edge descriptor.
20 typedef boost::adjacency_list<
21     boost::listS, boost::vecS, boost::bidirectionalS,
22     City, Highway>
23 Map;
```

Listing 3.13: Bundled properties in a graph.

```
1 typedef boost::adjacency_list<
2     boost::listS, boost::vecS, boost::bidirectionalS,
3     // Vertex properties
4     boost::property<boost::vertex_name_t, std::string,
5     boost::property<boost::population_t, int,
6     boost::property<boost::zipcodes_t, std::vector<int> > > >,
7     // Edge properties
8     boost::property<boost::edge_name_t, std::string,
9     boost::property<boost::edge_weight_t, double,
10     boost::property<boost::edge_speed_limit_t, int,
11     boost::property<boost::edge_lanes_t, int,
12     boost::property<boost::edge_divided_t, bool> > > > >
13 Map;
```

Listing 3.14: Property lists in a graph.

In this project, the *bundled properties* were chosen for their ease of understanding and reading.

4 Implementation

As stated at the start of chapter 3, the software module called the “*Line Graph Utility*”, (*LGU*), that should be the outcome of this project, is sequential in nature. The complete specification is available in appendix A, but here is an outline of the main use case.

- The using application calls the LGU’s `get_directed_line_graph()`.
- LGU queries the PostGIS database and builds a graph from the road network.
- LGU builds a directed line graph from the previous step (i.e. it converts nodes to edges and assigns weight to those edges based on road signs and other elements which are present in the nodes).
- `get_directed_line_graph()` returns a directed line graph structure which is based on a C Boost graph structure to the function caller.

This can be expanded to a series of steps. First comes a preliminary step, not actually part of the module, but essential during development and testing:

- Loading the map data into the database and build a topology.

The following steps are performed during development and usage of the tool:

- Load configurations from *json*-file.
- Get the relevant edges and vertices from the database; store the topology.
- Apply restrictions and costs on the topology.
- Build a graph structure from the topology, using *Boost Graph Library*.
- Transform the structure into a *line graph* (*edge-based/arc-based graph*).
- Return the line graph.

4.1 Design

The sequential nature of the module, with a few easily identifiable objects, lead to no big design process was deemed necessary. Taking an object oriented approach, it is easy from the above list to identify *configuration* (and *configuration reader*); *edges*; *vertices*; *database*; *topology*; *restrictions*; *costs*; *graph* (and *graph builder and transformer*); *line graph*. All can be packaged up in a *Line Graph Utility*. The design therefore evolved gradually without a master plan more specific than this.

Another reason for this, was that this project was a discovery into not really well understood territory, despite some introductory research. It was necessary to learn the tools and concepts as the project proceeded, so the design and implementation grew incrementally. The incremental goals set during development, was to be able to build a graph from the map data, later extended to being able to build a line graph from that, to finally being able to apply restrictions and costs to the graphs.

A decision that was made early on, was to try not to pass pointers around, but instead use references, to reduce the complexity of memory handling. That means that a lot of functions gets passed in a reference to an object to fill in, rather than return a pointer to a newly constructed object. All the same, some pointers could not be avoided and raw pointers were used in those cases.

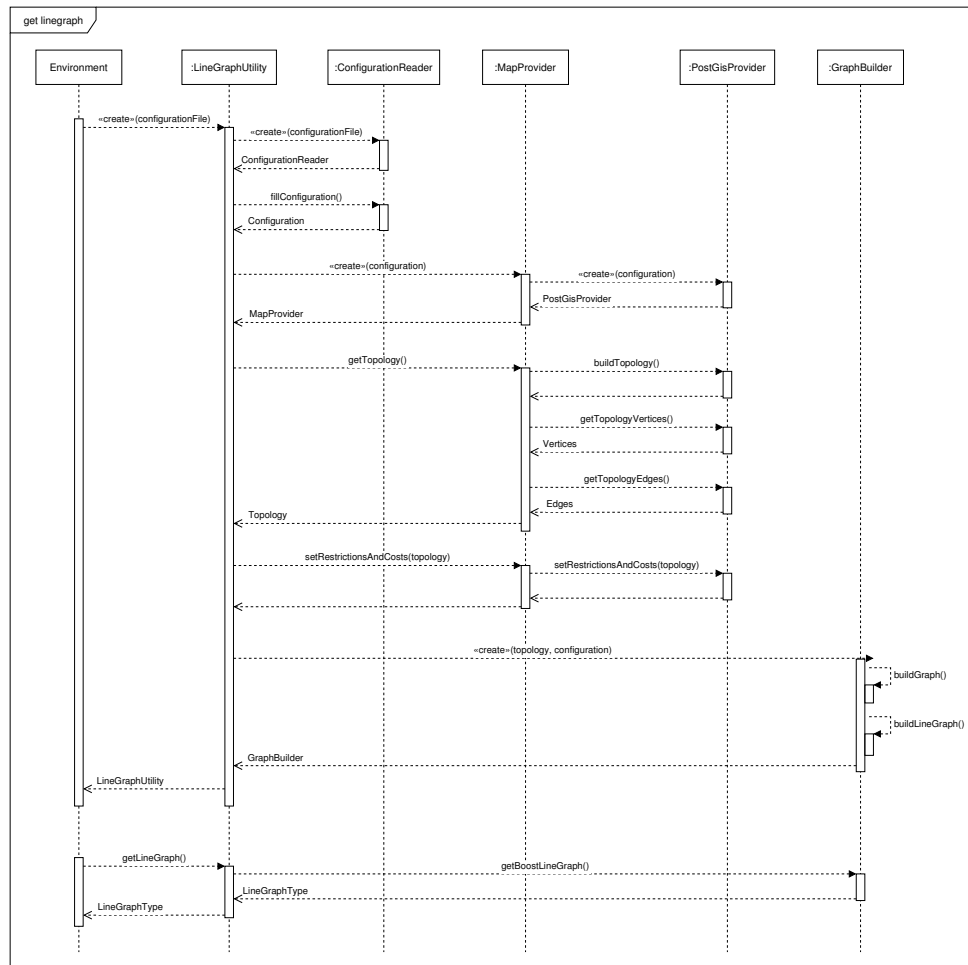


Figure 4.1: Sequence diagram of main use case to get a line graph.

4.1.1 Dynamic design

The sequence presented above has been refined into a design that can be shown in a sequence diagram, see figure 4.1 and appendix B.1.

The calling application “*Environment*” instantiates a *LineGraphUtility* object with the file name to a configuration file. The *LineGraphUtility* instantiates a *ConfigurationReader* that can be asked to fill in a *Configuration* object. The configuration contains among other things, a setting for which *MapProvider* to use. The idea is that one can read the *OpenStreetMap* data in several ways; for example parse the *.osm*-file, or use different databases or different tools to import *.osm*-files into the database. Hence the flexibility by using an abstract *map provider*. The only implementation in this project so far is the *PostGisProvider*, but others could be developed if it turns out there are better ways to access the map data.

So the actual work on retrieving the map data is performed by the *PostGisProvider*, that is fetching the *Topology* and applying *restrictions* and *costs* on the topology. The idea behind this separation is that the topology should be reasonably stable and constant, and that dynamic changes in the traffic, such as blocked roads, should be handled as restrictions and costs that are applied to the static topology. But it is also possible to perform an update on the topology if needed, for example if there has been built a new road. See figure 4.2 for a diagram of updating the restrictions and costs, and figure 4.3 for a diagram on updating the topology, (also in appendix B.2 and appendix B.3).

Back to figure 4.1, after having a restricted topology we instantiate a *GraphBuilder* object with the topology och configurations. This *GraphBuilder* builds a directed graph, and converts it to a *line graph*. If all went well the *LineGraphUtility* now is ready to serve the calling application a *line graph* any time it gets called.

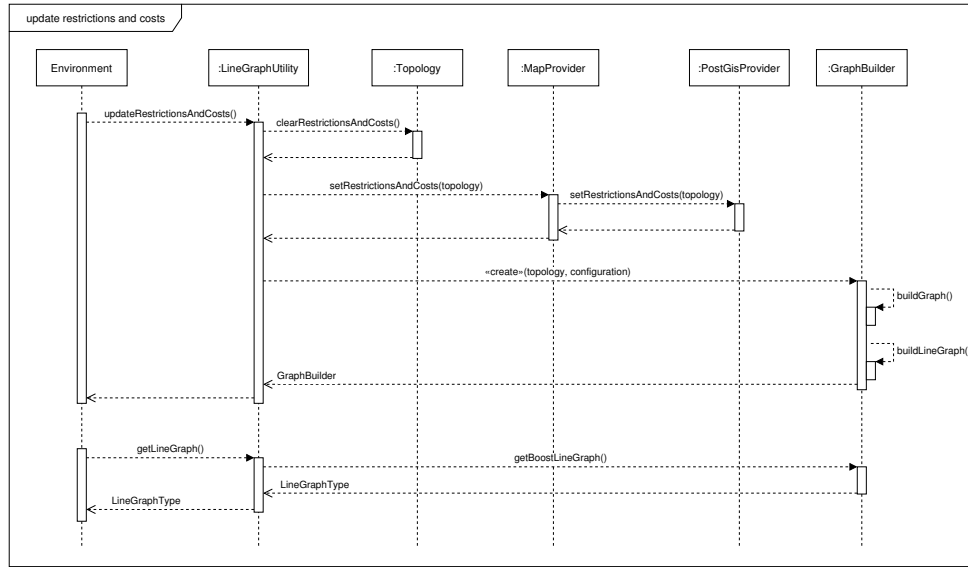


Figure 4.2: Sequence diagram of updating costs and restrictions on a topology.

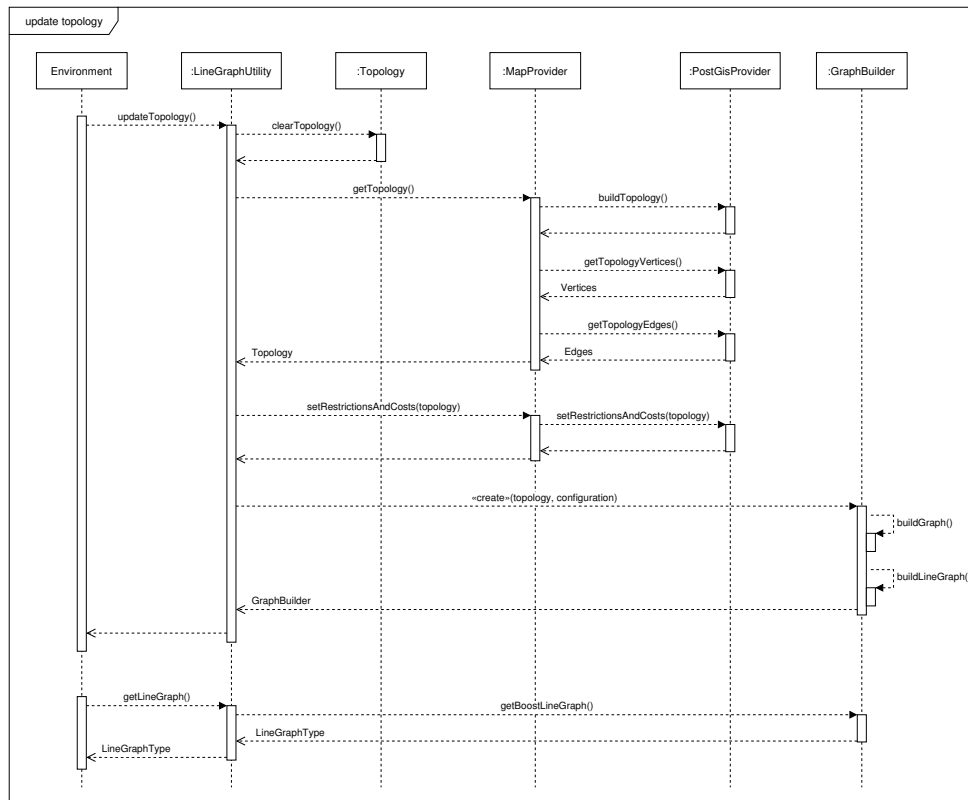


Figure 4.3: Sequence diagram of updating the topology.

4.1.2 Static design

A few classes were introduced in the sequence diagrams above, and a more complete view of the classes can be seen in the class diagram in figure 4.4 and in appendix B.4.

As can be seen, the application is divided in a few “*packages*”. The division is more to help when navigating code, it is not enforced by namespaces:

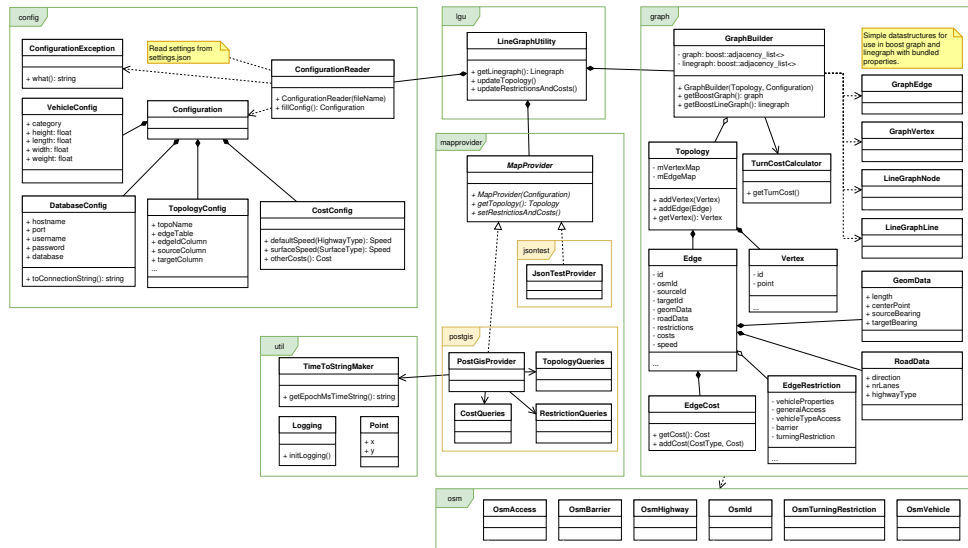


Figure 4.4: Class diagram of the *line graph utility*.

- lgu: The entry point to the LineGraphUtility.
- graph: Classes related to graphs like GraphBuilder, Topology, Edge, Vertex.
- mapprovider: Classes related to providing map data.
- config: For handling configurations.
- osm: Helper classes for constants and concepts related to *OpenStreetMap* data.
- util: A few general helper classes.

This is an attempt to modularize the development process; to keep related classes in a specific area. It also makes navigating the code easier. Another attempt to make the packages coherent is that each package should have its specific *exception* class, that is the only public exception that gets thrown by the classes in the package. Other exception classes might be used internally but not exposed publicly.

4.2 Project structure

Apart from the packages above, there are directories in the project to support testing, setting up and documentation. This gives the project a basic directory structure as shown in listing 4.1.

```
./
├── catchtest/
├── config/
├── doc/
├── graph/
├── lgu/
├── mapprovider/
├── osm/
├── preparation/
├── util/
└── README.md
```

Listing 4.1: First level directory structure of the project

Each directory has a `README.md` file, a textfile in markdown mark up, that explains the purpose of the directory. Each directory with code also should have a `catchtest` directory, where there are tests for the code in the directory/package.

4.2.1 catchtest

Most of the code developed in this project has been part of a test, and all “*packages*” have their own set of tests. *Catch* is a header-only framework, and that header resides in this root `catchtest` directory, and there is a source file that calls that header and functions as the entry point when testing, see appendix listing C.2. It also contains a sub-directory for configuration settings used during development.

In section 3.1.1 the *Catch* testing framework is introduced, and in listing 3.2 there is a small example of how to write a scenario. There one can see that the scenario is tagged with “[vector]”, and those tags can be used to determine which tests to run. If no tags are specified all tests are run, but if one specifies a tag, it only runs tests that matches that tag. One can also specify which tests *not* to run by prepending a tilde (‘~’) to the tag. See listing 4.2. If one wants to see the results of all tests and not only failed ones, one can add the flag `-s`. If running tests from inside and *integrated development environment*, *IDE* one can specify the arguments in a “*run configuration*” instead.

```
$ testapp ~[timing] -s
```

Listing 4.2: Running tests except those tagged with [timing], showing all results.

4.2.2 config

See appendix listing C.3 for the contents of this package, whose purpose is handling configurations. The central part is a data structure `Configuration`, made up of data structures for *cost*, *database*, *topology* and *vehicle*. The configurations are filled in by the `ConfigurationReader` class which reads from a specified settings file.

The `CostConfig` are mainly concerned with keeping track of speeds for different categories of roads and surfaces. The types are specified in `OsmHighway` in the `osm` package, see section 4.2.7.

The `DataBaseConfig` is about connecting to the database.

The `TopologyConfig` is about which tables and columns in the database to use when getting the topology.

The `VehicleConfig` keeps characteristics about the vehicle we are routing through the map, such as weight, height, category (as specified in `OsmVehicle`, see section 4.2.7).

4.2.3 doc

Listing C.4 shows the contents of this package, that contains the documentation for the project. It has a directory for this report, and a directory for the UML diagrams.

The diagrams are not meant to be exact documentation, but rather give an idea of the concepts and the big picture, and therefore method names might be missing or spelled differently than in the actual code.

4.2.4 graph

The `graph` package (see appendix listing C.5) is really the central package, where the `Edge`, `Vertex`, `Topology` classes are, and the `GraphBuilder` resides. In addition there are the classes for restrictions and costs for edges (`EdgeCost`, `EdgeRestriction`); a helper class for calculating costs for turns (`TurnCostCalculator`); and a couple of essential simple types, `Cost` and `Speed` who are simply typedefs.

Edge

(See source code in appendix [D.7.2](#) (header), [D.7.3](#) (implementation)).

The Edge class represents an edge in the topology. So it keeps track of the *source* and *target* vertices, the original *OSM id* and of course its *id* in the topology. It also keeps track of properties of the underlying *road* (number of lanes; one-way; the road category), and its geometrical properties (length; centre point and *bearing* of the edge at the vertices to calculate turning angles).

Vertex

(See source code in appendix [D.7.4](#) (header), [D.7.5](#) (implementation)).

The Vertex class simply keeps the *id* it has in the topology and the *coordinates* of it, it does not keep track of an *OSM id* as it might not correspond to nodes in the *OSM* data, since the vertices were calculated when building the topology.

Topology

(See source code in appendix [D.7.6](#) (header), [D.7.7](#) (implementation)).

The Topology class is a collection of maps. One maps $\{\text{edgeId} \mapsto \text{edge}\}$, that is it makes it possible to get to the topology's Edge object when one only has an *id* for it in the topology. The corresponding map exists for vertices, $\{\text{vertexId} \mapsto \text{vertex}\}$. In addition there is a *multi-map* $\{\text{osmId} \mapsto \text{edgeId}\}$ that has an *osmId* as the key, that maps to several *edgeIds*. The reason for this is that an original road in the *OpenStreetMap* might be split into several edges when building the topology.

GraphBuilder

(See source code in appendix [D.7.8](#) (header), [D.7.9](#) (implementation)).

The GraphBuilder keeps a Topology and a Configuration as the base for building a *graph* and a *line graph*. The GraphBuilder header begins with defining a bunch of types, such as the data structures to be used for *edges* and *vertices* in the *Boost graph* (GraphEdge, GraphVertex). They keep track of the *id in the topology* and the corresponding *id in the graph*, so one can move from the one to the other. The GraphBuilder keeps a *map* for *vertex* such as $\{\text{topoVertexId} \mapsto \text{graphVertexDescriptor}\}$, and a *multi-map* for *edges* such as $\{\text{topoEdgeId} \mapsto \text{graphEdgeDescriptor}\}$. These maps make it possible to access the data in the data structures underlying the *descriptor*, e.g to get to the fields in the GraphEdge through the descriptor. The reason to use a *multi-map* for the edges are that the edge in the topology is undirected, but in the graph the edges are directed, so in the graph there should be a directed edge for each lane of the road, and thus for most roads there will be several *graph edges* for each *topology edge*.

The GraphBuilder also has the data structures that makes up the *nodes* and *lines* in the *Boost line graph*, and a map $\{\text{edgeId} \mapsto \text{lineGraphNodeDescriptor}\}$, since that is the definition of a *line graph*: an edge turns into a node in the transformed graph.

There are also *typedefs* to make the code easier to work with, see listing [4.3](#).

```
1 typedef boost::adjacency_list
2 < boost::listS, boost::vecS, boost::directedS,
3   LineGraphNode, LineGraphLine > LineGraphType;
```

Listing 4.3: typedef a *line graph* to make the code more readable.

The operation when building the *graph* is that first all *vertices* in the *topology* gets added to the *Boost graph*, and then each *topology edge* gets examined to see if there are any restrictions that apply. If not, the correct number of edges (corresponding to the number of lanes) in each direction gets added to the graph.

When building the *line graph*, all the edges in the graph are added as *nodes* in the *Boost line graph*. To find which other nodes to connect to (= which travels are allowed), one has

to look at all *out-going* edges from the *end vertex* of the edge, functioning as a *via-vertex*. That *turn* (or travel) is really in three parts: *source edge* → *via vertex* → *target edge*. The *OpenStreetMap* data also gives the option to specify turns as travel via another edge instead of via a vertex, but that is complicated, see discussion in 4.2.7. When the *adjacent* edges have been identified, they are one by one checked if they are part of any *turning restriction*. If the edge is not part of such a restriction, then a *line* (that is a *line graph edge*) is constructed from the *source node* to this *target edge/node* and added to the *line graph*.

EdgeCost

(See source code in appendix D.7.12 (header), D.7.13 (implementation)).

The `EdgeCost` is a class for keeping track of different costs for edges. It has three types of costs: *travel time*; *barriers*; *other*. The *travel time* cost represents the time it takes to travel the edge, and is thus dependent on the *length*, *speed limit* or *road category* and *surface*. The *barrier type* is for costs that comes from slowdowns imposed by barriers such as *speed bumps*, *gates* and such. The *other* cost are for slowing down for *signs*, *traffic signals*, *zebra crossings* and the likes.

A note on stop signs: they are associated with a road. But it is generally only applicable in one direction. For example the stop sign only affects the incoming edge in a junction, not the reverse direction of the same road going out of the junction. Therefore one needs to look at the position of the stop signs and find out which junction it really belongs to, and then only apply the cost to the affected edge. This is not implemented yet, so at the moment edges in both directions of roads with signs have costs added, which is faulty behavior.

TurnCostCalculator

(See source code in appendix D.7.16 (header), D.7.17 (implementation)).

When calculating the *costs* or *weights* for a *line* in the *line graph* it is the cost for the *source node/edge* plus the cost for the *turn*. This `TurnCostCalculator` helps with that. The calculations for this has been re-factored out to its own class as one can imagine wanting to include different properties when calculating the cost. Thus it would make sense to make this an interface and add different implementing classes, but this project just has this one implementing class for now, and therefore skipped the interface.

The inspiration for the calculations made by this calculator comes from [7], but not all factors in that paper are included here.

It is obvious that it is more costly to make a sharp turn, as one needs to decelerate coming in to the turn, and accelerate going out of the turn. The sharper the turn, the slower one needs to go. The deceleration and acceleration characteristics are properties of the routed vehicle. Also if one is coming from a lower ranking road category and is turning into a higher category, one needs to give way, which is also a cost.

EdgeRestriction

(See source code in appendix D.7.14 (header), D.7.15 (implementation)).

Restrictions for edges/roads can be somewhat complicated. Some regulates *general access*¹ with values such as *yes*, *no*, but in addition much more arbitrary values such as *permissive*; *designated*; *discouraged*; *customer*. Then other restricts access depending on the *vehicle type* such as banning *cars* but allowing *buses*. Then again, the restriction can depend on the *vehicle properties* such as *weight* or *width*. In some cases, such as *sump buster barrier*², it can ban access for a car, but only impose a cost on a bus. A road can also be tagged as *disused*, which is clear, but it is not so clear what to do with a road marked as *no-exit*.

An edge might not have a restriction by itself, but be part of a *turning restriction relationship*, so that one can not turn from one edge to another, although traffic is allowed on both edges. In addition, the specifications (see appendix A) said that *conditional restrictions*

¹<http://wiki.openstreetmap.org/wiki/Key:access>

²http://wiki.openstreetmap.org/wiki/Tag:barrier%3Dsump_buster

should be respected, that is restrictions that only apply for example at a certain time, a certain day of the week, for vehicles with certain properties or of a certain category, see figure 4.5.

The *conditional restrictions* has not been implemented yet, and the whole class is marked by being developed incrementally while discovering how many separate and complex parts of *OpenStreetMap* represents some kinds of restrictions.



Figure 4.5: Conditional restrictions. [14]

4.2.5 lgu

The `lgu` package (see appendix listing C.6) is the *entry point* into the whole software module. The specification (appendix A) said that the module should be called from a function `get_directed_line_graph()`. This has not been written yet, so the entry point is by instantiating a `LineGraphUtility` object and call `get_line_graph()` on it, but it would be simple to write a wrapper to actually provide the specified function if needed.

The package is really only one class, `LineGraphUtility`, and how it works has been described in section 4.1.1.

4.2.6 mapprovider

This package (see appendix listing C.7), should contain sub-packages, as the `mapprovider` directory otherwise only contains an interface, `MapProvider`, and an exception class. The interface is the way to get map data from a source (such as a database) into the classes of the application.

There are two sub-packages in the project. One is `jsontest`, which in the initial phases of the project was used to load a small set of edges and vertices from a `json` file. It has been abandoned after loading from database was developed, but still hangs around.

The other sub-package is `postgis`, which is a map provider that uses a *PostGIS* database with the `postgis_topology` extension as the source for map data. This is where a lot of development has taken place during this project.

postgis

The `postgis` package uses the `libpqxx` to work with the *PostGIS* database. The `PostGisProvider` class gets passed in a `Topology` object to modify when asked for a *topology* or to set *restric-*

tions and costs. It also knows how to persist the *lines* and *nodes* of a *line graph* back to the database, which was desired functionality in the specification (see appendix A).

All the logic to work with the database and how to fill in the topology exists in this package. To make it more manageable, the `PostGisProvider` has four helper classes to actually perform the queries and handle the results from the database. They have names that describes their area of work: `CostQueries`; `LineGraphSaveQueries`; `RestrictionQueries`; `TopologyQueries`. They are all *static* classes and cannot be instantiated, one can only call the methods statically.

Some remarks about those classes:

The `TopologyQueries` simply fetches the relevant data for vertices and edges. For the latter case, it also performs some calculations in the *SQL* query to calculate the geometric data.

The `LineGraphSaveQueries` creates a new schema and table and inserts some basic information about the *nodes* and *lines*.

The `RestrictionQueries` has to extract all the different information for *edge restrictions* (see section 4.2.4). It uses an inner class for *turning restrictions* to work with those queries and to extract `OsmTurningRestriction` data (see section 4.2.7) so those restrictions can be resolved. Turning restrictions are not really attributes of edges, but *relations* in the *OpenStreetMap*, and the `osm2pgsql` tool for importing *osm* data into a *PostGis* database does not really handle relations so they can be used straightforwardly³. Therefore some workarounds have been made: In the process of initializing the database on creation a `turning_restrictions` is created and a couple of custom *sql* functions are installed (see appendix D.13.3 and D.13.2), that extract *turning restrictions* relations from the table `planet_osm_rels`, and parses what kind of restriction it is and the *osm ids* of the members (i.e. the edges and vertex involved). With those *ids* the involved *topology edges* are identified and stored as a string as the that is easier to make use of in the program than an array. The result are stored in the `turning_restrictions` table, and when running the `RestrictionQueries` for turning restrictions the topology ids are parsed and operation can continue.

4.2.7 osm

This package (see appendix listing C.8) deals with handling concepts and constants in *OpenStreetMap* data, such as enumerating the different categories of *accesses*⁴, *barriers*⁵, *highways*⁶ and *vehicles*⁷.

OsmTurningRestriction

In addition to those classes above, there is a class for dealing with the concept of *turning restrictions*, which are *relations* between *edges* and *vertices* in an *OpenStreetmap*. This class is an attempt to keep track of that information. In *OSM* a turning restriction is a relation of (*from* → *via* → *to*). The ‘*via*’ part can be either a vertex (at a junction) or other edges, saying “travel from Here to There via roads This and That are not allowed”. That kind of relationship is a lot trickier to represent, especially for this software module that only should build a *line graph* of the allowed turns, but has no routing information and thus cannot decide if a “*via way*” relation is allowed or not. It has therefore been disregarded in this project, and a routing application needs to decide that information some other way. The class `OsmTurningRestriction` has a field telling if it is a *via way* or a *via vertex* restriction.

4.2.8 preparation

Before anything else can be done, one needs to prepare the database. That means installing needed extensions to handle geometric and geographic data, and set up some tables and functions needed. Then one can add the map data to the database.

³<http://wiki.openstreetmap.org/wiki/Osm2pgsql/schema>

⁴<http://wiki.openstreetmap.org/wiki/Key:access>

⁵<http://wiki.openstreetmap.org/wiki/Key:barrier>

⁶<http://wiki.openstreetmap.org/wiki/Key:highway>

⁷<http://wiki.openstreetmap.org/wiki/Key:vehicle>

Appendix listing C.9 show the contents of this package. There is an .sql file (see listing D.13.3) for initializing extensions `postgis`; `postgis_topology`; `hstore` and installing functions for finding *turning restrictions*. And there is a .sql file to use when building the topology in advance. Then there is a file `LGU.style` which tells `osm2pgsql` which tags to create columns for in the tables, and which tags to ignore. Then there is also the original .osm files with map data for *Mikhailovsk* and *Partille* (they are not included in the appendix, but there are instructions how to download them there, see appendix listing D.1 and D.2).

The way to prepare the database is shown in listing 4.4, which sets up a new database `mikh_db` for the *Mikhailovsk* map data.

```
$ # 1. Create database
$ createdb mikh_db -U tester

$ # 2. Install extensions and functions
$ psql -U tester -d mikh_db -f init_osm2pgsql_postgis_topology.sql

$ # 3. Import OSM data
$ # Flags: -s      Slim mode (add data to db, do not build all in memory)
$ #        -k      Keep tags in `hstore` if not in own column
$ #        -S      Style-file to use
$ osm2pgsql -U tester -d mikh_db -s -k -S LGU.style mikhailovsk.osm

$ # 4. Building topology (optional)
$ psql -U tester -d mikh_db -f build_postgis_topology.sql
```

Listing 4.4: Preparing a database with map data.

4.2.9 util

This package (see listing in appendix C.10) contains a few utility classes: one for *logging* (using *Boost logging*) to be used where needed in the application; one for a *coordinate point* and one for *producing strings from current timestamp* which is used when building temporary topologies.

4.3 Development environment

Development of the project and the coding has taken place in *Eclipse Luna 4.4.2*. The build system is the default in Eclipse on Linux, generating *makefiles*.

- Compiler flags:
 - `std=c++11`
 - `DBOOST_LOG_DYN_LINK`
 - `O0`
 - `g3`
 - `Wall`
 - `c`
- Linker flags:
 - `lboost_log`
 - `lboost_log_setup`
 - `lboost_thread`
 - `lboost_system`
 - `lpthread`
 - `lpqxx`
 - `lpq`

The coding was to follow a *coding standard* (see appendix [A.7](#)) which regulates the naming scheme and the layout of the files.

As for working with the database the main tool has been *pgAdmin3*.

5 Results

The software module developed in this project does not fulfill all requirements (see appendix A), in that it does not handle *conditional restrictions* at all, and not all implemented restrictions are handled correctly, see section 5.1 below.

But the software does build a *line graph* that can be fetched and stored in database for inspection with visual tools, see section 5.2 below.

The project has so far been about implementing things and have not had any focus on performance, but some performance tests have been run, see section 5.3.

5.1 Specification fulfillment

Table 5.1 shows how much of the specification that has been fulfilled.

Table 5.1: Fulfillment of specification.

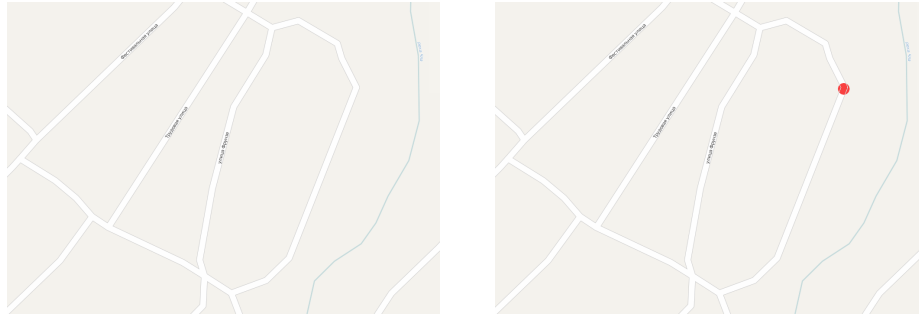
Section	Fulfills	Comment
1.2 Main use case		
1.2.1	X	As call to <code>LineGraphUtility::getLineGraph()</code> .
1.2.2	X	
1.2.3	X	
1.2.4	X	
1.3 Optional use case		
1.3.1	X	
1.3.2	X	
1.4 Functional requirements		
1.4.1		Lots of work remains to implement all restrictions.
1.4.2	X	
1.4.3	X	
1.4.4	X	Some small parts are hard coded.
1.5 Non-functional requirements		
1.5.1	X	Written in C++.
1.5.2	X	Did not find <code>pgRouting</code> really useable.
1.6 Testing requirements		
1.6	X	
1.7 Coding standard		
1.7	X	

5.2 Visual examination

Maps are easy to visualize, and a great number of tools exist to work with map data. Figure 5.1 shows a piece of a map over Mikhailovsk. In order to test if the handling of restrictions work, modified maps have been created. *JOSM*¹ is a tool for manipulating *OSM* data. In figure 5.1b it is indicated where a *bollard barrier* has been added in the middle of a road,

¹<https://josm.openstreetmap.de/>

just to see if the restrictions work, and the new map is saved in its own .osm file, and a new database built for it.



(a) Original.

(b) Modified with added barrier.

Figure 5.1: Map over part of Mikhailovsk. [15]

Using another tool, *QGIS*² can be used to load map data from for example a *PostGIS* database and viewed. In figure 5.2 the vertices and edges from the topology for that map has been layered on top of the image (with a slight misalignment). The topology is the same for both maps, it does not change with added barriers.

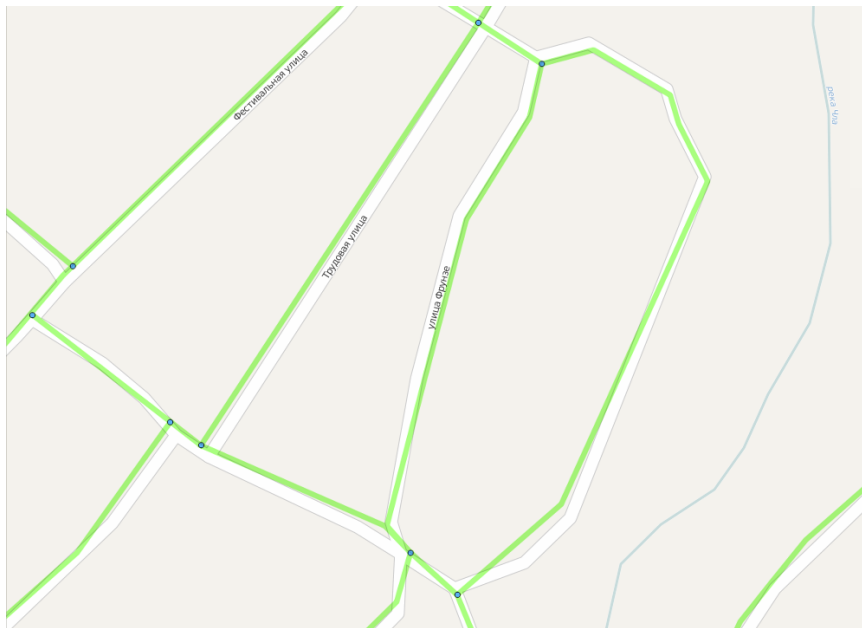


Figure 5.2: Edges (green) and vertices (blue) for the topology.

The interesting part is to see if the restriction has had any impact on the built *line graph*, see figure 5.3 for the original line graph, where the road is included in the line graph. It has a *node* in the middle and *lines* connecting to the adjacent *edges/nodes*.

Figure 5.4 shows the line graph after the restricting barrier has been added to the map. There one can see that the *edge* (road) has not been added as a *node* to the line graph, while all the other *lines* and *nodes* remain the same. This practically disables routing along that road.

²<http://www.qgis.org>



Figure 5.3: Original *line graph*. Lines in purple.

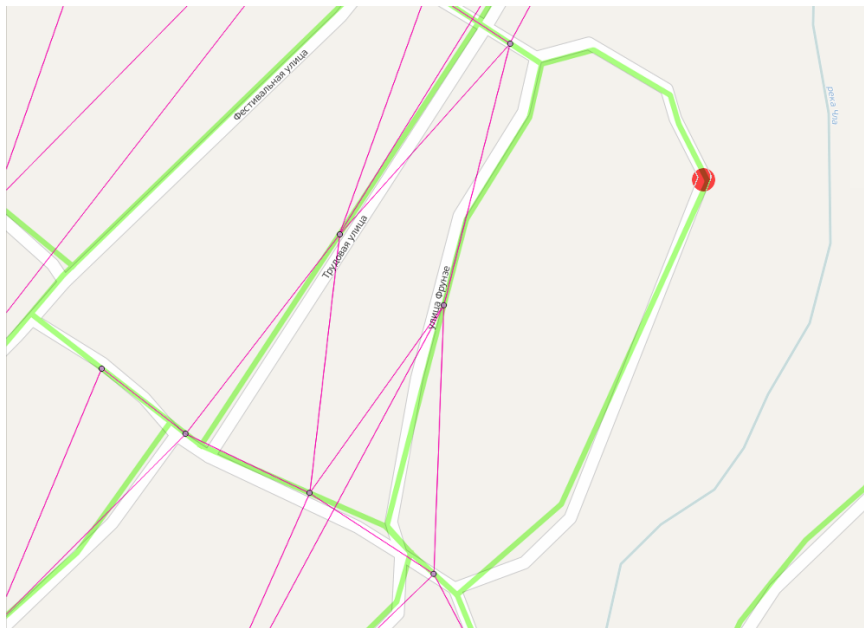


Figure 5.4: *Line graph* after added barrier. Lines in magenta.

5.3 Performance

There were *soft real time* requirements in the specification, but they were not specified more than that. But it is interesting so find out how long it takes to fetch a *line graph*, built on demand by the software module.

A few test cases were written in `LineGraphUtility_test.cc` that averages the number of *microseconds* it takes to instantiate a `LineGraphUtility` and fetch a *line graph*, over a given number of rounds.

The test runs on both a configuration with a pre-built topology, and a configuration that builds a temporary topology.

See table 5.2 for test results.

Table 5.2: Time in μs to fetch a *line graph*, with pre-built versus temporary topologies.

Test #		1	2	3	4	Sum
# of rounds		10	10	10	70	100
topology		avg (μs)	avg (μs)	avg (μs)	avg (μs)	avg (μs)
Mikhailovsk	normal	147859	149092	141782	133950	143171
	temporary	5026626	4924245	4917319	4875838	4936007
Partille	normal	180340	188405	179883	179978	182152
	temporary	10683194	10342420	10683873	10521535	10557756

The *size* (number of edges) and *order* (number of vertices) of the graphs are shown in table 5.3.

Table 5.3: Sizes of tested graphs

	Graph		Line graph	
	vertices	edges	nodes	lines
Mikhailovsk	654	1618	1618	4758
Partille	1645	2265	2265	5577

The results shows that, in order to meet *soft real time requirements* it is not possible to build temporary topologies at every instantiation of a `LineGraphUtility`, as the time increases dramatically. In the case of *Mikhailovsk*, the increase is from 0.14 s to 4.93 s, about 34 times as much. In the case of *Partille*, the increase is from 0.18 s to 10.55 s, nearly 58 times.

That fetching a line graph with a pre-built topology takes 0.15-0.2 s might fall within the requirements.

The test were conducted on a computer with 8 GB ram, processor Intel i7-4702MQ, running Linux Mint 17.1 with Linux kernel version 3.13.0-37-generic. The compiler flags were the same as for the rest of the project, i.e. no optimization.

6 Discussion

Presented below is my personal views of parts of the project and the outcome of it.

6.1 Research

6.1.1 Graph theory

Starting out on this project, I thought that one of the main obstacles would be no prior knowledge of *graph theory*, so I set out to allow for some time initially to get into the field. I am glad to have gained some fundamental knowledge of the area, but the time spent here could have been less.

6.1.2 Map routing

Reading about theory regarding map routing and graphs was really interesting, and a lot of research has been done in this area in later years. It initially gave me some ideas I thought I would like to try out, but once development got going, those theories vanished in favor of finding working solutions quickly.

6.1.3 Map data

OpenStreetMap is the source of map data for this project, and a lot of high quality projects. That puzzles me somewhat, because I have found it kind of messy. It is an *XML* application, but it has no official *schema*. That is, there is an informal consensus on which tags are good, but one can also make up ones own tags¹. Another example of the messiness is the `maxspeed` tag, which can have the values *60*; *50 mph*; *10 knots*. That is, the default case is a unit of *km/h* and one can read the value as numeric. But one cannot be sure of that, because other units are allowed, and in that case one needs to parse the value as a string to find out which unit is used. It would surely have been better to let the unit be an attribute of the value, so one did not need to parse every value. In this project I decided to skip parsing, and just assume all values are *km/h*.

But, as said, a lot of good applications using *OSM* exists, see 2.4, so it is possible to work with. And it might also be unfair to say that *OpenStreetmap* is messy; it might be the case that it simply reflects the complex and difficult reality in the traffic, with lots of different rules and restrictions dependent on context and conditions.

6.1.4 Available applications

The fact that a lot of applications already existed, and some of them being *open source* and using *OpenStreetMap* as the the source for map data, made the direction of this project a little difficult. I proposed to the company that there are some good solutions out there that might just need some adaption to work, but they wanted their own thing. So the question for me was if I was to look at and copy features and concepts of those existing solutions anyway or just blindly go down my own path. In order to steer clear of issues with plagiarism I chose the latter, and that has surely impacted the project negatively. It would have been wiser to build upon the experience of others, developed through years.

6.2 Methodology

The main methodology for the project was supposed to be test driven (either BDD or TDD), but to be honest, most tests were written after the implementation of a feature, functioning

¹http://wiki.openstreetmap.org/wiki/Map_Features

more as unit test, than driving the development. I don't think that has affected the outcome of the project negatively, it is more a matter which workflow feels best.

6.3 Design

Previously I have been more into heavy design and modeling before starting coding, but in the last year I have tried to become more “agile”, and start testing things out and be prepared to refactor and remodel when needed.

In this project perhaps it could have been good to design more, to have really thought through how the restrictions should work. On the other hand, a lot of the difficulties was discovered only when working on them, so it would be hard to have the full picture before. It is a balance in getting going and learning, and modeling before. What is clear, is that parts of the software as it stands now, should be re-modeled, specifically the *restrictions*.

6.4 Development

6.4.1 Coding standard

This was the first time I had to code to a standard. It was kind of awkward and unintuitive at first as it differs from my personal style, especially since having started to try to practice “*Clean Code*”. and have less comments and visual dividers in the file. But after a short time the style became pretty easy to use. I don't think I have followed the standard completely, but it was too long to read and get into before beginning to code.

6.4.2 Memory management

I tried to avoid pointers and only use references, but that turned out to be clumsy, so at times I reverted to using raw pointers. Eventually, I found out that it would have been a lot better to use the smart pointers from C++11 (or even Boost), but I did not want to spend the time needed for learning how to use them and redo the memory management completely.

6.4.3 Tools

OSM conversion

I tested and looked at a number of tools for converting *OpenStreetMap* data to a *PostGIS* database, and the choice fell on *osm2pgsql*. I am not certain that it was the right choice, as it has some shortcomings when working with restrictions. Fortunately, the developed software module is flexible so one can write a new *MapProvider* if one decides to work with another tool, that uses a different approach.

Database

The *pqxx* library was easy and straight-forward to work with.

Boost

This was the first time for me to use *Boost*. I have only used small parts of the library: obviously the *graph* package, the *property_tree* for parsing *json* and the *logging* package. There are some tricky concepts, but also a lot of useful stuff. Getting into all the long names and templates takes some getting used to, but it was OK.

Catch test

I really enjoyed the *Catch* testing library; small and easy to use. It didn't play so nicely with *Eclipse CDT*, marking errors throughout in the editor, but good enough.

6.4.4 OpenStreetMap Restrictions

Turning restrictions are *relations*, and *osm2pgsql* does not really handle relations, so a lot of parsing was needed. And in the case of *conditional restrictions* I have not found out how to work with them. *osm2pgsql* can be instructed to put tags into separate columns in the database, but with conditional restrictions the tags changes ‘looks’ and the only way to find them is by parsing the *hstore* column.

Also, the *restriction* class in the application is kind of messy. It could do with some remodeling, partly to clean up, and partly to make it more extensible to incorporate *conditions*. The *OSM* syntax for *conditional restrictions*² is shown in listing 6.1, and could work as a model for developing a more generic restrictions class.

```
<restriction-type>[:<transportation mode>][:<direction>]:conditional  
= <restriction-value> @ <condition>[:<restriction-value> @ <condition>]
```

Listing 6.1: Syntax of conditional restrictions in OpenStreetMap.

6.5 Documentation

A lot of the time of the project has also been devoted to documentation and writing this report. I took the opportunity to learn how to write a report in \LaTeX , using the excellent web service www.sharelatex.com. It has been a pleasure, and it feels really good not to depend on the shaky features with cross-referencing in word processors.

6.6 Results

As the project does not fulfill all requirements and did not finish on time, it was not all that successful. The reason for not meeting the specification is that I ran out of time, partly due to the specification was supplied more than two weeks late, and partly due to the complexities with handling restrictions.

It would be possible to continue development, most on finding good ways to handle conditional restrictions. From my horizon, I still think that the best solution would be to adapt an existing solution that has been developed and refined by many people through many years. Perhaps using *OSRM* together with a *PostGIS* database as demonstrated here: <https://www.mapbox.com/blog/osrm-using-external-data/>. But I do not have any overview of the greater project, and what it is trying to accomplish.

This project shows that there exists really good products, and that rolling ones own is not trivial. What first seemed like a straightforward sequential piece of software turned out to be tangled in complex handling of restrictions.

²http://wiki.openstreetmap.org/wiki/Conditional_restrictions

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- [15] OpenStreetMap contributors ©. *OpenStreetMap*. [License: Creative Commons Attribution-ShareAlike 2.0]. 2015. URL: <https://www.openstreetmap.org/#map=18/45.13903/42.03324> (visited on 2015-10-22).

A Specification

The complete specifications from the company.

A.1 General

Line Graph Utility, *LGU* is a software utility which can poll a PostGIS database for a road network and builds a directed line graph from that. The directed line graph is stored in memory and the call to `get_directed_line_graph()` returns a directed line graph stored in a C++ *Boost* graph structure. The directed line graph is built based on the time of the day, road signs, traffic lights and other conditions.

A.2 Main use case

A.2.1 Call `get_directed_line_graph()` from C++ code.

A.2.2 LGU queries the PostGIS database and builds a graph from the road network.

A.2.3 LGU builds a directed line graph from the previous step (i.e. it converts nodes to edges and assigns weight to those edges based on road signs and other elements which are present in the nodes).

A.2.4 `get_directed_line_graph()` returns a directed line graph structure which is based on a C Boost graph structure to the function caller.

A.3 Optional use case

A.3.1 All main use case steps.

A.3.2 Write the resulting directed line graph to a separate heterogeneous table in the PostGIS database so that the graph can be viewed in QGIS.

A.4 Functional requirements

A.4.1 LGU should take into account the following elements when building a directed line graph and calculating a weight for each edge: road signs (including time scheduling for those), traffic lights, road type (OSM road types), time of the day, road marking (i.e. separate lanes should be treated as separate edges), crossing and roundabouts slowdown, slopes and downhill, one way streets, road conditions, 'closed road' attribute.

A.4.2 LGU should take into account restricted turns in the road network when building a directed line graph; i.e. it should not create edges between newly created nodes in a line graph.

A.4.3 LGU should only take road signs and other conditions which are already present in the PostGIS database, the database is the only source of data for LGU.

A.4.4 LGU should store all its settings in a `settings.json` file.

A.5 Non-functional requirements

A.5.1 LGU should be written in C/C++; or, Boost.Python can be used

A.5.2 LGU can re-use architecture and code from the pgRouting software, which has a very similar structure. Namely it can re-use the steps 1 and 2 of the pgRouting's source code:

- A C module that uses a query is passed in Postgresql in order to build a line graph.
- C++ modules that convert it into a boost graph, and launch the routing.
- Return a result into psql server (this step is not required)

A.6 Testing requirements

LGU should be tested with a road network map built from 2 .osm files, `partille.osm` and `mikhailovsk.osm`.

A.7 Coding standard

Not actually written down in this document, but noted in an earlier conversation was that the company uses a *coding standard* ¹ that must be followed.

¹<http://www.possibility.com/Cpp/CppCodingStandard.html>

B UML Diagrams

Sequence and class diagrams of the software module.

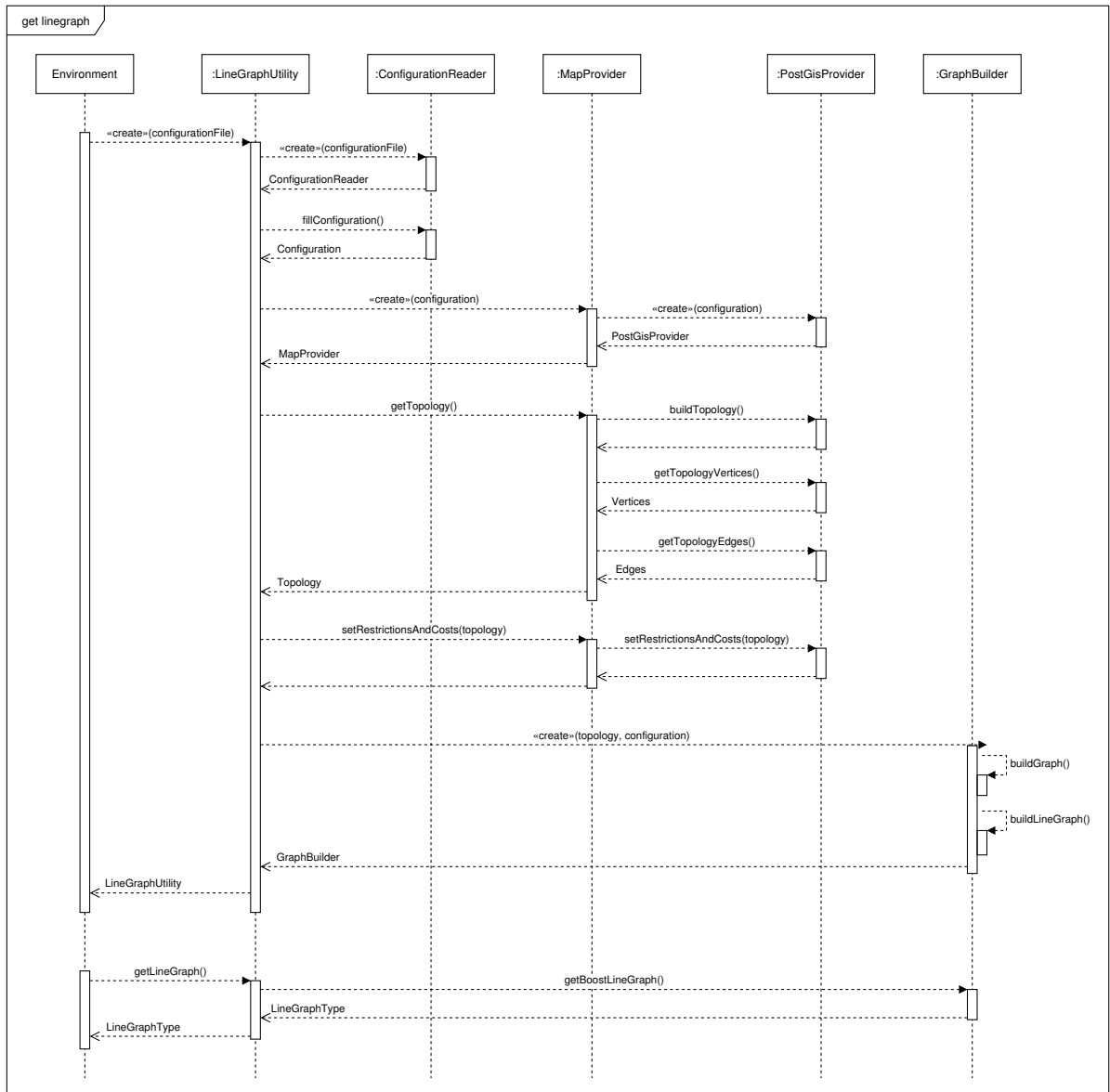


Figure B.1: Sequence diagram of main use case to get a line graph.

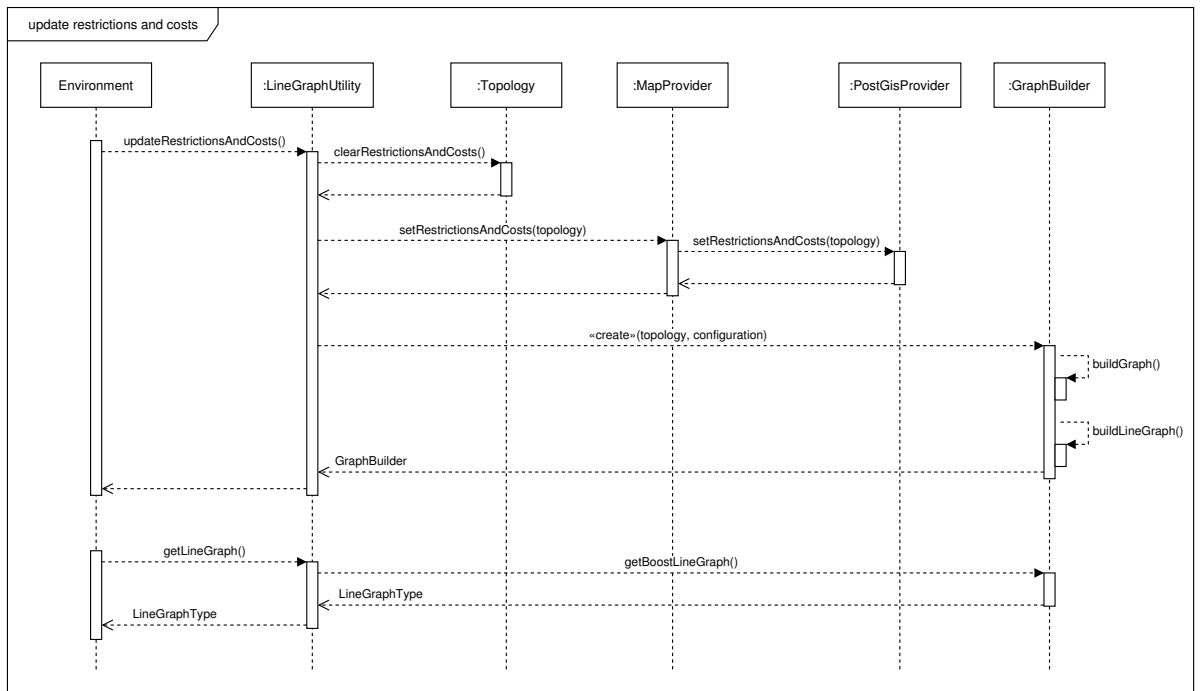


Figure B.2: Sequence diagram of updating costs and restrictions on a topology.

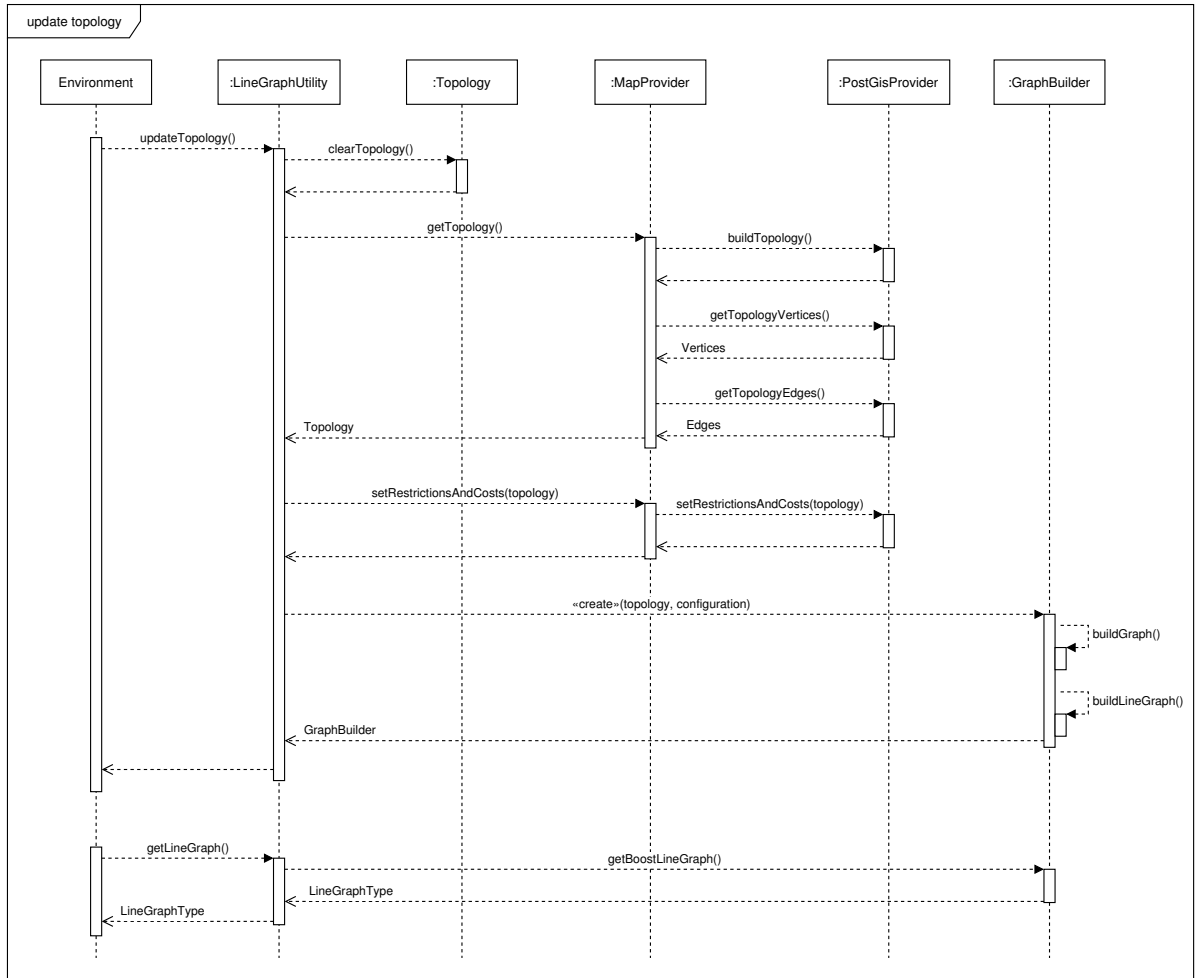


Figure B.3: Sequence diagram of updating the topology.

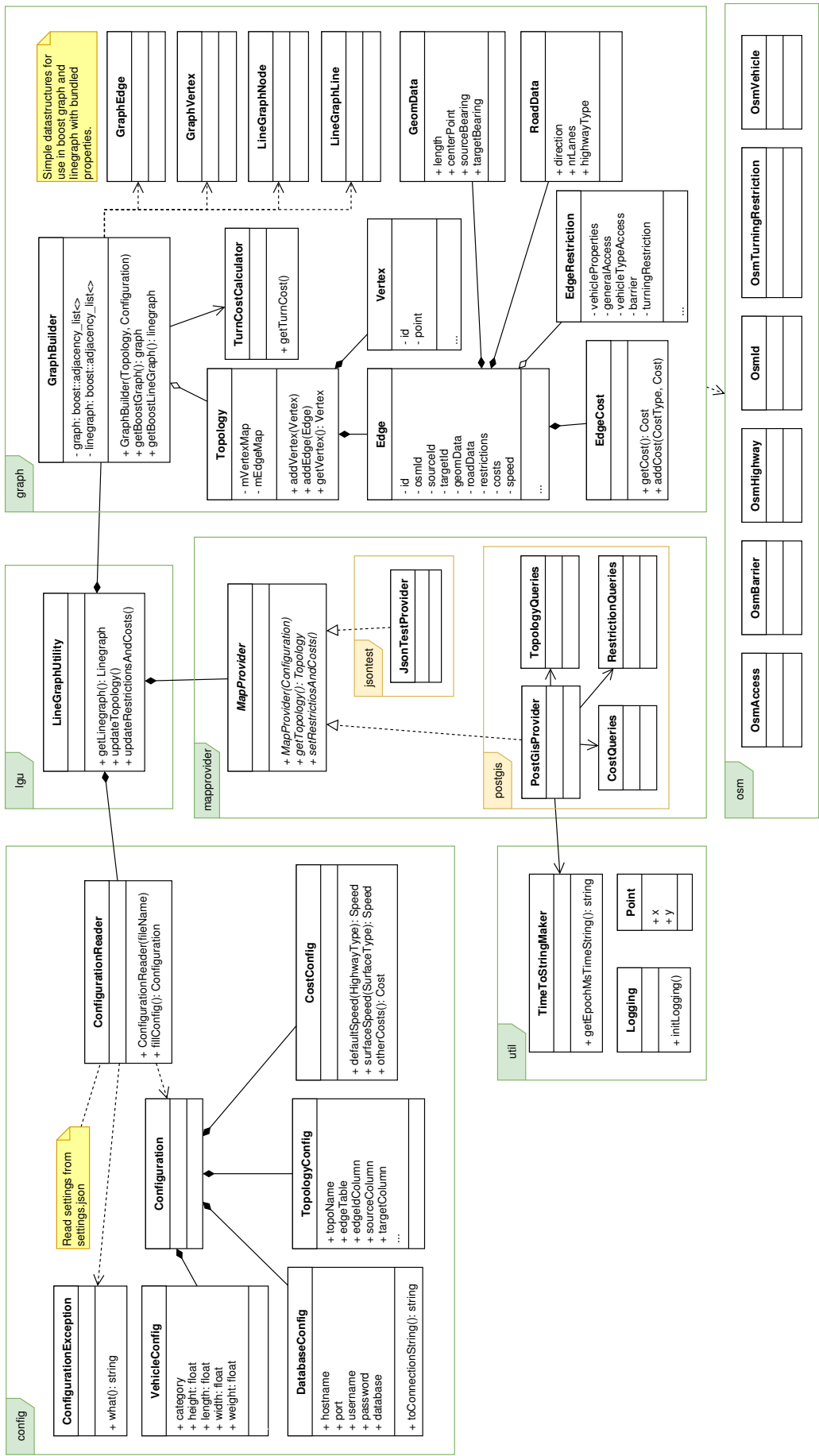


Figure B.4: Class diagram of the *line graph utility*.

C Directory listings

Contents of the directories in this project.

```
/
├── catchtest/
├── config/
├── doc/
├── graph/
├── lgu/
├── mapprovider/
├── osm/
├── preparation/
├── util/
└── README.md
```

Listing C.1: Directory structure in root of the project

```
/
├── catchtest/
│   ├── catch.hpp
│   ├── catchmain.cc
│   ├── README.md
│   └── testsettings/
│       ├── mikhailovsk-original.json
│       ├── mikhailovsk-original-temp.json
│       ├── partille-original-temp.json
│       ├── partille-original-temp.json
│       ├── ..... (10 more .json files)
│       └── restrictions/
│           ├── mikhailovsk-barrier_block.json
│           ├── partille-highway_traffic_signals.json
│           ├── ..... (17 more .json files)
```

Listing C.2: Files in /catchtest

```
/
└─ config/
    └─ catchtest/
        └─ ConfigurationReader_test.cc
    Configuration.cc
    Configuration.h
    ConfigurationException.h
    ConfigurationReader.cc
    ConfigurationReader.h
    CostConfig.h
    DatabaseConfig.h
    README.md
    TopologyConfig.h
    VehicleConfig.h
```

Listing C.3: Files in /config

```
/
└─ doc/
    └─ presentation/
    └─ report/
        └─ latex/ ..... LATEXoriginal
        jobe0900_report.pdf
        README.md
    └─ uml/
        ..... .xml, .svg, .pdf diagram files
        README.md
    README.md
```

Listing C.4: Files in /doc

```
/
└─ graph/
    └─ catchtest/
        └─ EdgeCost_test.cc
        └─ GraphBuilder_test.cc
        └─ RestrictionsAndCosts_test.cc
        └─ Topology_test.cc
        └─ TurnCostCalculator_test.cc
    └─ Cost.h
    └─ Edge.cc
    └─ Edge.h
    └─ EdgeCost.cc
    └─ EdgeCost.h
    └─ EdgeRestriction.cc
    └─ EdgeRestriction.h
    └─ GraphBuilder.cc
    └─ GraphBuilder.h
    └─ GraphException.h
    └─ README.md
    └─ RestrictionsException.h
    └─ Speed.h
    └─ Topology.cc
    └─ Topology.h
    └─ TopologyException.h
    └─ TurnCostCalculator.cc
    └─ TurnCostCalculator.h
    └─ Vertex.cc
    └─ Vertex.h
```

Listing C.5: Files in /graph

```
/
└─ lgu/
    └─ catchtest/
        └─ LineGraphUtility_test.cc
    └─ LineGraphUtility.cc
    └─ LineGraphUtility.h
    └─ LineGraphUtilityException.h
    └─ README.md
```

Listing C.6: Files in /lgu

```
/
├── mapprovider/
│   ├── catchtest/
│   │   └── MapProvider_test.cc
│   ├── jsontest/
│   │   ├── catchtest/
│   │   │   ├── JsonTestProvider_test.cc
│   │   │   ├── jsontest-settings.json
│   │   │   └── test-topology.json
│   │   ├── JsonTestProvider.cc
│   │   ├── JsonTestProvider.h
│   │   └── README.md
│   ├── postgis/
│   │   ├── catchtest/
│   │   │   └── PostGisProvider_test.cc
│   │   ├── CostQueries.cc
│   │   ├── CostQueries.h
│   │   ├── LineGraphSaveQueries.cc
│   │   ├── LineGraphSaveQueries.h
│   │   ├── PostGisProvider.cc
│   │   ├── PostGisProvider.h
│   │   ├── RestrictionQueries.cc
│   │   ├── RestrictionQueries.h
│   │   ├── TopologyQueries.cc
│   │   └── README.md
│   ├── MapProvider.h
│   ├── MapProviderException.h
│   └── README.md
```

Listing C.7: Files in /mapprovider

```
/
└─ osm/
    └─ catchtest/
        ├── OsmAccess_test.cc
        ├── OsmBarrier_test.cc
        ├── OsmHighway_test.cc
        ├── OsmTurningRestriction_test.cc
        └── OsmVehicle_test.cc
    ├── OsmAccess.cc
    ├── OsmAccess.h
    ├── OsmBarrier.cc
    ├── OsmBarrier.h
    ├── OsmException.h
    ├── OsmHighway.cc
    ├── OsmHighway.h
    ├── OsmId.cc
    ├── OsmId.h
    ├── OsmTurningRestriction.cc
    ├── OsmTurningRestriction.h
    ├── OsmVehicle.cc
    ├── OsmVehicle.h
    └── README.md
```

Listing C.8: Files in /osm

```
/
└─ preparation/
    └─ restrictions/
        ├── ..... osm-files modified with added restrictions
        ├── build_postgis_topology.sql
        ├── init_osm2pgsql_postgis_topology.sql
        ├── LGU.style
        ├── mikhailovsk.osm
        ├── partille.osm
        └── README.md
```

Listing C.9: Files in /preparation

```
/
└─ util/
    ├── catchtest/ ..... empty directory
    ├── Logging.cc
    ├── Logging.h
    ├── Point.h
    ├── TimeToStringMaker.cc
    └── TimeToStringMaker.h
```

Listing C.10: Files in /util

D Source code

A complete repository can be found at:
<https://bitbucket.org/job0900/exjobb/src> or
<https://github.com/job0900/exjobb>.

D.1 README.md

LineGraphUtility (lgu)

=====

This software module uses OpenStreetMap data to fetch topology, restrictions and
↪ costs, and uses them to build a Graph, which is converted to a LineGraph.

State of the software

The software module does not fulfill the specification yet.

Working features

- Building graph and linegraph respecting some **edge** restrictions:
 - Turning restrictions.
 - General access restrictions.
 - Vehicle type specific restrictions.
 - Vehicle property restrictions (weight, height...).
- Some restrictions on edges.
- Turning restrictions via a node, not via other roads.
- Costs.

NOT implemented features

- Inclination, different speed uphill or down hill.
- Conditional restrictions.
- Turning restrictions that are not one-to-one, but one-to-many.
- Turning restrictions via ways (not via nodes).
- Parsing units, i.e. assuming all dimensions are meters and weight in metric
↪ tons and speed in km/h.

Organization

The code is organized in folders (kind of "packages") to keep it modularized. The
↪ packages are:

- **catchtest**: The main for the testing framework.
- **config**: For configuration related code.
- **graph**: For code that is related to Graphs.
- **lgu**: The main entry point into this software.
- **mapprovider**: The package for code providing access to map data.
- **osm**: Classes representing some concepts in OpenStreetMap data.
- **preparation**: osm-files and sql-files and instructions on how to set up
↪ database.
- **uml**: For uml documentation.
- **util**: A few utility classes.

Each folder should have its own `README.md` that describes what the contents and
↪ the purpose of that package is. Each package should also have their own tests
↪ in a `catchtest` folder, and preferably an `*exception class*`.

Building

Right now all development has been in Eclipse, so it is just a standard Eclipse
→ project with the makefiles that Eclipse has set up in the `Debug` folder. The
→ file `catchtest/catchmain.cc` provides the entry point for the software
→ module during testing.

Libraries

There was only need for linking with `-lpqxx` and `-lpq` (for connecting to the
→ database) until *Boost logging* was included, at which point it also became
→ necessary to link with `-lboost_log -lboost_log_setup -lboost_thread
→ -lboost_system -lpthread`.

Testing

As mentioned, testing is done with [Catch](https://github.com/philsquared/Catch).
→ Tests can be written BDD-style, and it is header only. A few quirks: some of
→ the macro-keywords, most notably ` REQUIRE`, is reported as an error in the
→ Eclipse editor, but one can ignore that.

Style

I have tried to follow the style given in [C++ Coding
→ Standard](http://www.possibility.com/Cpp/CppCodingStandard.html).

Design

I have deliberately tried to avoid passing pointers around, and rather pass in
→ references as IN-OUT parameters. The idea is that the central LGU class has
→ stack variables of `Graph`, `Topology` that gets filled in, rather than
→ obtained as pointers to objects on the heap. This is to try to reduce risks
→ of complicated memory handling, while not have too much copying of large
→ objects.

Logging

Boost logging was the last feature added, and is so far only used in the `Graph`
→ class. It needs to be compiled and linked with a lot of libraries:

```
-lboost_log -lboost_log_setup -lboost_thread -lboost_system -lpthread
```

The log produced is `lg_u.log` in the top level of the project.

D.2 catchtest

D.2.1 README.md

CATCH
=====

This project uses [Catch](https://github.com/philsquared/Catch) for testing. It
→ allows for writing tests BDD-style.

It doesn't play really nicely with Eclipse, as Eclipse's editor marks ` REQUIRE`
→ as errors, so the project has a lot of error markers throughout, without any
→ real errors. But the Catch way of testing is nice, so it is worth it. And
→ Eclipse flags a lot of errors for standard c++11 features as well...

When writing `SCENARIO`s or `TESTCASE`s one can tag those, which makes it easy to
→ test small parts of the code. After building you can modify the Eclipse `Run
→ Configuration` (or write on the command line) to only run those tests.

Example:

```
```cpp
SCENARIO ("Testing this module but not other", "[moduletag]")
{
 GIVEN ("a")
 {
 WHEN ("b")
 {
 THEN ("c")
 {
 REQUIRE (c)
 }
 }
 }
}
```
```

To specify which test to run, go to `Run` > `Run Configurations...`, select the
→ `Arguments` tab and in `Program arguments` write the tag, e.g. `[moduletag]`,
→ click `Apply` and `Run`.

A useful flag to add to the program arguments when running tests is `-s` to have
→ print out of every step, else you only get the final report of how many
→ scenarios have run.

D.2.2 catchmain.cc

```
1 #define CATCH_CONFIG_MAIN
2 #include "catch.hpp"
```

D.2.3 mikhailovsk-original.json

```
1 {
2     "database":
3     {
4         "host":      "127.0.0.1",
5         "port":      5432,
6         "username":  "tester",
7         "password":  "tester",
8         "database":  "mikhailovsk-original"
9     },
10
11     "topology":
12     {
13         "provider":  "postgis",
14
15         "postgis":
16         {
17
18             "topo_name":  "lgu",
19             "roads_prefix": "highways",
20             "schema_prefix": "topo",
21             "build": {
22                 "temp_topo_name": "",
23                 "srid": 900913,
24                 "tolerance": 1.0
25             },
26             "edge":
```

```
27         {
28             "table":      "edge_data",
29             "id_col":     "edge_id",
30             "source_col": "start_node",
31             "target_col": "end_node",
32             "geom_col":   "geom"
33         },
34         "vertex":
35         {
36             "table":      "node",
37             "id_col":     "node_id",
38             "geom_col":   "geom"
39         }
40     },
41
42     "pgrouting":
43     {
44     },
45
46     "jsontest":
47     {
48         "test_file": ""
49     }
50
51 },
52
53 "vehicle":
54 {
55     "category": "motorcar",
56     "motorcar":
57     {
58         "height": 1.6,
59         "length": 4.5,
60         "width": 1.9,
61         "weight": 2.0,
62         "maxspeed": 200,
63         "acceleration": 10,
64         "deceleration": 7
65     }
66 },
67
68     "access":
69     {
70         "allow":
71         [
72             "yes",
73             "permissive",
74             "designated"
75         ]
76     },
77
78     "restrict":
79     {
80         "barriers":
81         [
82             "block",
83             "bollard",
```



```
84         "bus_trap",
85         "chain",
86         "cycle_barrier",
87         "debris",
88         "full-height_turnstile",
89         "horse_stile",
90         "jersey_barrier",
91         "kent_carriage_gap",
92         "kissing_gate",
93         "log",
94         "motorcycle_barrier",
95         "rope",
96         "sally_port",
97         "spikes",
98         "stile",
99         "sump_buster",
100        "swing_gate",
101        "turnstile",
102        "yes"
103    ]
104
105 },
106
107 "cost":
108 {
109     "default_speed":
110     {
111         "motorway":      {"high": 110, "low": 90},
112         "motorway_link": {"high": 90,  "low": 90},
113         "trunk":         {"high": 90,  "low": 60},
114         "trunk_link":    {"high": 90,  "low": 60},
115         "primary":       {"high": 90,  "low": 60},
116         "primary_link":  {"high": 90,  "low": 60},
117         "secondary":     {"high": 90,  "low": 60},
118         "secondary_link": {"high": 90,  "low": 60},
119         "tertiary":      {"high": 90,  "low": 60},
120         "tertiary_link": {"high": 90,  "low": 60},
121         "unclassified":  {"high": 90,  "low": 60},
122         "residential":   {"high": 90,  "low": 60},
123         "service":       {"high": 40,  "low": 20},
124         "living_street": {"high": 20,  "low": 20},
125         "bus_guideway":  {"high": 80,  "low": 60},
126         "road":          {"high": 80,  "low": 50}
127     },
128
129     "surface":
130     {
131         "paved":          1000,
132         "asphalt":        1000,
133         "cobblestone":    20,
134         "cobblestone:flattened": 40,
135         "sett":           40,
136         "concrete":       1000,
137         "concrete:lanes": 40,
138         "concrete:plates": 100,
139         "paving_stones": 40,
140         "metal":          60,
```

```
141         "wood":          30,
142         "unpaved":        60,
143         "compacted":      70,
144         "dirt":           40,
145         "earth":          40,
146         "fine_gravel":    50,
147         "grass":          10,
148         "grass_paver":    20,
149         "gravel":         60,
150         "ground":         20,
151         "ice":            70,
152         "mud":            5,
153         "pebblestone":    50,
154         "salt":           70,
155         "sand":           70,
156         "snow":          50,
157         "woodchips":       5,
158         "metal_grid":     40
159     },
160
161     "barriers":
162     [
163         ["border_control", 120],
164         ["bump_gate",      30],
165         ["bus_trap",       30],
166         ["cattle_grid",    20],
167         ["entrance",       10],
168         ["gate",           30],
169         ["hampshire_gate", 60],
170         ["height_restricter", 5],
171         ["jersey_barrier", 10],
172         ["lift_gate",      60],
173         ["sump_buster",    30],
174         ["swing_gate",     60],
175         ["toll_booth",     40]
176     ],
177
178     "highway":
179     [
180         ["bus_stop",       5],
181         ["crossing",       5],
182         ["give_way",       20],
183         ["mini_roundabout", 20],
184         ["stop",           30],
185         ["traffic_signals", 30]
186     ],
187
188     "railway":
189     [
190         ["level_crossing", 20]
191     ],
192
193     "public_transport":
194     [
195         ["stop_position",  5]
196     ],
197
```

```
198     "traffic_calming":
199     [
200         ["yes",            10],
201         ["bump",           10],
202         ["hump",           10],
203         ["table",          10],
204         ["cushion",        10],
205         ["rumble_strip",   10],
206         ["chicane",        10],
207         ["choker",         10],
208         ["island",         5]
209     ]
210
211 }
212 }
```

D.2.4 mikhailovsk-original-temp.json

```
1  {
2      "database":
3      {
4          "host":        "127.0.0.1",
5          "port":        5432,
6          "username":    "tester",
7          "password":    "tester",
8          "database":    "mikhailovsk-original-temp"
9      },
10
11     "topology":
12     {
13         "provider":    "postgis",
14
15         "postgis":
16         {
17
18             "topo_name":    "lgu",
19             "roads_prefix": "highways",
20             "schema_prefix": "topo",
21             "build": {
22                 "temp_topo_name": "epoch_ms",
23                 "srid":           900913,
24                 "tolerance":      1.0
25             },
26             "edge":
27             {
28                 "table":        "edge_data",
29                 "id_col":       "edge_id",
30                 "source_col":   "start_node",
31                 "target_col":   "end_node",
32                 "geom_col":     "geom"
33             },
34             "vertex":
35             {
36                 "table":        "node",
37                 "id_col":       "node_id",
38                 "geom_col":     "geom"
39             }
40         }
41     }
42 }
```

```
40     },
41
42     "pgrouting":
43     {
44     },
45
46     "jsontest":
47     {
48         "test_file": ""
49     }
50
51 },
52
53 "vehicle":
54 {
55     "category": "motorcar",
56     "motorcar":
57     {
58         "height": 1.6,
59         "length": 4.5,
60         "width": 1.9,
61         "weight": 2.0,
62         "maxspeed": 200,
63         "acceleration": 10,
64         "deceleration": 7
65     }
66 },
67
68 "access":
69 {
70     "allow":
71     [
72         "yes",
73         "permissive",
74         "designated"
75     ]
76 },
77
78 "restrict":
79 {
80     "barriers":
81     [
82         "block",
83         "bollard",
84         "bus_trap",
85         "chain",
86         "cycle_barrier",
87         "debris",
88         "full-height_turnstile",
89         "horse_stile",
90         "jersey_barrier",
91         "kent_carriage_gap",
92         "kissing_gate",
93         "log",
94         "motorcycle_barrier",
95         "rope",
96         "sally_port",
```

```
97     "spikes",
98     "stile",
99     "sump_buster",
100    "swing_gate",
101    "turnstile",
102    "yes"
103  ]
104
105  },
106
107  "cost":
108  {
109    "default_speed":
110    {
111      "motorway":      {"high": 110, "low": 90},
112      "motorway_link": {"high": 90, "low": 90},
113      "trunk":         {"high": 90, "low": 60},
114      "trunk_link":    {"high": 90, "low": 60},
115      "primary":       {"high": 90, "low": 60},
116      "primary_link":  {"high": 90, "low": 60},
117      "secondary":     {"high": 90, "low": 60},
118      "secondary_link": {"high": 90, "low": 60},
119      "tertiary":      {"high": 90, "low": 60},
120      "tertiary_link": {"high": 90, "low": 60},
121      "unclassified":  {"high": 90, "low": 60},
122      "residential":   {"high": 90, "low": 60},
123      "service":       {"high": 40, "low": 20},
124      "living_street": {"high": 20, "low": 20},
125      "bus_guideway":  {"high": 80, "low": 60},
126      "road":          {"high": 80, "low": 50}
127    },
128
129    "surface":
130    {
131      "paved":          1000,
132      "asphalt":        1000,
133      "cobblestone":    20,
134      "cobblestone:flattened": 40,
135      "sett":           40,
136      "concrete":       1000,
137      "concrete:lanes": 40,
138      "concrete:plates": 100,
139      "paving_stones": 40,
140      "metal":          60,
141      "wood":           30,
142      "unpaved":        60,
143      "compacted":      70,
144      "dirt":           40,
145      "earth":          40,
146      "fine_gravel":    50,
147      "grass":          10,
148      "grass_paver":    20,
149      "gravel":         60,
150      "ground":         20,
151      "ice":            70,
152      "mud":            5,
153      "pebblestone":    50,
```

```
154         "salt":          70,
155         "sand":          70,
156         "snow":         50,
157         "woodchips":     5,
158         "metal_grid":    40
159     },
160
161     "barriers":
162     [
163         ["border_control", 120],
164         ["bump_gate",      30],
165         ["bus_trap",       30],
166         ["cattle_grid",    20],
167         ["entrance",       10],
168         ["gate",           30],
169         ["hampshire_gate", 60],
170         ["height_restrictor", 5],
171         ["jersey_barrier", 10],
172         ["lift_gate",      60],
173         ["sump_buster",    30],
174         ["swing_gate",     60],
175         ["toll_booth",     40]
176     ],
177
178     "highway":
179     [
180         ["bus_stop",       5],
181         ["crossing",       5],
182         ["give_way",      20],
183         ["mini_roundabout", 20],
184         ["stop",          30],
185         ["traffic_signals", 30]
186     ],
187
188     "railway":
189     [
190         ["level_crossing", 20]
191     ],
192
193     "public_transport":
194     [
195         ["stop_position",  5]
196     ],
197
198     "traffic_calming":
199     [
200         ["yes",            10],
201         ["bump",           10],
202         ["hump",           10],
203         ["table",          10],
204         ["cushion",        10],
205         ["rumble_strip",   10],
206         ["chicane",        10],
207         ["choker",         10],
208         ["island",         5]
209     ]
210 }
```

211 }

D.2.5 partille-original.json

```
1  {
2    "database":
3    {
4      "host":      "127.0.0.1",
5      "port":      5432,
6      "username":  "tester",
7      "password":  "tester",
8      "database":  "partille-original"
9    },
10
11   "topology":
12   {
13     "provider":   "postgis",
14
15     "postgis":
16     {
17
18       "topo_name": "lgu",
19       "roads_prefix": "highways",
20       "schema_prefix": "topo",
21       "build": {
22         "temp_topo_name": "",
23         "srid": 900913,
24         "tolerance": 1.0
25       },
26       "edge":
27       {
28         "table": "edge_data",
29         "id_col": "edge_id",
30         "source_col": "start_node",
31         "target_col": "end_node",
32         "geom_col": "geom"
33       },
34       "vertex":
35       {
36         "table": "node",
37         "id_col": "node_id",
38         "geom_col": "geom"
39       }
40     },
41
42     "pgrouting":
43     {
44     },
45
46     "jsontest":
47     {
48       "test_file": ""
49     }
50
51   },
52
53   "vehicle":
```

```
54     {
55         "category":    "motorcar",
56         "motorcar":
57         {
58             "height":    1.6,
59             "length":    4.5,
60             "width":     1.9,
61             "weight":    2.0,
62             "maxspeed":  200,
63             "acceleration": 10,
64             "deceleration": 7
65         }
66     },
67
68     "access":
69     {
70         "allow":
71         [
72             "yes",
73             "permissive",
74             "designated"
75         ]
76     },
77
78     "restrict":
79     {
80         "barriers":
81         [
82             "block",
83             "bollard",
84             "bus_trap",
85             "chain",
86             "cycle_barrier",
87             "debris",
88             "full-height_turnstile",
89             "horse_stile",
90             "jersey_barrier",
91             "kent_carriage_gap",
92             "kissing_gate",
93             "log",
94             "motorcycle_barrier",
95             "rope",
96             "sally_port",
97             "spikes",
98             "stile",
99             "sump_buster",
100            "swing_gate",
101            "turnstile",
102            "yes"
103        ]
104    },
105
106
107     "cost":
108     {
109         "default_speed":
110         {
```



```
111         "motorway":      {"high": 110, "low": 90},
112         "motorway_link": {"high": 90, "low": 90},
113         "trunk":          {"high": 90, "low": 60},
114         "trunk_link":     {"high": 90, "low": 60},
115         "primary":        {"high": 90, "low": 60},
116         "primary_link":   {"high": 90, "low": 60},
117         "secondary":      {"high": 90, "low": 60},
118         "secondary_link": {"high": 90, "low": 60},
119         "tertiary":       {"high": 90, "low": 60},
120         "tertiary_link":  {"high": 90, "low": 60},
121         "unclassified":   {"high": 90, "low": 60},
122         "residential":    {"high": 90, "low": 60},
123         "service":        {"high": 40, "low": 20},
124         "living_street":  {"high": 20, "low": 20},
125         "bus_guideway":   {"high": 80, "low": 60},
126         "road":           {"high": 80, "low": 50}
127     },
128
129     "surface":
130     {
131         "paved":          1000,
132         "asphalt":        1000,
133         "cobblestone":    20,
134         "cobblestone:flattened": 40,
135         "sett":           40,
136         "concrete":       1000,
137         "concrete:lanes": 40,
138         "concrete:plates": 100,
139         "paving_stones": 40,
140         "metal":          60,
141         "wood":           30,
142         "unpaved":        60,
143         "compacted":      70,
144         "dirt":           40,
145         "earth":          40,
146         "fine_gravel":    50,
147         "grass":          10,
148         "grass_paver":    20,
149         "gravel":         60,
150         "ground":         20,
151         "ice":            70,
152         "mud":            5,
153         "pebblestone":    50,
154         "salt":           70,
155         "sand":           70,
156         "snow":           50,
157         "woodchips":      5,
158         "metal_grid":     40
159     },
160
161     "barriers":
162     [
163         ["border_control", 120],
164         ["bump_gate",      30],
165         ["bus_trap",       30],
166         ["cattle_grid",    20],
167         ["entrance",       10],
```

```
168         ["gate", 30],
169         ["hampshire_gate", 60],
170         ["height_restrictor", 5],
171         ["jersey_barrier", 10],
172         ["lift_gate", 60],
173         ["sump_buster", 30],
174         ["swing_gate", 60],
175         ["toll_booth", 40]
176     ],
177
178     "highway":
179     [
180         ["bus_stop", 5],
181         ["crossing", 5],
182         ["give_way", 20],
183         ["mini_roundabout", 20],
184         ["stop", 30],
185         ["traffic_signals", 30]
186     ],
187
188     "railway":
189     [
190         ["level_crossing", 20]
191     ],
192
193     "public_transport":
194     [
195         ["stop_position", 5]
196     ],
197
198     "traffic_calming":
199     [
200         ["yes", 10],
201         ["bump", 10],
202         ["hump", 10],
203         ["table", 10],
204         ["cushion", 10],
205         ["rumble_strip", 10],
206         ["chicane", 10],
207         ["choker", 10],
208         ["island", 5]
209     ]
210 }
211 }
```

D.2.6 partille-original-temp.json

```
1  {
2      "database":
3      {
4          "host": "127.0.0.1",
5          "port": 5432,
6          "username": "tester",
7          "password": "tester",
8          "database": "partille-original-temp"
9      },
10 }
```

```
11     "topology":
12     {
13         "provider":      "postgis",
14
15         "postgis":
16         {
17
18             "topo_name":      "lgu",
19             "roads_prefix":   "highways",
20             "schema_prefix":  "topo",
21             "build": {
22                 "temp_topo_name": "epoch_ms",
23                 "srid":           900913,
24                 "tolerance":      1.0
25             },
26             "edge":
27             {
28                 "table":      "edge_data",
29                 "id_col":     "edge_id",
30                 "source_col": "start_node",
31                 "target_col": "end_node",
32                 "geom_col":   "geom"
33             },
34             "vertex":
35             {
36                 "table":      "node",
37                 "id_col":     "node_id",
38                 "geom_col":   "geom"
39             }
40         },
41
42         "pgrouting":
43         {
44         },
45
46         "jsontest":
47         {
48             "test_file": ""
49         }
50     },
51
52     "vehicle":
53     {
54         "category":      "motorcar",
55         "motorcar":
56         {
57             "height":      1.6,
58             "length":      4.5,
59             "width":        1.9,
60             "weight":       2.0,
61             "maxspeed":     200,
62             "acceleration": 10,
63             "deceleration": 7
64         }
65     },
66 },
67
```

```
68     "access":
69     {
70         "allow":
71         [
72             "yes",
73             "permissive",
74             "designated"
75         ]
76     },
77
78     "restrict":
79     {
80         "barriers":
81         [
82             "block",
83             "bollard",
84             "bus_trap",
85             "chain",
86             "cycle_barrier",
87             "debris",
88             "full-height_turnstile",
89             "horse_stile",
90             "jersey_barrier",
91             "kent_carriage_gap",
92             "kissing_gate",
93             "log",
94             "motorcycle_barrier",
95             "rope",
96             "sally_port",
97             "spikes",
98             "stile",
99             "sump_buster",
100            "swing_gate",
101            "turnstile",
102            "yes"
103        ]
104    },
105
106
107     "cost":
108     {
109         "default_speed":
110         {
111             "motorway":      {"high": 110, "low": 90},
112             "motorway_link": {"high": 90, "low": 90},
113             "trunk":         {"high": 90, "low": 60},
114             "trunk_link":    {"high": 90, "low": 60},
115             "primary":       {"high": 90, "low": 60},
116             "primary_link":  {"high": 90, "low": 60},
117             "secondary":     {"high": 90, "low": 60},
118             "secondary_link":{"high": 90, "low": 60},
119             "tertiary":      {"high": 90, "low": 60},
120             "tertiary_link": {"high": 90, "low": 60},
121             "unclassified":  {"high": 90, "low": 60},
122             "residential":   {"high": 90, "low": 60},
123             "service":       {"high": 40, "low": 20},
124             "living_street": {"high": 20, "low": 20},
```

```
125         "bus_guideway": {"high": 80, "low": 60},
126         "road":          {"high": 80, "low": 50}
127     },
128
129     "surface":
130     {
131         "paved":          1000,
132         "asphalt":        1000,
133         "cobblestone":    20,
134         "cobblestone:flattened": 40,
135         "sett":           40,
136         "concrete":        1000,
137         "concrete:lanes":  40,
138         "concrete:plates": 100,
139         "paving_stones":  40,
140         "metal":           60,
141         "wood":            30,
142         "unpaved":         60,
143         "compacted":       70,
144         "dirt":            40,
145         "earth":           40,
146         "fine_gravel":     50,
147         "grass":           10,
148         "grass_paver":     20,
149         "gravel":          60,
150         "ground":          20,
151         "ice":             70,
152         "mud":             5,
153         "pebblestone":     50,
154         "salt":            70,
155         "sand":            70,
156         "snow":            50,
157         "woodchips":        5,
158         "metal_grid":      40
159     },
160
161     "barriers":
162     [
163         ["border_control", 120],
164         ["bump_gate",      30],
165         ["bus_trap",       30],
166         ["cattle_grid",    20],
167         ["entrance",       10],
168         ["gate",           30],
169         ["hampshire_gate", 60],
170         ["height_restrictor", 5],
171         ["jersey_barrier", 10],
172         ["lift_gate",      60],
173         ["sump_buster",    30],
174         ["swing_gate",     60],
175         ["toll_booth",     40]
176     ],
177
178     "highway":
179     [
180         ["bus_stop",       5],
181         ["crossing",       5],
```

```
182         ["give_way",          20],
183         ["mini_roundabout",    20],
184         ["stop",               30],
185         ["traffic_signals",    30]
186     ],
187
188     "railway":
189     [
190         ["level_crossing",     20]
191     ],
192
193     "public_transport":
194     [
195         ["stop_position",      5]
196     ],
197
198     "traffic_calming":
199     [
200         ["yes",                10],
201         ["bump",               10],
202         ["hump",               10],
203         ["table",              10],
204         ["cushion",            10],
205         ["rumble_strip",       10],
206         ["chicane",            10],
207         ["choker",             10],
208         ["island",             5]
209     ]
210 }
211 }
```

D.2.7 mikhailovsk-barrier_block.json

```
1  {
2      "database":
3      {
4          "host":          "127.0.0.1",
5          "port":          5432,
6          "username":      "tester",
7          "password":      "tester",
8          "database":      "mikhailovsk-barrier_block"
9      },
10
11     "topology":
12     {
13         "provider":       "postgis",
14
15         "postgis":
16         {
17
18             "topo_name":   "lgu",
19             "roads_prefix": "highways",
20             "schema_prefix": "topo",
21             "build": {
22                 "temp_topo_name": "",
23                 "srid":           900913,
24                 "tolerance":      1.0
25             }
26         }
27     }
28 }
```

```
25         },
26         "edge":
27         {
28             "table":      "edge_data",
29             "id_col":     "edge_id",
30             "source_col": "start_node",
31             "target_col": "end_node",
32             "geom_col":   "geom"
33         },
34         "vertex":
35         {
36             "table":      "node",
37             "id_col":     "node_id",
38             "geom_col":   "geom"
39         }
40     },
41
42     "pgrouting":
43     {
44     },
45
46     "jsontest":
47     {
48         "test_file": ""
49     }
50 },
51
52
53 "vehicle":
54 {
55     "category": "motorcar",
56     "motorcar":
57     {
58         "height": 1.6,
59         "length": 4.5,
60         "width": 1.9,
61         "weight": 2.0,
62         "maxspeed": 200,
63         "acceleration": 10,
64         "deceleration": 7
65     }
66 },
67
68 "access":
69 {
70     "allow":
71     [
72         "yes",
73         "permissive",
74         "designated"
75     ]
76 },
77
78 "restrict":
79 {
80     "barriers":
81     [
```

```
82         "block",
83         "bollard",
84         "bus_trap",
85         "chain",
86         "cycle_barrier",
87         "debris",
88         "full-height_turnstile",
89         "horse_stile",
90         "jersey_barrier",
91         "kent_carriage_gap",
92         "kissing_gate",
93         "log",
94         "motorcycle_barrier",
95         "rope",
96         "sally_port",
97         "spikes",
98         "stile",
99         "sump_buster",
100        "swing_gate",
101        "turnstile",
102        "yes"
103    ]
104
105    },
106
107    "cost":
108    {
109        "default_speed":
110        {
111            "motorway":      {"high": 110, "low": 90},
112            "motorway_link": {"high": 90,  "low": 90},
113            "trunk":         {"high": 90,  "low": 60},
114            "trunk_link":    {"high": 90,  "low": 60},
115            "primary":       {"high": 90,  "low": 60},
116            "primary_link":  {"high": 90,  "low": 60},
117            "secondary":     {"high": 90,  "low": 60},
118            "secondary_link": {"high": 90,  "low": 60},
119            "tertiary":      {"high": 90,  "low": 60},
120            "tertiary_link": {"high": 90,  "low": 60},
121            "unclassified":   {"high": 90,  "low": 60},
122            "residential":    {"high": 90,  "low": 60},
123            "service":        {"high": 40,  "low": 20},
124            "living_street":  {"high": 20,  "low": 20},
125            "bus_guideway":   {"high": 80,  "low": 60},
126            "road":           {"high": 80,  "low": 50}
127        },
128
129        "surface":
130        {
131            "paved":          1000,
132            "asphalt":        1000,
133            "cobblestone":    20,
134            "cobblestone:flattened": 40,
135            "sett":           40,
136            "concrete":       1000,
137            "concrete:lanes": 40,
138            "concrete:plates": 100,
```



```
139         "paving_stones": 40,
140         "metal": 60,
141         "wood": 30,
142         "unpaved": 60,
143         "compacted": 70,
144         "dirt": 40,
145         "earth": 40,
146         "fine_gravel": 50,
147         "grass": 10,
148         "grass_paver": 20,
149         "gravel": 60,
150         "ground": 20,
151         "ice": 70,
152         "mud": 5,
153         "pebblestone": 50,
154         "salt": 70,
155         "sand": 70,
156         "snow": 50,
157         "woodchips": 5,
158         "metal_grid": 40
159     },
160
161     "barriers":
162     [
163         ["border_control", 120],
164         ["bump_gate", 30],
165         ["bus_trap", 30],
166         ["cattle_grid", 20],
167         ["entrance", 10],
168         ["gate", 30],
169         ["hampshire_gate", 60],
170         ["height_restrictor", 5],
171         ["jersey_barrier", 10],
172         ["lift_gate", 60],
173         ["sump_buster", 30],
174         ["swing_gate", 60],
175         ["toll_booth", 40]
176     ],
177
178     "highway":
179     [
180         ["bus_stop", 5],
181         ["crossing", 5],
182         ["give_way", 20],
183         ["mini_roundabout", 20],
184         ["stop", 30],
185         ["traffic_signals", 30]
186     ],
187
188     "railway":
189     [
190         ["level_crossing", 20]
191     ],
192
193     "public_transport":
194     [
195         ["stop_position", 5]
```

```
196     ],
197
198     "traffic_calming":
199     [
200         ["yes",            10],
201         ["bump",           10],
202         ["hump",           10],
203         ["table",          10],
204         ["cushion",         10],
205         ["rumble_strip",    10],
206         ["chicane",         10],
207         ["choker",          10],
208         ["island",          5]
209     ]
210
211 }
212 }
```

D.2.8 partille-highway_traffic_signals.json

D.3 config

D.3.1 README.md

Configuration
=====

Configurations are set in the file `settings.json`. The different parts of the
↪ configuration is:

- Database
- Topology
- Vehicle
- Access
- Restrictions
- Costs

If one wishes to edit the setting, one can freely add and remove objects in
↪ `_braces_` (``[`` and ``]``), for example if one wishes to edit which values for a
↪ tag inflicts a cost. But the strings in `_curly braces_` (``{`` and ``}``) are keys
↪ that must exist, but the values for the keys can of course be edited.

Database

Configuration for connecting to the database holding map data. The expected keys
↪ and values are:

- `**"host"**`:
 - `*hostname*` (e.g. ``"localhost"``) or
 - `*ip-address*` (e.g. ``"127.0.0.1"``).
- `**"port"**`:
 - `*portnumber*` (e.g. ``5432``).
- `**"username"**`:
 - `*username*` (e.g. ``"tester"``).
- `**"password"**`:

- `*password*` (e.g. ``"tester_pass"``).
- `**"database"**`:
 - `*database name*` (e.g. ``"db_name"``).

Topology

Configurations for building or reading topology from a database. Might have

- ↳ different meanings depending on which `*MapProvider*` are used. Topologies can
- ↳ be pre-built, or they can be generated each time, depending on the settings
- ↳ in ``"build_topo"``. It is also possible to define a simple json test file, for
- ↳ testing simple topologies.

- `**"provider"**`:
 - `*name*` of `*MapProvider*`
 - ``"postgis"`` when using ``postgis_topology`` for building topologies.
 - ``"pgrouting"`` when using ``pgrouting`` for building topologies.
 - ``"jsontest"`` for simple json test topology.
- `**"postgis"**`:
 - `**"topo_name"**`:
 - `*basename*` for pre-built topologies (e.g. ``"test"``), combined with
 - ↳ ``roads_prefix`` and ``topo_prefix`` for actual names such as
 - ↳ ``"highways_test"`` and ``"topo_test"``.
 - `**"roads_prefix"**`:
 - `*prefix*` to add to ``topo_name`` (e.g. ``"highways"``) for table of roads
 - ↳ network, see above.
 - `**"schema_prefix"**`:
 - `*prefix*` to add to ``topo_name`` (e.g. ``"topo"``) for schema with topology
 - ↳ data when using ``postgis_topology``, see above.
 - `**"build"**`:
 - `**"temp_topo_name"**`:
 - ``""`` (`*empty*`) if not building temporary topologies.
 - ``"epoch_ms"`` for adding a string with the count of milliseconds
 - ↳ since "Epoch" as the ``topo_name``.
 - `**"srid"**`:
 - `*number*` identifying which projection to use.
 - ``900913`` for geometric metrical projection, unit meters.
 - ``4326`` for geographic spherical projection, unit degrees.
 - `**"tolerance"**`:
 - `*snapping*` of nodes in unit of projection when building topology,
 - ↳ e.g. 1.0 for srid 900913, or 0.001 for srid 4326.
 - `**"edge"**`:
 - `**"table"**`:
 - `*name*` of the table with topology edges (e.g. ``"edge_data"``), with
 - ↳ column for id, source, target and geometry.
 - `**"id_col"**`:

- **name** of the column in edge table with id of edges (e.g.
↪ `"edge_id"`).
- ****"source_col"****:
 - **name** of the column in edge table with vertex id of ****source**** of
↪ edge (e.g. `"start_node"`).
- ****"target_col"****:
 - **name** of the column in edge table with vertex id of ****target**** of
↪ edge (e.g. `"end_node"`).
- ****"geom_col"****:
 - **name** of the column in edge table with geometry of edge (e.g.
↪ `"geom"`).
- ****"vertex"****:
 - ****"table"****:
 - **name** of the table with topology vertices (e.g. `"node"`), with
↪ column for id and geometry.
 - ****"id_col"****:
 - **name** of the column in vertex table with id of vertices (e.g.
↪ `"node_id"`).
 - ****"geom_col"****:
 - **name** of the column in vertex table with geometry of vertex (e.g.
↪ `"geom"`).
- ****"pgrouting"****:
 - TODO.
- ****"jstest"****:
 - ****"test_file"****:
 - `""` (*empty*) if not using `*json-test` provider*.
 - **filename** to a json test-file (e.g. `"test.json"`) looking like:

```
```json
{
 "vertices": [
 [1,2,0],
 [2,2,1]
],
 "edges": [
 [1,1,2,0]
]
}
```
```

where each row in `"vertices"` are `[id,x,y]` and each row in `"edges"` are
↪ `[id, source vertex id, target vertex id, direction]`. Values for
↪ `"direction"` is `0 = BOTH`, `1 = FROM_TO`, `2 = TO_FROM`.

Vehicle

Configuration about the vehicle to route through the topology. Information might
↪ be needed to take restrictions in account.

- **category**:
 - **name** of OSM category of the vehicle. [OSM
↪ Access](<http://wiki.openstreetmap.org/wiki/Key:access>). (E.g.
↪ "motorcar"). Definition of the category must state dimensions as below.
- **category_name**:
 - **height** of vehicle in meters.
 - **length** of vehicle in meters.
 - **width** of vehicle in meters.
 - **weight** of vehicle in tons.
 - **maxspeed** of vehicle in km/h.
 - **acceleration** is the time it takes from 0 to 100 km/h.
 - **deceleration** is the time it takes from 100 to 0 km/h.

Access -----

- **allow**:
 - List of which values for tag 'access' that permits access. Those values for
↪ 'access' that are not listed here are considered to restrict access.

Restrictions -----

- **barriers**:
 - List of which values for 'barriers' that restricts access. Those values not
↪ listed are assumed to allow access.

Cost ----

Configuration relating to costs when routing through the graph.

- **default_speed**:
 - each road category has default speeds when none is specified. [OSM default
↪ speeds](http://wiki.openstreetmap.org/wiki/OSM_tags_for_routing/Maxspeed).
↪ Most roads have two speeds, 'high' and 'low', which differentiate the
↪ speeds inside and outside of a town. 'living_street' is always inside so
↪ only the low is important. 'motorway' is really the 'high' number, and
↪ the 'low' number is the speed on the links (ramps). It is not trivial to
↪ find out if a road is inside or outside of that area, so for this
↪ application which is meant to be used for routing in urban areas (?), the
↪ 'low' number is assumed for all cost calculations.
- **surface**:
 - each surface type is associated with a max speed in km/h over which one
↪ should not drive.
- **barriers**:
 - this is a list of which barriers causes a slow-down, and the number of
↪ seconds it is probable it takes to pass.
- **highway**:
 - a list of values for the 'highway' tag that can mean a time cost in seconds,
↪ such as zebra crossings, bus stops, stop or give way sign, and more.

- **"""railway"""**:
 - a list of values for the ``railway`` tag that can mean a time cost in seconds,
 - ↪ such as a crossing between railway and highway (``level_crossing``).
- **"""public_transport"""**:
 - a list of values for the ``public_transport`` tag that can mean a time cost in seconds, such as a ``stop_position`` if one thinks it is suitable to slow down when passing a bus stop.
- **"""traffic_calming"""**:
 - a list of traffic calming objects and their time costs in seconds.

D.3.2 Configuration.h

```
1  /** A container for configurations.
2      *
3      * #include "Configuration.h"
4      *
5      * @author Jonas Bergman
6      */
7
8  #ifndef CONFIG_CONFIGURATION_H_
9  #define CONFIG_CONFIGURATION_H_
10
11 // SYSTEM INCLUDES
12 //
13
14 // PROJECT INCLUDES
15 //
16
17 // LOCAL INCLUDES
18 //
19 #include "DatabaseConfig.h"
20 #include "VehicleConfig.h"
21 #include "CostConfig.h"
22 #include "../osm/OsmAccess.h"
23 #include "../osm/OsmBarrier.h"
24
25 // FORWARD REFERENCES
26 //
27
28 /**
29  * This class holds configurations for different parts of the utility.
30  * The ConfigurationReader is friend so it can populate the different
31  * configurations.
32  */
33 class Configuration
34 {
35     friend class ConfigurationReader;
36 public:
37     // LIFECYCLE
38
39     /** Default constructor.
40         */
41     Configuration() = default;
42
43
44     /** Copy constructor.
```

```
45     *
46     * @param from The value to copy to this object.
47     */
48     Configuration(const Configuration& from) = delete;
49
50
51     /** Destructor.
52     */
53     ~Configuration(void) = default;
54
55
56     // OPERATORS
57     // OPERATIONS
58     // ACCESS
59     /** Get the database related parts of the configuration.
60     * @return Reference to a DatabaseConfig.
61     */
62     const DatabaseConfig& getDatabaseConfig() const;
63
64     /** Get the topology related parts of the configuration.
65     * @return Reference to a TopologyConfig.
66     */
67     const TopologyConfig& getTopologyConfig() const;
68
69     /** Get the vehicle related parts of the configuration.
70     * @return Reference to a VehicleConfig.
71     */
72     const VehicleConfig& getVehicleConfig() const;
73
74     /** Get the rules for which values of the `access`-tag allows access
75     * and hence which values restricts access to an Edge.
76     * @return Reference to an AccessRule
77     */
78     const OsmAccess::AccessRule&
79         getAccessRule() const;
80
81     /** Get the rules for which values of the `barrier`-tag restricts access
82     * @return Reference to an RestrictionsRule
83     */
84     const OsmBarrier::RestrictionsRule&
85         getBarrierRestrictionsRule() const;
86
87     /** Get the rules for which values of the `barrier`-tag costs to pass
88     * @return Reference to an CostsRule
89     */
90     const OsmBarrier::CostsRule&
91         getBarrierCostsRule() const;
92
93     /** Get the cost related parts of the configuration.
94     * @return Reference to a CostConfig.
95     */
96     const CostConfig& getCostConfig() const;
97
98     // INQUIRY
99
100     protected:
101     private:
```

```
102 // ATTRIBUTES
103     DatabaseConfig      mDbConfig;
104     TopologyConfig      mTopoConfig;
105     VehicleConfig       mVehicleConfig;
106     CostConfig          mCostConfig;
107     OsmAccess::AccessRule mAccessRule;
108     OsmBarrier::CostsRule mBarrierCostsRule;
109     OsmBarrier::RestrictionsRule mBarrierRestrictionsRule;
110 };
111
112 // INLINE METHODS
113 //
114
115 // EXTERNAL REFERENCES
116 //
117
118 #endif /* CONFIG_CONFIGURATION_H_ */
```

D.3.3 Configuration.cc

```
1  /*
2   * Configuration.cc
3   * @author Jonas Bergman
4   */
5
6  #include "Configuration.h" // class implemented
7
8  ////////////////////////////////// PUBLIC //////////////////////////////////
9
10 //===== LIFECYCLE =====
11 //===== OPERATORS =====
12 //===== OPERATIONS =====
13 //===== ACCESS =====
14 const DatabaseConfig&
15 Configuration::getDatabaseConfig() const
16 {
17     return mDbConfig;
18 }
19
20 const TopologyConfig&
21 Configuration::getTopologyConfig() const
22 {
23     return mTopoConfig;
24 }
25
26 const VehicleConfig&
27 Configuration::getVehicleConfig() const
28 {
29     return mVehicleConfig;
30 }
31
32 const OsmAccess::AccessRule&
33 Configuration::getAccessRule() const
34 {
35     return mAccessRule;
36 }
37
```



```
38  const OsmBarrier::RestrictionsRule&
39  Configuration::getBarrierRestrictionsRule() const
40  {
41      return mBarrierRestrictionsRule;
42  }
43
44  const OsmBarrier::CostsRule&
45  Configuration::getBarrierCostsRule() const
46  {
47      return mBarrierCostsRule;
48  }
49
50  const CostConfig&
51  Configuration::getCostConfig() const
52  {
53      return mCostConfig;
54  }
55
56  //===== INQUIRY =====
57  ////////////////////////////////// PROTECTED //////////////////////////////////
58
59  ////////////////////////////////// PRIVATE //////////////////////////////////
```

D.3.4 ConfigurationException.h

```
1  /** Exception thrown by the Configuration package.
2   *
3   * #include "ConfigurationException.h"
4   *
5   * @author Jonas Bergman
6   */
7
8  #ifndef CONFIG_CONFIGURATIONEXCEPTION_H_
9  #define CONFIG_CONFIGURATIONEXCEPTION_H_
10
11  // SYSTEM INCLUDES
12  //
13  #include <exception>
14  #include <string>
15
16  // PROJECT INCLUDES
17  //
18
19  // LOCAL INCLUDES
20  //
21
22  // FORWARD REFERENCES
23  //
24
25  /**
26   * Exception to throw from the 'config' package.
27   * More information of the type of exception is given in the 'what()' message.
28   */
29  class ConfigurationException : public std::exception
30  {
31  public:
32  // LIFECYCLE
```

```
33     /** Default constructor.
34     */
35     ConfigurationException() = delete;
36
37     /** Constructor taking a message to display.
38     *
39     * @param      message      The message to prepend when 'what()' is called.
40     */
41     ConfigurationException(const std::string& rMessage) noexcept
42         : std::exception(), mMessage(rMessage)
43     {}
44
45     // OPERATORS
46     // OPERATIONS
47     // ACCESS
48     // INQUIRY
49     const char* what() const noexcept
50     { return (mMessage + " " + std::exception::what()).c_str(); }
51
52 protected:
53 private:
54     // ATTRIBUTES
55     std::string      mMessage;
56 };
57
58 // INLINE METHODS
59 //
60
61 // EXTERNAL REFERENCES
62 //
63
64 #endif /* CONFIG_CONFIGURATIONEXCEPTION_H_ */
```

D.3.5 ConfigurationReader.h

```
1  /** Read configurations from a json file.
2  *
3  * #include "ConfigurationReader.h"
4  *
5  * @author  Jonas Bergman
6  */
7  #ifndef CONFIG_CONFIGURATIONREADER_H_
8  #define CONFIG_CONFIGURATIONREADER_H_
9
10 // SYSTEM INCLUDES
11 //
12 #include <string>
13
14 // PROJECT INCLUDES
15 //
16 #include <boost/property_tree/ptree.hpp>
17 #include <boost/property_tree/json_parser.hpp>
18
19 // LOCAL INCLUDES
20 //
21 #include "Configuration.h"
22 #include "ConfigurationException.h"
```

```
23 #include "DatabaseConfig.h"
24 #include "TopologyConfig.h"
25 #include "VehicleConfig.h"
26 #include "../osm/OsmVehicle.h"
27
28 // FORWARD REFERENCES
29 //
30
31 /**
32  * A class to handle the reading of data from a json configuration file.
33  */
34 class ConfigurationReader
35 {
36 public:
37     // LIFECYCLE
38     /** Default constructor.
39      */
40     ConfigurationReader() = delete;
41
42     /** Constructor.
43      * Always initialize a Configuration reader with the configuration file.
44      *
45      * @param rFilename The filename for the configuration json file
46      * @throw ConfigurationException If invalid file
47      */
48     ConfigurationReader(const std::string& rFilename);
49
50
51 // OPERATORS
52 // OPERATIONS
53
54     /** Get the configurations from the file.
55      * @param Reference to a Configuration to populate.
56      * @throws ConfigurationException
57      */
58     void fillConfiguration(Configuration& rConfig) const;
59
60 // ACCESS
61 // INQUIRY
62
63 protected:
64
65 private:
66     // ATTRIBUTES
67     std::string mFilename;
68     boost::property_tree::ptree mPropertyTree;
69
70 // HELPERS
71     /** Read the database part of the configuration and populate config struct.
72      * @param The Database configuration
73      * @throw ConfigurationException If missing configuration.
74      */
75     void fillDatabaseConfiguration(DatabaseConfig& rDatabaseConfig) const;
76
77     /** Read the topology part of the configuration and populate config struct.
78      * @param The Topology configuration
79      * @throw ConfigurationException If missing configuration.
```

```
80     */
81     void fillTopologyConfiguration(TopologyConfig& rTopologyConfig) const;
82
83     /** Read the vehicle part of the configuration and populate config struct.
84     * @param The Vehicle configuration
85     * @throw ConfigurationException If missing configuration.
86     */
87     void fillVehicleConfiguration(VehicleConfig& rVehicleConfig) const;
88
89     /** Read the Access part of the configuration and build the rule for
90     * which tags allows access (and hence which tags restricts access).
91     * @param rAccessRule The rule to fill out.
92     * @throw ConfigurationException If missing configuration.
93     */
94     void fillAccessRule(OsmAccess::AccessRule& rAccessRule) const;
95
96     /** Read the Barrier part of the configuration and build the rule for
97     * which barriers restricts access.
98     * @param rRestrictRule The rule to fill out.
99     * @throw ConfigurationException If missing configuration.
100    */
101    void fillBarrierRestrictRule(OsmBarrier::RestrictionsRule& rRestrictRule) const;
102
103    /** Read the Barrier part of the configuration and build the rule for
104    * which barriers imposes a cost.
105    * @param rCostRule The rule to fill out.
106    * @throw ConfigurationException If missing configuration.
107    */
108    void fillBarrierCostsRule(OsmBarrier::CostsRule& rCostsRule) const;
109
110    /** Read the Cost part of the configuration and populate config struct.
111    * @param The Cost configuration
112    * @throw ConfigurationException If missing configuration.
113    */
114    void fillCostConfiguration(CostConfig& rCostConfig) const;
115
116    /** Helper to `fillCostConfig()`. Fill in the Default Speed part.
117    * @param The Cost configuration.
118    */
119    void fillDefaultSpeedCost(CostConfig& rCostConfig) const;
120
121    /** Helper to `fillCostConfig()`. Fill in the Surface Max Speed part.
122    * @param The Cost configuration.
123    */
124    void fillSurfaceMaxSpeedCost(CostConfig& rCostConfig) const;
125
126    /** Helper to `fillCostConfig()`. Fill in the cost for other edge costs.
127    * @param The Cost configuration.
128    */
129    void fillOtherEdgeCosts(CostConfig& rCostConfig) const;
130 };
131
132 // INLINE METHODS
133 //
134
135 // EXTERNAL REFERENCES
136 //
```

```
137
138 #endif /* CONFIG_CONFIGURATIONREADER_H_ */
```

D.3.6 ConfigurationReader.cc

```
1  /*
2   * ConfigurationReader.cc
3   *
4   * @author Jonas Bergman
5   */
6
7  #include "ConfigurationReader.h" // class implemented
8
9  ////////////////////////////////// PUBLIC //////////////////////////////////
10
11  //===== LIFECYCLE =====
12
13  ConfigurationReader::ConfigurationReader(const std::string& rFilename)
14      : mFilename(rFilename)
15  {
16      try
17      {
18          boost::property_tree::read_json(mFilename, mPropertyTree);
19      }
20      catch (boost::property_tree::json_parser_error& e)
21      {
22          throw ConfigurationException("Could not read file " + mFilename);
23      }
24  }
25
26  //===== OPERATORS =====
27
28  //===== OPERATIONS =====
29  void ConfigurationReader::fillConfiguration(Configuration& rConfig) const
30  {
31      fillDatabaseConfiguration(rConfig.mDbConfig);
32      fillTopologyConfiguration(rConfig.mTopoConfig);
33      fillVehicleConfiguration(rConfig.mVehicleConfig);
34      fillAccessRule(rConfig.mAccessRule);
35      fillBarrierRestrictRule(rConfig.mBarrierRestrictionsRule);
36      fillBarrierCostsRule(rConfig.mBarrierCostsRule);
37      fillCostConfiguration(rConfig.mCostConfig);
38  }
39
40  //===== ACCESS =====
41  //===== INQUIRY =====
42  ////////////////////////////////// PROTECTED //////////////////////////////////
43
44  ////////////////////////////////// PRIVATE //////////////////////////////////
45  void ConfigurationReader::fillDatabaseConfiguration(
46      DatabaseConfig& rDbConfig) const
47  {
48      std::string prefix("database.");
49
50      try
51      {
52          rDbConfig.hostname = mPropertyTree.get<std::string>(prefix + "host");
```

```
53         rDbConfig.port = mPropertyTree.get<int>(prefix + "port");
54         rDbConfig.username = mPropertyTree.get<std::string>(
55             prefix + "username");
56         rDbConfig.password = mPropertyTree.get<std::string>(
57             prefix + "password");
58         rDbConfig.database = mPropertyTree.get<std::string>(
59             prefix + "database");
60     }
61     catch (boost::property_tree::ptree_error& e)
62     {
63         throw ConfigurationException(
64             std::string("Could not read config ") + e.what());
65     }
66 }
67
68 void ConfigurationReader::fillTopologyConfiguration(
69     TopologyConfig& rTopoConfig) const
70 {
71     std::string prefix("topology.");
72
73     try
74     {
75         rTopoConfig.providerName = mPropertyTree.get<std::string>(
76             prefix + "provider");
77
78         if(rTopoConfig.providerName == TopologyConfig::PROVIDER_JSONTEST)
79         {
80             rTopoConfig.testFile = mPropertyTree.get<std::string>(
81                 prefix + "jsontest.test_file");
82         }
83         else if(rTopoConfig.providerName == TopologyConfig::PROVIDER_POSTGIS
84             || rTopoConfig.providerName == TopologyConfig::PROVIDER_PGRROUTING)
85         {
86             prefix += rTopoConfig.providerName + ".";
87
88             rTopoConfig.topoName = mPropertyTree.get<std::string>(
89                 prefix + "topo_name");
90
91             rTopoConfig.roadsPrefix = mPropertyTree.get<std::string>(
92                 prefix + "roads_prefix");
93             rTopoConfig.topologySchemaPrefix = mPropertyTree.get<std::string>(
94                 prefix + "schema_prefix");
95
96             rTopoConfig.tempTopoName = mPropertyTree.get<std::string>(
97                 prefix + "build.temp_topo_name");
98             rTopoConfig.srid = mPropertyTree.get<int>(prefix + "build.srid");
99             rTopoConfig.tolerance = mPropertyTree.get<double>(
100                 prefix + "build.tolerance");
101
102             rTopoConfig.edgeTableName = mPropertyTree.get<std::string>(
103                 prefix + "edge.table");
104             rTopoConfig.edgeIdColumnName = mPropertyTree.get<std::string>(
105                 prefix + "edge.id_col");
106             rTopoConfig.sourceColumnName = mPropertyTree.get<std::string>(
107                 prefix + "edge.source_col");
108             rTopoConfig.targetColumnName = mPropertyTree.get<std::string>(
109                 prefix + "edge.target_col");
```

```
110         rTopoConfig.edgeGeomColumnName = mPropertyTree.get<std::string>(
111             prefix + "edge.geom_col");
112
113         rTopoConfig.vertexTableName = mPropertyTree.get<std::string>(
114             prefix + "vertex.table");
115         rTopoConfig.vertexIdColumnName = mPropertyTree.get<std::string>(
116             prefix + "vertex.id_col");
117         rTopoConfig.vertexGeomColumnName = mPropertyTree.get<std::string>(
118             prefix + "vertex.geom_col");
119     }
120 }
121 catch (boost::property_tree::ptree_error& e)
122 {
123     throw ConfigurationException(
124         std::string("Could not read config ") + e.what());
125 }
126 }
127
128 void ConfigurationReader::fillVehicleConfiguration(
129     VehicleConfig& rVehicleConfig) const
130 {
131     std::string prefix("vehicle.");
132
133     try
134     {
135         std::string categoryString = mPropertyTree.get<std::string>(
136             prefix + "category");
137         rVehicleConfig.category = OsmVehicle::parseString(categoryString);
138         prefix += categoryString + ".";
139         rVehicleConfig.height = mPropertyTree.get<double>(prefix + "height");
140         rVehicleConfig.length = mPropertyTree.get<double>(prefix + "length");
141         rVehicleConfig.weight = mPropertyTree.get<double>(prefix + "weight");
142         rVehicleConfig.width = mPropertyTree.get<double>(prefix + "width");
143         rVehicleConfig.maxspeed = mPropertyTree.get<unsigned>(
144             prefix + "maxspeed");
145         rVehicleConfig.acceleration = mPropertyTree.get<unsigned>(
146             prefix + "acceleration");
147         rVehicleConfig.deceleration = mPropertyTree.get<unsigned>(
148             prefix + "deceleration");
149     }
150     catch (ConfigurationException& e)
151     {
152         throw e;
153     }
154     catch (boost::property_tree::ptree_error& e)
155     {
156         throw ConfigurationException(
157             std::string("Could not read config ") + e.what());
158     }
159 }
160
161 void ConfigurationReader::fillAccessRule(
162     OsmAccess::AccessRule& rAccessRule) const
163 {
164     std::string prefix("access.allow");
165
166     try
```

```
167     {
168         std::vector<OsmAccess::AccessType> allow_tags;
169         for (auto& item : mPropertyTree.get_child(prefix))
170         {
171             std::string tag_string = item.second.get_value<std::string>();
172             allow_tags.push_back(OsmAccess::parseString(tag_string));
173         }
174         rAccessRule.allowAccessToTypes = allow_tags;
175     }
176     catch (ConfigurationException& e)
177     {
178         throw e;
179     }
180     catch (OsmException& ose)
181     {
182         throw ConfigurationException(
183             std::string("Could not read config")
184             + ", error parsing access tag: " + ose.what());
185     }
186     catch (boost::property_tree::ptree_error& e)
187     {
188         throw ConfigurationException(
189             std::string("Could not read config ") + e.what());
190     }
191 }
192
193 void ConfigurationReader::fillBarrierRestrictRule(
194     OsmBarrier::RestrictionsRule& rRestrictRule) const
195 {
196     std::string prefix("restrict.barriers");
197
198     try
199     {
200         std::vector<OsmBarrier::BarrierType> restrict_barriers;
201         for (auto& item : mPropertyTree.get_child(prefix))
202         {
203             std::string restrict_string =
204                 item.second.get_value<std::string>();
205             restrict_barriers.push_back(
206                 OsmBarrier::parseString(restrict_string));
207         }
208         rRestrictRule.restrictionTypes = restrict_barriers;
209     }
210     catch (ConfigurationException& e)
211     {
212         throw e;
213     }
214     catch (OsmException& ose)
215     {
216         throw ConfigurationException(
217             std::string("Could not read config")
218             + ", error parsing barrier restrictions: " + ose.what());
219     }
220     catch (boost::property_tree::ptree_error& e)
221     {
222         throw ConfigurationException(
223             std::string("Could not read config ") + e.what());
```



```
224     }
225 }
226
227 void ConfigurationReader::fillBarrierCostsRule(
228     OsmBarrier::CostsRule& rCostsRule) const
229 {
230     std::string prefix("cost.barriers");
231
232     try
233     {
234         for (auto& row : mPropertyTree.get_child(prefix))
235         {
236             int i = 0;
237             std::string type_string;
238             unsigned cost;
239             for (auto& item : row.second)
240             {
241                 if(i == 0)
242                 {
243                     type_string = item.second.get_value<std::string>();
244                 }
245                 else
246                 {
247                     cost = item.second.get_value<unsigned>();
248                 }
249                 ++i;
250             }
251             OsmBarrier::BarrierType barrier_type = OsmBarrier::parseString(
252                 type_string);
253             rCostsRule.addCost(barrier_type, cost);
254         }
255     }
256     catch (ConfigurationException& e)
257     {
258         throw e;
259     }
260     catch (OsmException& ose)
261     {
262         throw ConfigurationException(
263             std::string("Could not read config")
264             + ", error parsing barrier costs: " + ose.what());
265     }
266     catch (boost::property_tree::ptree_error& e)
267     {
268         throw ConfigurationException(
269             std::string("Could not read config ") + e.what());
270     }
271 }
272
273 void ConfigurationReader::fillCostConfiguration(CostConfig& rCostConfig) const
274 {
275     try
276     {
277         fillDefaultSpeedCost(rCostConfig);
278         fillSurfaceMaxSpeedCost(rCostConfig);
279         fillOtherEdgeCosts(rCostConfig);
280     }
```

```
281     catch (ConfigurationException& e)
282     {
283         throw e;
284     }
285     catch (boost::property_tree::ptree_error& e)
286     {
287         throw ConfigurationException(
288             std::string("Could not read config ") + e.what());
289     }
290 }
291
292 void ConfigurationReader::fillDefaultSpeedCost(CostConfig& rCostConfig) const
293 {
294     std::string prefix("cost.default_speed.");
295
296     CostConfig::DefaultSpeed::HighLowSpeed hilo;
297     std::string type_string;
298     OsmHighway::HighwayType type;
299
300     for (size_t i = 0; i < OsmHighway::NR_HIGHWAY_TYPES; ++i)
301     {
302         type_string = OsmHighway::typeStrings().at(i);
303         hilo.high = mPropertyTree.get<int>(prefix + type_string + ".high");
304         hilo.low = mPropertyTree.get<int>(prefix + type_string + ".low");
305         type = static_cast<OsmHighway::HighwayType>(i);
306         rCostConfig.defaultSpeed.addDefaultSpeed(type, hilo);
307     }
308 }
309
310 void ConfigurationReader::fillSurfaceMaxSpeedCost(
311     CostConfig& rCostConfig) const
312 {
313     std::string prefix("cost.surface.");
314
315     Speed speed;
316     std::string type_string;
317     OsmHighway::SurfaceType type;
318
319     for (size_t i = 0; i < OsmHighway::NR_SURFACE_TYPES; ++i)
320     {
321         type_string = OsmHighway::surfaceTypeStrings().at(i);
322         speed = mPropertyTree.get<int>(prefix + type_string);
323         type = static_cast<OsmHighway::SurfaceType>(i);
324         rCostConfig.surfaceMaxSpeed.addSurfaceMaxSpeed(type, speed);
325     }
326 }
327
328 void ConfigurationReader::fillOtherEdgeCosts(CostConfig& rCostConfig) const
329 {
330     std::string section("cost.");
331     std::vector<std::string> subsections { "highway", "railway",
332         "public_transport", "traffic_calming" };
333
334     try
335     {
336         for (const auto& sub : subsections)
337         {
```

```
338         std::string prefix(section + sub + ".");
339
340         for (auto& row : mPropertyTree.get_child(prefix))
341         {
342             int i = 0;
343             std::string key;
344             Cost cost;
345             for (auto& item : row.second)
346             {
347                 if(i == 0)
348                 {
349                     key = item.second.get_value<std::string>();
350                 }
351                 else
352                 {
353                     cost = item.second.get_value<Cost>();
354                 }
355                 ++i;
356             }
357             rCostConfig.otherEdgeCosts.addOtherCost(sub + "=" + key,
358                 cost);
359         }
360     }
361 }
362 catch (ConfigurationException& e)
363 {
364     throw e;
365 }
366 catch (OsmException& ose)
367 {
368     throw ConfigurationException(
369         std::string("Could not read config")
370         + ", error parsing other costs: " + ose.what());
371 }
372 catch (boost::property_tree::ptree_error& e)
373 {
374     throw ConfigurationException(
375         std::string("Could not read config ") + e.what());
376 }
377 }
```

D.3.7 CostConfig.h

```
1  /** Data structure for configuration of costs.
2   *
3   * #include "CostConfig.h"
4   *
5   * @author Jonas Bergman
6   */
7
8  #ifndef CONFIG_COSTCONFIG_H_
9  #define CONFIG_COSTCONFIG_H_
10
11 // SYSTEM INCLUDES
12 //
13 #include <map>
14 #include <string>
```

```
15
16 // PROJECT INCLUDES
17 //
18
19 // LOCAL INCLUDES
20 //
21 #include "../osm/OsmHighway.h"
22 #include "../graph/Cost.h"
23 #include "../graph/Speed.h"
24
25 // FORWARD REFERENCES
26 //
27
28 /**
29  * Information about names in the database for cost data.
30  */
31 struct CostConfig
32 {
33 // TYPES
34
35 /** Keep track of default speeds for different categories of roads.
36  * The values are a high and a low value, depending of if we are inside or
37  * outside of an urban area.
38  */
39 struct DefaultSpeed
40 {
41     enum HIGH_LOW
42     {
43         HIGH,
44         LOW
45     };
46
47     struct HighLowSpeed
48     {
49         Speed high {0};
50         Speed low {0};
51     };
52
53     std::map<OsmHighway::HighwayType, HighLowSpeed> defaultSpeed;
54
55     /** Add a speed far a specific road category (highway type).
56      * @param type The highway type
57      * @param speed The high and low speed limits.
58      */
59     void addDefaultSpeed(
60         OsmHighway::HighwayType type,
61         HighLowSpeed speed)
62     {
63         defaultSpeed.erase(type);
64         defaultSpeed.insert({type, speed});
65     }
66
67     /**
68      * @param type The highway type
69      * @return The high/low speed for this type of highway.
70      */
71     HighLowSpeed getDefaultSpeed(OsmHighway::HighwayType type) const
```

```
72     {
73         const auto& it = defaultSpeed.find(type);
74         if(it != defaultSpeed.end())
75         {
76             return it->second;
77         }
78         return HighLowSpeed();
79     }
80
81     /** Get a high or low speed limit for a highway type.
82     * @param   type       The Type of highway.
83     * @param   highOrLow   Either HIGH or LOW speed
84     * @return   Either the high or low speed for a highway type.
85     */
86     Speed      getDefaultSpeed(
87                 OsmHighway::HighwayType type,
88                 HIGH_LOW             highOrLow) const
89     {
90         HighLowSpeed hl = getDefaultSpeed(type);
91         if(highOrLow == HIGH)
92         {
93             return hl.high;
94         }
95         else
96         {
97             return hl.low;
98         }
99     }
100 };
101
102 /** Keep track of max speed that are suitable for different kind of
103 * surfaces.
104 */
105 struct SurfaceMaxSpeed
106 {
107     std::map<OsmHighway::SurfaceType, Speed> surfaceSpeed;
108
109     /** Add a surface type and the max speed.
110     * @param   type       The type of surface.
111     * @param   speed      The max suitable speed for the surface type.
112     */
113     void      addSurfaceMaxSpeed(OsmHighway::SurfaceType type, Speed speed)
114     {
115         surfaceSpeed.erase(type);
116         surfaceSpeed.insert({type, speed});
117     }
118
119     /**
120     * @return   The suitable max speed for a surface type.
121     */
122     Speed     getSurfaceMaxSpeed(OsmHighway::SurfaceType type) const
123     {
124         const auto& it = surfaceSpeed.find(type);
125         if(it != surfaceSpeed.end())
126         {
127             return it->second;
128         }
```

```
129         return 0;
130     }
131 };
132
133 /** Other edge costs are kept track of simply by strings as keys and
134  * Costs as values. The costs are "penalties" added to the travel time.
135  * The string that make up the keys are simply constructed as "tag=value",
136  * e.g. "highway=give_way".
137  */
138 struct OtherEdgeCosts
139 {
140     std::map<std::string, Cost> otherCostValues;
141
142     /** Add a 'penalty' for another kind of EdgeCost.
143      * @param key    String of "tag=value" that makes up the cost.
144      * @param cost    The cost for this kind of hindrance.
145      */
146     void addOtherCost(std::string key, Cost cost)
147     {
148         otherCostValues.erase(key);
149         otherCostValues.insert({key, cost});
150     }
151
152     /** Get other costs associated with the key.
153      * @param key
154      * @return The cost for this key.
155      */
156     Cost getOtherCost(std::string key) const
157     {
158         const auto& it = otherCostValues.find(key);
159         if(it != otherCostValues.end())
160         {
161             return it->second;
162         }
163         return 0;
164     }
165 };
166
167 // ATTRIBUTES
168     DefaultSpeed    defaultSpeed;
169     SurfaceMaxSpeed surfaceMaxSpeed;
170     OtherEdgeCosts  otherEdgeCosts;
171
172 // ACCESS
173 // CONSTANTS
174
175 private:
176 };
177
178 // INLINE METHODS
179 //
180
181 // EXTERNAL REFERENCES
182 //
183
184 #endif /* CONFIG_COSTCONFIG_H_ */
```

D.3.8 DatabaseConfig.h

```
1  /** Data structure for configuration of database connection.
2   *
3   * #include "DatabaseConfig.h"
4   *
5   * @author Jonas Bergman
6   */
7  #ifndef CONFIG_DATABASECONFIG_H_
8  #define CONFIG_DATABASECONFIG_H_
9
10 // SYSTEM INCLUDES
11 //
12 #include <string>
13 #include <sstream>
14
15 // PROJECT INCLUDES
16 //
17
18 // LOCAL INCLUDES
19 //
20 #include "TopologyConfig.h"
21
22 // FORWARD REFERENCES
23 //
24
25 /** A simple data structure for holding the configuration
26  * for database connections.
27  */
28 struct DatabaseConfig
29 {
30     // ATTRIBUTES
31     std::string      hostname;
32     int              port;
33     std::string      username;
34     std::string      password;
35     std::string      database;
36
37
38     // OPERATIONS
39     /** Construct a connection string from the attributes.
40      * @return A valid connection string for 'pqxx::conn()'
41      */
42     std::string      getConnectionString() const
43     {
44         std::ostringstream oss;
45         oss << "host=" << hostname
46             << " port=" << port
47             << " user=" << username
48             << " password=" << password
49             << " dbname=" << database;
50         return oss.str();
51     }
52
53 private:
54 };
55
56 // INLINE METHODS
```

```
57 //
58
59 // EXTERNAL REFERENCES
60 //
61
62 #endif /* CONFIG_DATABASECONFIG_H_ */
```

D.3.9 TopologyConfig.h

```
1 /** Data structure for configuration of topology data in database.
2  *
3  * #include "TopologyConfig.h"
4  *
5  * @author Jonas Bergman
6  */
7
8 #ifndef CONFIG_TOPOLOGYCONFIG_H_
9 #define CONFIG_TOPOLOGYCONFIG_H_
10
11 // SYSTEM INCLUDES
12 //
13 #include <string>
14
15 // PROJECT INCLUDES
16 //
17
18 // LOCAL INCLUDES
19 //
20
21 // FORWARD REFERENCES
22 //
23
24 /**
25  * Information about names in the database for topology data.
26  */
27 struct TopologyConfig
28 {
29 // ATTRIBUTES
30     std::string    providerName;
31
32     std::string    tempTopoName;
33     std::string    topoName;
34
35     std::string    roadsPrefix;
36     std::string    topologySchemaPrefix;
37
38     int            srid;
39     double         tolerance;
40
41     std::string    edgeTableName;
42     std::string    edgeIdColumnName;
43     std::string    sourceColumnName;
44     std::string    targetColumnName;
45     std::string    edgeGeomColumnName;
46
47     std::string    vertexTableName;
48     std::string    vertexIdColumnName;
```



```
49     std::string      vertexGeomColumnName;
50
51     std::string      testFile;
52
53     // CONSTANTS
54     static constexpr const char* PROVIDER_POSTGIS = "postgis";
55     static constexpr const char* PROVIDER_PGRROUTING = "pgrouting";
56     static constexpr const char* PROVIDER_JSONTEST = "jsontest";
57     static constexpr const char* TEMP_TOPO_NAMEBASE = "epoch_ms";
58
59
60 };
61
62 // INLINE METHODS
63 //
64
65 // EXTERNAL REFERENCES
66 //
67
68 #endif /* CONFIG_TOPOLOGYCONFIG_H_ */
```

D.3.10 VehicleConfig.h

```
1  /** Data structure for configuration of vehicle we are routing.
2   *
3   * #include "VehicleConfig.h"
4   *
5   * @author Jonas Bergman
6   */
7  #ifndef CONFIG_VEHICLECONFIG_H_
8  #define CONFIG_VEHICLECONFIG_H_
9
10 // SYSTEM INCLUDES
11 //
12 #include <string>
13
14 // PROJECT INCLUDES
15 //
16
17 // LOCAL INCLUDES
18 //
19 #include "../osm/OsmVehicle.h"
20
21 // FORWARD REFERENCES
22 //
23
24 /** A simple data structure for holding the configuration
25  * of the vehicle we are routing.
26  */
27 struct VehicleConfig
28 {
29     // ATTRIBUTES
30     OsmVehicle::VehicleType category;
31     double height;
32     double length;
33     double weight;
34     double width;
```

```
35     unsigned                maxspeed;
36     unsigned                acceleration; // seconds 0 - 100 km/h
37     unsigned                deceleration; // seconds 100 - 0 km/h
38 };
39
40 // INLINE METHODS
41 //
42
43 // EXTERNAL REFERENCES
44 //
45
46 #endif /* CONFIG_VEHICLECONFIG_H_ */
```

D.3.11 ConfigurationReader_test.cc

```
1  /*
2   * ConfigurationReader_test.cc
3   * @author Jonas Bergman
4   */
5
6  #include "../catchtest/catch.hpp"
7  #include "../Configuration.h"
8  #include "../ConfigurationReader.h"
9  #include "../ConfigurationException.h"
10
11  SCENARIO ("Use ConfigurationReader to read configuration from json file",
12           "[json],[config]")
13  {
14      //-----
15      GIVEN ("a filename to a valid configuration file")
16      {
17          std::string filename("catchtest/testsettings/testsettings.json");
18
19          WHEN ("asking for database configuration")
20          {
21              ConfigurationReader config_reader(filename);
22              Configuration config;
23              config_reader.fillConfiguration(config);
24              const DatabaseConfig& r_db_config = config.getDatabaseConfig();
25
26              THEN ("we get a database configuration filled out")
27              {
28                  REQUIRE (r_db_config.hostname == "127.0.0.1");
29                  REQUIRE (r_db_config.port == 5432);
30                  REQUIRE (r_db_config.username == "tester");
31                  REQUIRE (r_db_config.password == "tester");
32                  REQUIRE (r_db_config.database == "mikh_0530");
33              }
34          }
35      }
36
37      //-----
38      GIVEN ("a filename to a configuration file with missing information")
39      {
40          std::string filename("catchtest/testsettings/testsettings-missing-name.json");
41
42          WHEN ("asking for database configuration")
```

```
43     {
44         ConfigurationReader config_reader(filename);
45
46         THEN ("we get an exception")
47         {
48             Configuration config;
49             REQUIRE_THROWS_AS (config_reader.fillConfiguration(config),
50                               ConfigurationException&);
51         }
52     }
53 }
54
55 //-----
56 GIVEN ("a filename to a non-existing file")
57 {
58     std::string filename("config/catchtest/foo.json");
59
60     WHEN ("asking for database configuration")
61     {
62         THEN ("we get an exception")
63         {
64             REQUIRE_THROWS_AS (ConfigurationReader config_reader(filename),
65                               ConfigurationException&);
66         }
67     }
68 }
69
70 //-----
71 GIVEN ("a filename to a valid configuration file")
72 {
73     std::string filename("catchtest/testsettings/testsettings.json");
74     ConfigurationReader config_reader(filename);
75     Configuration config;
76     config_reader.fillConfiguration(config);
77
78     //.....
79     WHEN ("asking for topology configuration")
80     {
81         const TopologyConfig& r_topo_config = config.getTopologyConfig();
82
83         THEN ("we get a topology configuration filled out")
84         {
85             REQUIRE (r_topo_config.providerName == "postgis");
86             REQUIRE (r_topo_config.topoName == "lgu");
87             REQUIRE (r_topo_config.roadsPrefix == "highways");
88             REQUIRE (r_topo_config.topologySchemaPrefix == "topo");
89             REQUIRE (r_topo_config.tempTopoName == "");
90             REQUIRE (r_topo_config.srid == 900913);
91             REQUIRE (r_topo_config.tolerance == Approx(1.0));
92
93             REQUIRE (r_topo_config.edgeTableName == "edge_data");
94             REQUIRE (r_topo_config.edgeIdColumnName == "edge_id");
95             REQUIRE (r_topo_config.sourceColumnName == "start_node");
96             REQUIRE (r_topo_config.targetColumnName == "end_node");
97             REQUIRE (r_topo_config.edgeGeomColumnName == "geom");
98             REQUIRE (r_topo_config.vertexTableName == "node");
99             REQUIRE (r_topo_config.vertexIdColumnName == "node_id");
```

```
100         REQUIRE (r_topo_config.vertexGeomColumnName == "geom");
101     }
102 }
103
104 //.....
105 WHEN ("asking for vehicle configuration")
106 {
107     const VehicleConfig& r_vehicle_config = config.getVehicleConfig();
108
109     THEN ("we get a vehicle configuration filled out")
110     {
111         REQUIRE (r_vehicle_config.category == OsmVehicle::MOTORCAR);
112         REQUIRE (r_vehicle_config.height == Approx(1.6));
113         REQUIRE (r_vehicle_config.length == Approx(4.5));
114         REQUIRE (r_vehicle_config.weight == Approx(2.0));
115         REQUIRE (r_vehicle_config.width == Approx(1.9));
116         REQUIRE (r_vehicle_config.maxspeed == 200);
117         REQUIRE (r_vehicle_config.acceleration == 10);
118         REQUIRE (r_vehicle_config.deceleration == 7);
119     }
120 }
121
122 //.....
123 WHEN ("asking for cost configuration")
124 {
125     const CostConfig& r_cost_config = config.getCostConfig();
126
127     THEN ("we get a cost configuration filled out")
128     {
129         REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
130             OsmHighway::MOTORWAY, CostConfig::DefaultSpeed::HIGH) == 110);
131         REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
132             OsmHighway::MOTORWAY, CostConfig::DefaultSpeed::LOW) == 90);
133         REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
134             OsmHighway::MOTORWAY_LINK, CostConfig::DefaultSpeed::HIGH) == 90);
135         REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
136             OsmHighway::MOTORWAY_LINK, CostConfig::DefaultSpeed::LOW) == 90);
137
138         REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
139             OsmHighway::TRUNK, CostConfig::DefaultSpeed::HIGH) == 90);
140         REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
141             OsmHighway::TRUNK, CostConfig::DefaultSpeed::LOW) == 60);
142         REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
143             OsmHighway::TRUNK_LINK, CostConfig::DefaultSpeed::HIGH) == 90);
144         REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
145             OsmHighway::TRUNK_LINK, CostConfig::DefaultSpeed::LOW) == 60);
146
147         REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
148             OsmHighway::PRIMARY, CostConfig::DefaultSpeed::HIGH) == 90);
149         REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
150             OsmHighway::PRIMARY, CostConfig::DefaultSpeed::LOW) == 60);
151         REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
152             OsmHighway::PRIMARY_LINK, CostConfig::DefaultSpeed::HIGH) == 90);
153         REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
154             OsmHighway::PRIMARY_LINK, CostConfig::DefaultSpeed::LOW) == 60);
155
156         REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
```

```
157         OsmHighway::SECONDARY, CostConfig::DefaultSpeed::HIGH) == 90);
158     REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
159         OsmHighway::SECONDARY, CostConfig::DefaultSpeed::LOW) == 60);
160     REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
161         OsmHighway::SECONDARY_LINK, CostConfig::DefaultSpeed::HIGH) == 90);
162     REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
163         OsmHighway::SECONDARY_LINK, CostConfig::DefaultSpeed::LOW) == 60);
164
165     REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
166         OsmHighway::TERTIARY, CostConfig::DefaultSpeed::HIGH) == 90);
167     REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
168         OsmHighway::TERTIARY, CostConfig::DefaultSpeed::LOW) == 60);
169     REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
170         OsmHighway::TERTIARY_LINK, CostConfig::DefaultSpeed::HIGH) == 90);
171     REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
172         OsmHighway::TERTIARY_LINK, CostConfig::DefaultSpeed::LOW) == 60);
173
174     REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
175         OsmHighway::UNCLASSIFIED, CostConfig::DefaultSpeed::HIGH) == 90);
176     REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
177         OsmHighway::UNCLASSIFIED, CostConfig::DefaultSpeed::LOW) == 60);
178
179     REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
180         OsmHighway::RESIDENTIAL, CostConfig::DefaultSpeed::HIGH) == 90);
181     REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
182         OsmHighway::RESIDENTIAL, CostConfig::DefaultSpeed::LOW) == 60);
183
184     REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
185         OsmHighway::SERVICE, CostConfig::DefaultSpeed::HIGH) == 40);
186     REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
187         OsmHighway::SERVICE, CostConfig::DefaultSpeed::LOW) == 20);
188
189     REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
190         OsmHighway::LIVING_STREET, CostConfig::DefaultSpeed::HIGH) == 20);
191     REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
192         OsmHighway::LIVING_STREET, CostConfig::DefaultSpeed::LOW) == 20);
193
194     REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
195         OsmHighway::BUS_GUIDEWAY, CostConfig::DefaultSpeed::HIGH) == 80);
196     REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
197         OsmHighway::BUS_GUIDEWAY, CostConfig::DefaultSpeed::LOW) == 60);
198
199     REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
200         OsmHighway::ROAD, CostConfig::DefaultSpeed::HIGH) == 80);
201     REQUIRE (r_cost_config.defaultSpeed.getDefaultSpeed(
202         OsmHighway::ROAD, CostConfig::DefaultSpeed::LOW) == 50);
203
204     REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(
205         OsmHighway::PAVED) == 1000);
206     REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(
207         OsmHighway::ASPHALT) == 1000);
208     REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(
209         OsmHighway::COBBLESTONE) == 20);
210     REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(
211         OsmHighway::COBBLESTONE_FLATTENED) == 40);
212     REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(
213         OsmHighway::SETT) == 40);
```

```
214         REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(  
215             OsmHighway::CONCRETE) == 1000);  
216         REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(  
217             OsmHighway::CONCRETE_LANES) == 40);  
218         REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(  
219             OsmHighway::CONCRETE_PLATES) == 100);  
220         REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(  
221             OsmHighway::PAVING_STONES) == 40);  
222         REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(  
223             OsmHighway::METAL) == 60);  
224         REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(  
225             OsmHighway::WOOD) == 30);  
226         REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(  
227             OsmHighway::UNPAVED) == 60);  
228         REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(  
229             OsmHighway::COMPACTED) == 70);  
230         REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(  
231             OsmHighway::DIRT) == 40);  
232         REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(  
233             OsmHighway::EARTH) == 40);  
234         REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(  
235             OsmHighway::FINE_GRAVEL) == 50);  
236         REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(  
237             OsmHighway::GRASS) == 10);  
238         REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(  
239             OsmHighway::GRASS_PAVER) == 20);  
240         REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(  
241             OsmHighway::GRAVEL) == 60);  
242         REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(  
243             OsmHighway::GROUND) == 20);  
244         REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(  
245             OsmHighway::ICE) == 70);  
246         REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(  
247             OsmHighway::MUD) == 5);  
248         REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(  
249             OsmHighway::PEBBLESTONE) == 50);  
250         REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(  
251             OsmHighway::SALT) == 70);  
252         REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(  
253             OsmHighway::SAND) == 70);  
254         REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(  
255             OsmHighway::SNOW) == 50);  
256         REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(  
257             OsmHighway::WOODCHIPS) == 5);  
258         REQUIRE (r_cost_config.surfaceMaxSpeed.getSurfaceMaxSpeed(  
259             OsmHighway::METAL_GRID) == 40);  
260  
261         REQUIRE(r_cost_config.otherEdgeCosts.getOtherCost(  
262             "highway=bus_stop") == 5);  
263         REQUIRE(r_cost_config.otherEdgeCosts.getOtherCost(  
264             "highway=crossing") == 5);  
265         REQUIRE(r_cost_config.otherEdgeCosts.getOtherCost(  
266             "highway=give_way") == 20);  
267         REQUIRE(r_cost_config.otherEdgeCosts.getOtherCost(  
268             "highway=mini_roundabout") == 20);  
269         REQUIRE(r_cost_config.otherEdgeCosts.getOtherCost(  
270             "highway=stop") == 30);
```

```
271         REQUIRE(r_cost_config.otherEdgeCosts.getOtherCost(  
272             "highway=traffic_signals") == 30);  
273  
274         REQUIRE(r_cost_config.otherEdgeCosts.getOtherCost(  
275             "railway=level_crossing") == 20);  
276  
277         REQUIRE(r_cost_config.otherEdgeCosts.getOtherCost(  
278             "public_transport=stop_position") == 5);  
279  
280         REQUIRE(r_cost_config.otherEdgeCosts.getOtherCost(  
281             "traffic_calming=yes") == 10);  
282         REQUIRE(r_cost_config.otherEdgeCosts.getOtherCost(  
283             "traffic_calming=bump") == 10);  
284         REQUIRE(r_cost_config.otherEdgeCosts.getOtherCost(  
285             "traffic_calming=table") == 10);  
286         REQUIRE(r_cost_config.otherEdgeCosts.getOtherCost(  
287             "traffic_calming=cushion") == 10);  
288         REQUIRE(r_cost_config.otherEdgeCosts.getOtherCost(  
289             "traffic_calming=rumble_strip") == 10);  
290         REQUIRE(r_cost_config.otherEdgeCosts.getOtherCost(  
291             "traffic_calming=chicane") == 10);  
292         REQUIRE(r_cost_config.otherEdgeCosts.getOtherCost(  
293             "traffic_calming=choker") == 10);  
294         REQUIRE(r_cost_config.otherEdgeCosts.getOtherCost(  
295             "traffic_calming=island") == 5);  
296     }  
297 }  
298  
299 WHEN ("asking for access rules")  
300 {  
301     const OsmAccess::AccessRule r_access_rule = config.getAccessRule();  
302  
303     THEN ("we get an AccessRule filled out")  
304     {  
305         std::vector<OsmAccess::AccessType> types =  
306             r_access_rule.allowAccessToTypes;  
307         REQUIRE (types.size() == 3);  
308  
309         auto it = std::find(types.begin(), types.end(),  
310             OsmAccess::AccessType::YES);  
311         INFO ("Allows access:" + OsmAccess::toString(*it));  
312         REQUIRE (it != types.end());  
313  
314         it = std::find(types.begin(), types.end(),  
315             OsmAccess::AccessType::PERMISSIVE);  
316         INFO ("Allows access:" + OsmAccess::toString(*it));  
317         REQUIRE (it != types.end());  
318  
319         it = std::find(types.begin(), types.end(),  
320             OsmAccess::AccessType::DESIGNATED);  
321         INFO ("Allows access:" + OsmAccess::toString(*it));  
322         REQUIRE (it != types.end());  
323  
324         it = std::find(types.begin(), types.end(),  
325             OsmAccess::AccessType::NO);  
326         INFO ("Denies access: no");  
327         REQUIRE (it == types.end());
```

```
328     }
329 }
330
331 WHEN ("asking for restrictions rules")
332 {
333     const OsmBarrier::RestrictionsRule
334     r_restrict_rule = config.getBarrierRestrictionsRule();
335
336     THEN ("we get RestrictionsRule filled out")
337     {
338         std::vector<OsmBarrier::BarrierType> types =
339             r_restrict_rule.restrictionTypes;
340         REQUIRE (types.size() == 21);
341
342         auto it = std::find(types.begin(), types.end(),
343             OsmBarrier::BarrierType::BLOCK);
344         INFO ("Restrict: " + OsmBarrier::toString(*it));
345         REQUIRE (it != types.end());
346
347         it = std::find(types.begin(), types.end(),
348             OsmBarrier::BarrierType::BOLLARD);
349         INFO ("Restrict: " + OsmBarrier::toString(*it));
350         REQUIRE (it != types.end());
351
352         it = std::find(types.begin(), types.end(),
353             OsmBarrier::BarrierType::BUS_TRAP);
354         INFO ("Restrict: " + OsmBarrier::toString(*it));
355         REQUIRE (it != types.end());
356
357         it = std::find(types.begin(), types.end(),
358             OsmBarrier::BarrierType::CHAIN);
359         INFO ("Restrict: " + OsmBarrier::toString(*it));
360         REQUIRE (it != types.end());
361
362         it = std::find(types.begin(), types.end(),
363             OsmBarrier::BarrierType::CYCLE_BARRIER);
364         INFO ("Restrict: " + OsmBarrier::toString(*it));
365         REQUIRE (it != types.end());
366
367         it = std::find(types.begin(), types.end(),
368             OsmBarrier::BarrierType::DEBRIS);
369         INFO ("Restrict: " + OsmBarrier::toString(*it));
370         REQUIRE (it != types.end());
371
372         it = std::find(types.begin(), types.end(),
373             OsmBarrier::BarrierType::FULLHEIGHT_TURNSTILE);
374         INFO ("Restrict: " + OsmBarrier::toString(*it));
375         REQUIRE (it != types.end());
376
377         it = std::find(types.begin(), types.end(),
378             OsmBarrier::BarrierType::HORSE_STILE);
379         INFO ("Restrict: " + OsmBarrier::toString(*it));
380         REQUIRE (it != types.end());
381
382         it = std::find(types.begin(), types.end(),
383             OsmBarrier::BarrierType::JERSEY_BARRIER);
384         INFO ("Restrict: " + OsmBarrier::toString(*it));
```



```
385         REQUIRE (it != types.end());
386
387         it = std::find(types.begin(), types.end(),
388             OsmBarrier::BarrierType::KENT_CARRIAGE_GAP);
389         INFO ("Restrict: " + OsmBarrier::toString(*it));
390         REQUIRE (it != types.end());
391
392         it = std::find(types.begin(), types.end(),
393             OsmBarrier::BarrierType::KISSING_GATE);
394         INFO ("Restrict: " + OsmBarrier::toString(*it));
395         REQUIRE (it != types.end());
396
397         it = std::find(types.begin(), types.end(),
398             OsmBarrier::BarrierType::LOG);
399         INFO ("Restrict: " + OsmBarrier::toString(*it));
400         REQUIRE (it != types.end());
401
402         it = std::find(types.begin(), types.end(),
403             OsmBarrier::BarrierType::MOTORCYCLE_BARRIER);
404         INFO ("Restrict: " + OsmBarrier::toString(*it));
405         REQUIRE (it != types.end());
406
407         it = std::find(types.begin(), types.end(),
408             OsmBarrier::BarrierType::ROPE);
409         INFO ("Restrict: " + OsmBarrier::toString(*it));
410         REQUIRE (it != types.end());
411
412         it = std::find(types.begin(), types.end(),
413             OsmBarrier::BarrierType::SALLY_PORT);
414         INFO ("Restrict: " + OsmBarrier::toString(*it));
415         REQUIRE (it != types.end());
416
417         it = std::find(types.begin(), types.end(),
418             OsmBarrier::BarrierType::SPIKES);
419         INFO ("Restrict: " + OsmBarrier::toString(*it));
420         REQUIRE (it != types.end());
421
422         it = std::find(types.begin(), types.end(),
423             OsmBarrier::BarrierType::STILE);
424         INFO ("Restrict: " + OsmBarrier::toString(*it));
425         REQUIRE (it != types.end());
426
427         it = std::find(types.begin(), types.end(),
428             OsmBarrier::BarrierType::SUMP_BUSTER);
429         INFO ("Restrict: " + OsmBarrier::toString(*it));
430         REQUIRE (it != types.end());
431
432         it = std::find(types.begin(), types.end(),
433             OsmBarrier::BarrierType::SWING_GATE);
434         INFO ("Restrict: " + OsmBarrier::toString(*it));
435         REQUIRE (it != types.end());
436
437         it = std::find(types.begin(), types.end(),
438             OsmBarrier::BarrierType::TURNSTILE);
439         INFO ("Restrict: " + OsmBarrier::toString(*it));
440         REQUIRE (it != types.end());
441
```

```
442         it = std::find(types.begin(), types.end(),
443             OsmBarrier::BarrierType::YES);
444         INFO ("Restrict: " + OsmBarrier::toString(*it));
445         REQUIRE (it != types.end());
446
447         it = std::find(types.begin(), types.end(),
448             OsmBarrier::BarrierType::GATE);
449         INFO ("Allow: gate");
450         REQUIRE (it == types.end());
451     }
452 }
453
454 WHEN ("asking for costs rules")
455 {
456     const OsmBarrier::CostsRule r_costs_rule = config.getBarrierCostsRule();
457
458     THEN ("we get CostssRule filled out")
459     {
460         REQUIRE (r_costs_rule.costs.size() == 13);
461
462         INFO("Costs: border control");
463         REQUIRE (r_costs_rule.getCost(
464             OsmBarrier::BarrierType::BORDER_CONTROL) == 120);
465
466         INFO("Costs: bump gate");
467         REQUIRE (r_costs_rule.getCost(
468             OsmBarrier::BarrierType::BUMP_GATE) == 30);
469
470         INFO("Costs: bus trap");
471         REQUIRE (r_costs_rule.getCost(
472             OsmBarrier::BarrierType::BUS_TRAP) == 30);
473
474         INFO("Costs: cattle grid");
475         REQUIRE (r_costs_rule.getCost(
476             OsmBarrier::BarrierType::CATTLE_GRID) == 20);
477
478         INFO("Costs: entrance");
479         REQUIRE (r_costs_rule.getCost(
480             OsmBarrier::BarrierType::ENTRANCE) == 10);
481
482         INFO("Costs: gate");
483         REQUIRE (r_costs_rule.getCost(
484             OsmBarrier::BarrierType::GATE) == 30);
485
486         INFO("Costs: hampshire gate");
487         REQUIRE (r_costs_rule.getCost(
488             OsmBarrier::BarrierType::HAMPSHIRE_GATE) == 60);
489
490         INFO("Costs: height restrictor");
491         REQUIRE (r_costs_rule.getCost(
492             OsmBarrier::BarrierType::HEIGHT_RESTRICTOR) == 5);
493
494         INFO("Costs: jersey barrier");
495         REQUIRE (r_costs_rule.getCost(
496             OsmBarrier::BarrierType::JERSEY_BARRIER) == 10);
497
498         INFO("Costs: lift gate");
```

```
499         REQUIRE (r_costs_rule.getCost(  
500             OsmBarrier::BarrierType::LIFT_GATE) == 60);  
501  
502         INFO("Costs: sump buster");  
503         REQUIRE (r_costs_rule.getCost(  
504             OsmBarrier::BarrierType::SUMP_BUSTER) == 30);  
505  
506         INFO("Costs: swing gate");  
507         REQUIRE (r_costs_rule.getCost(  
508             OsmBarrier::BarrierType::SWING_GATE) == 60);  
509  
510         INFO("Costs: toll both");  
511         REQUIRE (r_costs_rule.getCost(  
512             OsmBarrier::BarrierType::TOLL_BOOTH) == 40);  
513  
514         INFO("No cost: yes");  
515         REQUIRE (r_costs_rule.costsToPass(  
516             OsmBarrier::BarrierType::YES) == false);  
517     }  
518 }  
519 }  
520 }
```

D.4 doc

D.4.1 README.md

Documentation
=====

This directory contains a directory for the project's report, and a directory for
↪ the UML diagrams.

D.5 report

D.5.1 README.md

Report
=====

The originals for the project's report. Written in
↪ [ShareLaTeX](https://www.sharelatex.com).

D.6 uml

D.6.1 README.md

UML
===

Class and sequence diagrams to get an idea of the concepts, although not 100%
↪ accurate.

Diagrams are created in `draw.io`, exported as `.svg` files, opened in
↪ `Inkscape` and saved as `.pdf` files (for usage in report).

D.7 graph

D.7.1 README.md

graph
=====

The `graph` package consists of classes for representing graphs.

GraphBuilder

The GraphBuilder is responsible for building graphs and linegraphs. It takes a

- ↳ `Topology` and a `Configuration` and uses them for building a `graph` and
- ↳ `linegraph` based on [Boost adjacency
- ↳ lists](http://www.boost.org/doc/libs/1_54_0/libs/graph/doc/adjacency_list.html).
- ↳ The `GraphBuilder` class holds several `maps` that connects the original
- ↳ Edges and Vertices to those used internally in the Boost graphs, so that it
- ↳ is possible to backtrack information about those elements. The internal Boost
- ↳ types keeps some properties
- ↳ [“bundled”](http://www.boost.org/doc/libs/1_54_0/libs/graph/doc/bundles.html),
- ↳ instead of as “interior” properties.

The ordinary `graph` is a directed graph that connects the `__vertices__` and

- ↳ `__edges__` from the topology. The `linegraph` transforms that graph to an
- ↳ edge-based graph that turns the graph’s edges into `__nodes__` in the
- ↳ linegraph, and those edges are connected with `__lines__`.

Topology

`Topology` is a class holding `Edges` and `Vertices` for the topology fetched

- ↳ from the `MapProvider`. It simply states which `Vertices` are connected by
- ↳ which `Edges`, without any costs or restrictions or directions. When created
- ↳ it validates that the `source` and `target` Vertices of the Edges actually
- ↳ exists in the topology.

Edge

The Edge holds some relevant data from the topology. It has an `id`, and a field

- ↳ for which the original `osm_id` was before building the database topology. It
- ↳ also holds id to `source` Vertex and id to `target` Vertex, some data about
- ↳ the geometry and the “road” such as number of lanes, a structure for costs
- ↳ and optionally for restrictions.

EdgeCost

The cost for travel among an edge is the number of seconds it takes. The base for

- ↳ this calculation is of course dependent on the length of the edge, and the
- ↳ speed. The speed can be set as an explicit `maxspeed` restriction, or by
- ↳ looking up the configuration for a `surface` if such is stated, else the
- ↳ speed is found by a look up for the default speed for the “highway type”
- ↳ (road category).

The travel time cost can then be modified by barriers, speed bumps, traffic

- ↳ lights ... on the edge (or points that can be applied on the edge).

EdgeRestriction

The `EdgeRestriction` keeps track of restrictions that can be imposed on an edge. Those restrictions are:

- `__Vehicle properties__`: weight, height, length, width, maxspeed.
- `__General access__`: [OSM wiki for
- ↳ access](<http://wiki.openstreetmap.org/wiki/Key:access>).

- ****Vehicle type access****: as for General access, but specified for a category of
↳ vehicles, such as `motorcar` or `goods`.
- ****Barrier****: if the edge is blocked with some kind of barrier.
- ****Turning restrictions****: [OSM wiki for turn
↳ restrictions](http://wiki.openstreetmap.org/wiki/Relation:restriction).
- ****Disused****: if the edge (road) is marked as no longer in use.
- ****NoExit****: if the edge has no exit, it should not be used for building a
↳ linegraph.

(Turn restriction via other edges and not just via a vertex are difficult. At the
↳ time when converting the topology to a line graph it is impossible to have the
↳ relevant information. The solution is to set a flag on the Edge that there
↳ exist a VIA_WAY restriction that must be taken into account when routing, and
↳ the routing module must look up and make its own decisions somehow.)

Vertex

The Vertex class is simple with just an `id` and a `point` location.

TurnCostCalculator

This is a static helper class that assist in calculating the cost of making
↳ turns, when transforming the `_graph_` into a `_linegraph_`. The cost for making
↳ turns are dependent on the angle of the turn, the category of the roads and
↳ the size of the vehicle. Other factors can be added.

Exceptions

`GraphException` is the main public exception to be thrown from this package.
↳ `RestrictionsException` and `TopologyException` are thrown when building
↳ those classes, but not as exposed externally.

D.7.2 Edge.h

```
1  /** Data structure for edges in Topology.
2   *
3   * #include "Edge.h"
4   *
5   * @author Jonas Bergman
6   */
7
8  #ifndef GRAPH_EDGE_H_
9  #define GRAPH_EDGE_H_
10
11 // SYSTEM INCLUDES
12 //
13 #include <limits>
14
15 // PROJECT INCLUDES
16 //
17
18 // LOCAL INCLUDES
19 //
20 #include "Vertex.h"
21 #include "../config/Configuration.h"
22 #include "../osm/OsmHighway.h"
23 #include "../osm/OsmId.h"
24 #include "EdgeCost.h"
25 #include "Speed.h"
26
```

```
27 // FORWARD REFERENCES
28 //
29 typedef long      EdgeIdType;
30 class             EdgeRestriction;
31
32 /**
33  * Data structure for edges in the topology.
34  */
35 class Edge
36 {
37 public:
38 // TYPES
39 //-----
40 enum DirectionType
41 {
42     BOTH,           // bidirectional
43     TO_FROM,        // one-way: from Source to Target
44     FROM_TO         // one-way: from Target to Source
45 };
46
47 //-----
48 /** A data structure for geometric information for the Edge.
49  * Bearing is the compass direction in degrees at source and at target.
50  */
51 struct GeomData
52 {
53     double      length {1.0};
54     Point        centerPoint;
55     int          sourceBearing {0};
56     int          targetBearing {0};
57
58     /** Constructor. */
59     GeomData() = default;
60
61     /** Constructor. */
62     GeomData(double length,
63              Point centerPoint,
64              int sourceBearing,
65              int targetBearing);
66 };
67
68 //-----
69 /** A data structure for road related information for the Edge.
70  */
71 struct RoadData
72 {
73     DirectionType direction {BOTH};
74     size_t         nrLanes   {1};
75     OsmHighway::HighwayType roadType {OsmHighway::HighwayType::ROAD};
76
77     /** Constructor. */
78     RoadData() = default;
79
80     /** Constructor. */
81     RoadData(DirectionType direction, size_t nrLanes);
82
83     /** Print this information. */
```

```
84         void print(std::ostream& os) const;
85     };
86
87     static const EdgeIdType MAX_ID;
88
89     // LIFECYCLE
90     /** Constructor.
91     */
92     Edge() = delete;
93
94     /** Constructor.
95     * @param id Id for this Edge
96     * @param osmId The original OsmId this edge belongs to.
97     * @param source Source vertex
98     * @param target Target vertex
99     * @param geomData Geometric data for the edge.
100    * @param roadData Road data for the edge.
101    */
102    Edge(EdgeIdType id,
103         OsmIdType osmId,
104         VertexIdType source,
105         VertexIdType target,
106         GeomData geomData,
107         RoadData roadData);
108
109    /** Constructor.
110    * Using default values for geometry and road.
111    * @param id Id for this Edge
112    * @param osmId The original OsmId this edge belongs to.
113    * @param source Source vertex
114    * @param target Target vertex
115    */
116    Edge(EdgeIdType id,
117         OsmIdType osmId,
118         VertexIdType source,
119         VertexIdType target);
120
121    /** Move constructor.
122    * @param from The Edge to make a move of.
123    */
124    Edge(Edge&& from);
125
126    /** Destructor.
127    */
128    ~Edge();
129
130    // OPERATORS
131    /** Textual output of Edge.
132    */
133    friend
134    std::ostream& operator<<(std::ostream& os, const Edge& rEdge);
135
136    // OPERATIONS
137    /** Set the Geometric data for this edge.
138    * @param geomData The GeomData to use.
139    */
140    void setGeomData(GeomData geomData);
```

```
141
142     /** Set the Road data for this edge.
143      * @param   roadData   The RoadData to use.
144      */
145     void                setRoadData(RoadData roadData);
146
147     /** Set the OsmId corresponding to this edge.
148      * @param   osmId   The OsmId to set.
149      */
150     void                setOsmId(OsmIdType osmId);
151
152     /** Set the restrictions for this edge.
153      * @param   pRestrictions   The restrictions for this edge.
154      */
155     void                setRestrictions(EdgeRestriction* pRestrictions);
156
157     /** Set the speed for the edge in this actual configuration.
158      * @param   speed   The speed to set in km/h.
159      */
160     void                setSpeed(Speed speed);
161
162     /** Remove the restrictions for this edge.
163      */
164     void                clearCostsAndRestrictions();
165
166     /** Parse a string into an EdgeIdType.
167      * @param   idString   The string representing the id.
168      * @return  The corresponding edge id.
169      * @throw   std::invalid_argument
170      * @throw   std::out_of_range
171      */
172     static EdgeIdType  parse(const std::string& idStr);
173
174     // ACCESSORS
175     /**
176      * @return  The id of this edge.
177      */
178     EdgeIdType         id()          const;
179
180     /**
181      * @return  The source vertex for this edge.
182      */
183     VertexIdType       sourceId()   const;
184
185     /**
186      * @return  The target vertex of this edge.
187      */
188     VertexIdType       targetId()   const;
189
190     /**
191      * @return  The original OSM id for this edge.
192      */
193     OsmIdType          osmId()      const;
194
195     /**
196      * @return  The geometric data for this edge.
197      */
```



```
198     const GeomData&   geomData() const;  
199  
200     /**  
201      * @return The road data for this edge.  
202      */  
203     const RoadData&   roadData() const;  
204  
205     /** Get hold of the restrictions associated with the edge.  
206      * @return Reference to EdgeRestriction  
207      * @throw RestrictionException if no restriction is applied on Edge.  
208      */  
209     EdgeRestriction& restrictions();  
210  
211     /** Get hold of the restrictions associated with the edge.  
212      * @return Reference to EdgeRestriction  
213      * @throw RestrictionException if no restriction is applied on Edge.  
214      */  
215     const EdgeRestriction&  
216             restrictions() const;  
217  
218     /** Get the structure of different costs for traveling the edge.  
219      * @return Reference to EdgeCost  
220      */  
221     EdgeCost&         edgeCost();  
222  
223     /** Get the structure of different costs for traveling the edge.  
224      * @return Reference to EdgeCost  
225      */  
226     const EdgeCost&   edgeCost() const;  
227  
228     /**  
229      * @return The cost or weight for this edge.  
230      */  
231     Cost              cost() const;  
232  
233     /** The speed must be kept track of because of turn cost calculations,  
234      * but they are not part of `RoadData` which are meant to be constant,  
235      * while the speed varies with configuration.  
236      * @return The speed for this edge in km/h  
237      */  
238     Speed             speed() const;  
239  
240     // INQUIRY  
241     /**  
242      * @return true if there exists restrictions for this edge.  
243      */  
244     bool              hasRestrictions() const;  
245  
246     /** An edge needs special attention during routing if there exists  
247      * a turning restriction via other ways (edges).  
248      * @return true if there exists a turn restriction via ways.  
249      */  
250     bool              hasViaWayRestriction() const;  
251  
252     /** Check if travel on the Edge is restricted given the configuration.  
253      * @param rConfig Configuration with restriction rules.  
254      * @return true If travel is restricted.
```

```
255     * @throws RestrictionsException
256     */
257     bool                isRestricted(const Configuration& rConfig) const;
258
259 private:
260 // ATTRIBUTES
261     EdgeIdType          mId;          // id in topology
262     OsmIdType           mOsmId;
263     VertexIdType        mSourceId;
264     VertexIdType        mTargetId;
265     GeomData            mGeomData;
266     RoadData            mRoadData;
267     EdgeRestriction*    mpRestrictions;
268     EdgeCost            mCost;
269     Speed              mSpeed;
270 };
271
272 // INLINE METHODS
273 //
274
275 // EXTERNAL REFERENCES
276 //
277
278 #endif /* GRAPH_EDGE_H_ */
```

D.7.3 Edge.cc

```
1  /*
2   * Edge.cc
3   *
4   * @author   Jonas Bergman
5   */
6
7  #include "Edge.h" // class implemented
8
9  #include "EdgeRestriction.h"
10
11 //===== TYPES =====
12 const EdgeIdType Edge::MAX_ID = std::numeric_limits<EdgeIdType>::max();
13
14 // Edge::GeomData -----
15 Edge::GeomData::GeomData(double length,
16                          Point centerPoint,
17                          int sourceBearing,
18                          int targetBearing)
19     : length(length),
20       centerPoint(centerPoint),
21       sourceBearing(sourceBearing),
22       targetBearing(targetBearing)
23 {}
24
25 // Edge::RoadData -----
26 Edge::RoadData::RoadData(DirectionType direction, size_t nrLanes)
27     : direction(direction), nrLanes(nrLanes)
28 {}
29
30 void
```

```
31 Edge::RoadData::print(std::ostream& os) const
32 {
33     os << "direction: ";
34
35     switch(direction)
36     {
37         case Edge::DirectionType::BOTH:
38             os << "BOTH"; break;
39         case Edge::DirectionType::FROM_TO:
40             os << "FROM_TO"; break;
41         case Edge::DirectionType::TO_FROM:
42             os << "TO_FROM"; break;
43     }
44
45     os << ", #lanes: " << nrLanes;
46     os << ", type: " << OsmHighway::toString(roadType);
47 }
48
49
50 // Edge -----
51 ////////////////////////////////////////////////// PUBLIC //////////////////////////////////////
52
53 //===== LIFECYCLE =====
54 Edge::Edge(EdgeIdType      id,
55            OsmIdType       osmId,
56            VertexIdType    source,
57            VertexIdType    target,
58            Edge::GeomData  geomData,
59            Edge::RoadData  roadData)
60 : mId(id),
61   mOsmId(osmId),
62   mSourceId(source),
63   mTargetId(target),
64   mGeomData(geomData),
65   mRoadData(roadData),
66   mpRestrictions(nullptr),
67   mCost(),
68   mSpeed()
69 { }
70
71 Edge::Edge(EdgeIdType      id,
72            OsmIdType       osmId,
73            VertexIdType    source,
74            VertexIdType    target)
75 : mId(id),
76   mOsmId(osmId),
77   mSourceId(source),
78   mTargetId(target),
79   mGeomData(),
80   mRoadData(),
81   mpRestrictions(nullptr),
82   mCost(),
83   mSpeed()
84 { }
85
86 Edge::Edge(Edge&& from)
87 : mId(from.mId),
```

```
88     mOsmId(from.mOsmId),
89     mSourceId(from.mSourceId),
90     mTargetId(from.mTargetId),
91     mGeomData(from.mGeomData),
92     mRoadData(from.mRoadData),
93     mpRestrictions(from.mpRestrictions),
94     mCost(),
95     mSpeed()
96 {
97     from.mpRestrictions = nullptr;
98 }
99
100 Edge::~Edge()
101 {
102     delete mpRestrictions;
103 }
104
105 //===== OPERATORS =====
106 std::ostream&
107 operator<<(std::ostream& os, const Edge& rEdge)
108 {
109     os << "Edge [id: " << rEdge.id()
110         << ", osmId: " << rEdge.osmId()
111         << ", source: " << rEdge.sourceId()
112         << ", target: " << rEdge.targetId()
113         << ", cost: " << rEdge.cost()
114         << ", length: " << rEdge.geomData().length
115         << ", speed: " << rEdge.speed()
116         << "\n  road data: ";
117     rEdge.roadData().print(os);
118
119     os << "]";
120
121     return os;
122 }
123
124
125 //===== OPERATIONS =====
126
127 void
128 Edge::setGeomData(Edge::GeomData geomData)
129 { mGeomData = geomData; }
130
131 void
132 Edge::setRoadData(Edge::RoadData roadData)
133 { mRoadData = roadData; }
134
135 void
136 Edge::setOsmId(OsmIdType osmId)
137 { mOsmId = osmId; }
138
139 void
140 Edge::setRestrictions(EdgeRestriction* pRestrictions)
141 {
142     delete mpRestrictions;
143     mpRestrictions = pRestrictions;
144 }
```

```
145
146 void
147 Edge::setSpeed(Speed speed)
148 {
149     mSpeed = speed;
150 }
151
152 void
153 Edge::clearCostsAndRestrictions()
154 {
155     mCost.clearCosts();
156
157     delete mpRestrictions;
158     mpRestrictions = nullptr;
159
160     mSpeed = 0;
161 }
162
163 //static
164 EdgeIdType
165 Edge::parse(const std::string& idStr)
166 {
167     return static_cast<EdgeIdType>(std::stoul(idStr));
168 }
169
170 //===== ACCESS =====
171 EdgeIdType
172 Edge::id() const
173 { return mId; }
174
175 VertexIdType
176 Edge::sourceId() const
177 { return mSourceId; }
178
179 VertexIdType
180 Edge::targetId() const
181 { return mTargetId; }
182
183 OsmIdType
184 Edge::osmId() const
185 { return mOsmId; }
186
187 const Edge::GeomData&
188 Edge::geomData() const
189 { return mGeomData; }
190
191 const Edge::RoadData&
192 Edge::roadData() const
193 { return mRoadData; }
194
195
196 EdgeRestriction&
197 Edge::restrictions()
198 {
199     if(mpRestrictions == nullptr) {
200         mpRestrictions = new EdgeRestriction();
201     }
```

```
202     return *mpRestrictions;
203 }
204
205 const EdgeRestriction&
206 Edge::restrictions() const
207 {
208     if(mpRestrictions == nullptr) {
209         throw RestrictionsException(std::string("No restriction on edge ")
210             + std::to_string(mId));
211     }
212     return *mpRestrictions;
213 }
214
215 EdgeCost&
216 Edge::edgeCost()
217 {
218     return mCost;
219 }
220
221 const EdgeCost&
222 Edge::edgeCost() const
223 {
224     return mCost;
225 }
226
227 Cost
228 Edge::cost() const
229 {
230     return mCost.getCost();
231 }
232
233 Speed
234 Edge::speed() const
235 {
236     return mSpeed;
237 }
238
239 //===== INQUIRY =====
240 bool
241 Edge::hasRestrictions() const
242 { return mpRestrictions != nullptr; }
243
244 bool
245 Edge::hasViaWayRestriction() const
246 {
247     if(hasRestrictions())
248     {
249         return mpRestrictions->hasViaWayRestriction();
250     }
251     return false;
252 }
253
254 bool
255 Edge::isRestricted(const Configuration& rConfig) const
256 {
257     if(mpRestrictions == nullptr)
258     {
```

```
259         return false;
260     }
261
262     try
263     {
264         return mpRestrictions->restricts(rConfig);
265     }
266     catch (RestrictionsException& re)
267     {
268         re.addEdgeId(std::to_string(mId));
269         throw re;
270     }
271 }
272
273 ////////////////////////////////// PROTECTED //////////////////////////////////
274
275 ////////////////////////////////// PRIVATE //////////////////////////////////
```

D.7.4 Vertex.h

```
1  /** Data structure for vertices in Topology.
2   *
3   * #include "Vertex.h"
4   *
5   * @author Jonas Bergman
6   */
7
8  #ifndef GRAPH_VERTEX_H_
9  #define GRAPH_VERTEX_H_
10
11 // SYSTEM INCLUDES
12 //
13 #include <limits>
14 #include <ostream>
15
16 // PROJECT INCLUDES
17 //
18
19 // LOCAL INCLUDES
20 //
21 #include "../util/Point.h"
22
23 // FORWARD REFERENCES
24 //
25 typedef long          VertexIdType;
26
27 /**
28  * Data structure for vertices in the topology.
29  */
30 class Vertex
31 {
32 public:
33     // TYPES and CONSTANTS
34     static const VertexIdType MAX_ID;
35     // LIFECYCLE
36     /** Constructor.
37      * @param id Id for this vertex.
```

```
38     * @param    point          The Point (geometry).
39     */
40     Vertex(VertexIdType id, Point point);
41
42     /** Default constructor. Deleted */
43     Vertex() = delete;
44
45     /** Copy constructor. Default. */
46     Vertex(const Vertex&) = default;
47
48     // OPERATORS
49     friend
50     std::ostream& operator<<(std::ostream& os, const Vertex& rVertex);
51
52     bool operator==(const Vertex& rhs) const;
53
54     // OPERATIONS
55     // ACCESS
56     /**
57      * @return The id of this Vertex.
58      */
59     VertexIdType id() const;
60
61     /**
62      * @return The coordinates for this Vertex.
63      */
64     Point point() const;
65
66     //INQUIRY
67     /**
68      * @return True if the Vertex has restrictions.
69      */
70     bool hasRestrictions() const;
71
72     private:
73     // ATTRIBUTES
74     VertexIdType mId;
75     Point mPoint;
76 };
77
78 // INLINE METHODS
79 //
80
81 // EXTERNAL REFERENCES
82 //
83
84 #endif /* GRAPH_VERTEX_H_ */
```

D.7.5 Vertex.cc

```
1  /*
2  * Vertex.cc
3  *
4  * @author Jonas Bergman
5  */
6
7  #include "Vertex.h" // class implemented
```



```

8
9
10 ////////////////////////////////////////////////// PUBLIC //////////////////////////////////////////
11 const VertexIdType Vertex::MAX_ID = std::numeric_limits<VertexIdType>::max();
12
13 //===== LIFECYCLE =====
14 Vertex::Vertex(VertexIdType id, Point point)
15     : mId(id), mPoint(point)
16 {}
17
18 //===== OPERATORS =====
19 std::ostream&
20 operator<<(std::ostream& os, const Vertex& rVertex)
21 {
22     os << "Vertex [id: " << rVertex.mId
23         << ", point: " << rVertex.mPoint << "]\n";
24     return os;
25 }
26
27 bool
28 Vertex::operator==(const Vertex& rhs) const
29 {
30     return (rhs.mId == mId) && (rhs.mPoint == mPoint);
31 }
32
33 //===== OPERATIONS =====
34 //===== ACCESS =====
35 VertexIdType
36 Vertex::id() const
37 { return mId; }
38
39 Point
40 Vertex::point() const
41 { return mPoint; }
42
43 //===== INQUIRY =====
44 bool
45 Vertex::hasRestrictions() const
46 { return false; }
47
48 ////////////////////////////////////////////////// PROTECTED //////////////////////////////////////////
49
50 ////////////////////////////////////////////////// PRIVATE //////////////////////////////////////////

```

D.7.6 Topology.h

```

1 /** A class holding the elements of the topology.
2  *
3  * #include "Topology.h"
4  *
5  * @author Jonas Bergman
6  */
7
8 #ifndef GRAPH_TOPOLOGY_H_
9 #define GRAPH_TOPOLOGY_H_
10
11 // SYSTEM INCLUDES

```

```
12 //
13 #include <map>
14
15 // PROJECT INCLUDES
16 //
17 #include <boost/graph/adjacency_list.hpp>
18 #include <boost/graph/graph_traits.hpp>
19
20 // LOCAL INCLUDES
21 //
22 #include "Edge.h"
23 #include "TopologyException.h"
24 #include "Vertex.h"
25 #include "../util/Point.h"
26
27
28 // FORWARD REFERENCES
29 //
30
31 // TYPES
32 //
33 /** Mapping of topology vertex id and topology Vertex object. */
34 typedef std::map<VertexIdType, Vertex>          TopoVertexMapType;
35
36 /** Mapping of topology edge id and topology Edge object. */
37 typedef std::map<EdgeIdType, Edge>              TopoEdgeMapType;
38
39 /** Keep track of which topology edges that make up an edge in the original
40  * OSM map data, as the OSM edge might have been split into several edges when
41  * building the topology.
42  */
43 typedef std::multimap<OsmIdType, EdgeIdType>    OsmIdToTopoIdEdgeMap;
44
45 /** This class holds Edges and Vertices such as they are in the database.
46  */
47 class Topology
48 {
49     friend class GraphBuilder;
50
51 public:
52     // LIFECYCLE
53
54     /** Default constructor.
55     */
56     Topology();
57
58     /** Copy constructor.
59     *
60     * @param from The value to copy to this object.
61     */
62     Topology(const Topology& from) = delete;
63
64
65 // OPERATORS
66 // OPERATIONS
67
68     /** Try to add a vertex to the topology.
```

```
69      * If a vertex with the id already exists: return old value.
70      * @param id      Id for the vertex
71      * @param point    The position of the vertex
72      * @return A reference to a vertex with given id
73      */
74      Vertex&      addVertex(VertexIdType id, Point point);
75
76
77      /** Try to add an edge to the topology.
78      * If an edge with the id already exists: return old value.
79      * @param id      Id for the edge
80      * @param osmId    The original OsmId this edge belongs to.
81      * @param source   Id for source vertex
82      * @param target   Id for target vertex
83      * @param geomData Geometric data for the edge
84      * @param roadData Road data for the edge
85      * @return A reference to an edge with given id
86      * @throw Topology Exception if vertices are not in topology.
87      */
88      Edge&      addEdge(EdgeIdType      id,
89                        OsmIdType        osmId,
90                        VertexIdType      source,
91                        VertexIdType      target,
92                        Edge::GeomData    geomData,
93                        Edge::RoadData    roadData);
94
95      /** Try to add an edge to the topology.
96      * Using default values for geometric and road data.
97      * If an edge with the id already exists: return old value.
98      * @param id      Id for the edge
99      * @param osmId    The original OsmId this edge belongs to.
100     * @param source   Id for source vertex
101     * @param target   Id for target vertex
102     * @return A reference to an edge with given id
103     * @throw Topology Exception if vertices are not in topology.
104     */
105     Edge&      addEdge(EdgeIdType      id,
106                       OsmIdType        osmId,
107                       VertexIdType      source,
108                       VertexIdType      target);
109
110     /** Fetch the vertex with given id.
111     * @param id      Id of the vertex to get
112     * @return Reference to the found vertex
113     * @throws TopologyException if vertex does not exist.
114     */
115     Vertex&      getVertex(VertexIdType id);
116     const Vertex& getVertex(VertexIdType id) const;
117
118     /** Fetch the edge with given id.
119     * @param id      Id of the edge to get
120     * @return Reference to the found vertex
121     * @throws TopologyException if vertex does not exist.
122     */
123     Edge&      getEdge(EdgeIdType id);
124     const Edge& getEdge(EdgeIdType id) const;
125
```

```
126     /** Clear everything in the topology: edges and vertices.
127     */
128     void                clearTopology();
129
130     /** Remove restrictions and costs on all edges in the topology.
131     */
132     void                clearEdgeCostAndRestrictions();
133
134     // ACCESS
135     /**
136     * @return    the Number of vertices in topology.
137     */
138     size_t          nrVertices() const;
139
140     /**
141     * @return    the Number of vertices in topology.
142     */
143     size_t          nrEdges() const;
144
145     // INQUIRY
146
147     protected:
148     private:
149     // ATTRIBUTES
150     TopoVertexMapType    mVertexMap;
151     TopoEdgeMapType      mEdgeMap;
152     OsmIdToTopoIdEdgeMap mOsmEdgeMap;
153 };
154
155 // INLINE METHODS
156 //
157
158 // EXTERNAL REFERENCES
159 //
160
161 #endif /* GRAPH_TOPOLOGY_H_ */
```

D.7.7 Topology.cc

```
1  /*
2   * Topology.cc
3   *
4   * @author  Jonas Bergman
5   */
6
7  #include "Topology.h" // class implemented
8
9  #include <utility>
10
11  ////////////////////////////////// PUBLIC //////////////////////////////////
12
13  //===== LIFECYCLE =====
14  Topology::Topology()
15      : mVertexMap(), mEdgeMap(), mOsmEdgeMap()
16  {
17  }
18  //===== OPERATORS =====
```

```
19 //===== OPERATIONS =====
20
21 Vertex&
22 Topology::addVertex(VertexIdType id, Point point)
23 {
24     auto res = mVertexMap.emplace(id, Vertex(id, point));
25     return res.first->second;
26 }
27
28
29 Edge&
30 Topology::addEdge(EdgeIdType      id,
31                  OsmIdType       osmId,
32                  VertexIdType    source,
33                  VertexIdType    target,
34                  Edge::GeomData   geomData,
35                  Edge::RoadData   roadData)
36 {
37     try
38     {
39         getVertex(source);
40         getVertex(target);
41         Edge edge(id, osmId, source, target, geomData, roadData);
42         auto res = mEdgeMap.emplace(id, std::move(edge));
43         mOsmEdgeMap.insert({osmId, id});
44         return res.first->second;
45     }
46     catch (TopologyException& e)
47     {
48         throw TopologyException("Cannot add edge: " + std::to_string(id) +
49                                ". " + e.what());
50     }
51 }
52
53 Edge&
54 Topology::addEdge(EdgeIdType      id,
55                  OsmIdType       osmId,
56                  VertexIdType    source,
57                  VertexIdType    target)
58 {
59     Edge::GeomData gd;
60     Edge::RoadData rd;
61     return addEdge(id, osmId, source, target, gd, rd);
62 }
63
64 Vertex&
65 Topology::getVertex(VertexIdType id)
66 {
67     auto it = mVertexMap.find(id);
68     if(it == mVertexMap.end()) {
69         throw TopologyException("Vertex not found: " + std::to_string(id));
70     }
71     return it->second;
72 }
73
74 const Vertex&
75 Topology::getVertex(VertexIdType id) const
```

```
76 {
77     return const_cast<Topology&>(*this).getVertex(id);
78 }
79
80 Edge&
81 Topology::getEdge(EdgeIdType id)
82 {
83     auto it = mEdgeMap.find(id);
84     if(it == mEdgeMap.end()) {
85         throw TopologyException("Edge not found: " + std::to_string(id));
86     }
87     return it->second;
88 }
89
90 const Edge&
91 Topology::getEdge(EdgeIdType id) const
92 {
93     auto it = mEdgeMap.find(id);
94     if(it == mEdgeMap.end()) {
95         throw TopologyException("Edge not found: " + std::to_string(id));
96     }
97     return it->second;
98 }
99
100 void
101 Topology::clearTopology()
102 {
103     mVertexMap.clear();
104     mEdgeMap.clear();
105     mOsmEdgeMap.clear();
106 }
107
108 void
109 Topology::clearEdgeCostAndRestrictions()
110 {
111     for(auto& it : mEdgeMap)
112     {
113         it.second.clearCostsAndRestrictions();
114     }
115 }
116
117
118 //===== ACCESS =====
119 size_t
120 Topology::nrVertices() const
121 {
122     return mVertexMap.size();
123 }
124
125 size_t
126 Topology::nrEdges() const
127 {
128     return mEdgeMap.size();
129 }
130 //===== INQUIRY =====
131 ////////////////////////////////// PROTECTED //////////////////////////////////
132
```

133 // PRIVATE //////////////////////////////////////

D.7.8 GraphBuilder.h

```
1  /** GraphBuilder.
2   *
3   * #include "GraphBuilder.h"
4   *
5   * @author Jonas Bergman
6   */
7
8  #ifndef GRAPH_GRAPHBUILDER_H_
9  #define GRAPH_GRAPHBUILDER_H_
10
11 // SYSTEM INCLUDES
12 //
13 #include <algorithm>
14 #include <map>
15 #include <ostream>
16
17 // PROJECT INCLUDES
18 //
19 #include <boost/graph/adjacency_list.hpp>
20
21 // LOCAL INCLUDES
22 //
23 #include "Edge.h"
24 #include "EdgeRestriction.h"
25 #include "GraphException.h"
26 #include "Topology.h"
27 #include "TurnCostCalculator.h"
28 #include "Vertex.h"
29 #include "../config/Configuration.h"
30 #include "../util/Logging.h"
31
32 // FORWARD REFERENCES
33 //
34
35 // TYPES
36 typedef EdgeIdType NodeIdType;
37 typedef EdgeIdType LineIdType;
38
39 /**
40  * Map the GraphEdges to the original Edge id in the Topology.
41  * Also indicate if the GraphEdge is the same or opposite direction to
42  * the graph in the topology.
43  */
44 struct GraphEdge
45 {
46     EdgeIdType    graphEdgeId;
47     EdgeIdType    topoEdgeId;
48     bool          oppositeDirection {false};
49 };
50
51 /**
52  * A Node in the LineGraph corresponds directly to an Edge in the original
53  * GraphBuilder and topology. It is connected to another Node (Edge) if both the
```

```
54  * edges are adjacent and there is no restriction in the Vertex for travel
55  * along them.
56  * lgNodeId === graphEdgeId
57  */
58  typedef GraphEdge    LineGraphNode;
59
60  /**
61  * Map the GraphVertices to the original Vertex id in the Topology.
62  */
63  struct GraphVertex
64  {
65      VertexIdType    graphVertexId;
66      VertexIdType    topoVertexId;
67  };
68
69  /**
70  * A LineGraphLine corresponds to a travel along an incoming edge,
71  * via a vertex and out an outgoing edge.
72  * The cost is the cost of travel on the incoming edge and the turn cost
73  * at the vertex.
74  * The Line connects two edges in the graph with an allowed turn in between.
75  */
76  struct LineGraphLine
77  {
78      NodeIdType      lgSourceNodeId;
79      NodeIdType      lgTargetNodeId;
80      VertexIdType    topoViaVertexId;
81      double          cost;
82  };
83
84  /** The 'normal' vertex based graph type. */
85  typedef boost::adjacency_list
86      < boost::listS, boost::vecS, boost::directedS,
87        GraphVertex, GraphEdge >                               GraphType;
88  /** The edge based graph type. */
89  typedef boost::adjacency_list
90      < boost::listS, boost::vecS, boost::directedS,
91        LineGraphNode, LineGraphLine >                           LineGraphType;
92
93  /** A vertex in the normal graph. */
94  typedef boost::graph_traits<GraphType>::vertex_descriptor    VertexType;
95  /** An edge in the normal graph. */
96  typedef boost::graph_traits<GraphType>::edge_descriptor     EdgeType;
97
98  /** A node in the line graph. */
99  typedef boost::graph_traits<LineGraphType>::vertex_descriptor  NodeType;
100  /** An edge in the line graph. */
101  typedef boost::graph_traits<LineGraphType>::edge_descriptor   LineType;
102
103  /** Mapping of a topology vertex id and graph vertex object. */
104  typedef std::map<VertexIdType, VertexType>    TopoVertexIdToGraphVertexMapType;
105  /** Mapping of a topology edge id and graph edge object. */
106  typedef std::multimap<EdgeIdType, EdgeType>    TopoEdgeIdToGraphEdgeMapType;
107  /** Mapping of a graph edge id and linegraph node object. */
108  typedef std::map<EdgeIdType, NodeType>        GraphEdgeIdToNodeMapType;
109
110
```



```
111  /**
112   * A class for building (Boost) Graph and LineGraph from a Topology and
113   * a Configuration with optional Restrictions and Costs applied.
114   */
115  class GraphBuilder
116  {
117  public:
118    // LIFECYCLE
119    /** Constructor.
120     * Disabled.
121     */
122    GraphBuilder() = delete;
123
124    /** Constructor.
125     * GraphBuilder should be based on the supplied topology.
126     * @param  rTopology      The topology to use as basis for the graph.
127     * @param  rConfig        The configuration used for topology and all.
128     * @param  useRestrictions If the graph should be built with restrictions or not.
129     */
130    GraphBuilder(
131        Topology& rTopology,
132        const Configuration& rConfig,
133        bool useRestrictions = true);
134
135    /** Copy constructor.
136     * Disabled.
137     */
138    GraphBuilder(const GraphBuilder& from) = delete;
139
140    /** Destructor.
141     */
142    ~GraphBuilder();
143
144    // OPERATORS
145    /** Output operator to print to a stream.
146     */
147    friend
148    std::ostream& operator<<(std::ostream& os, const GraphBuilder& rGraph);
149
150    // OPERATIONS
151    // ACCESS
152    /**
153     * @return The number of Vertices in the Graph.
154     */
155    size_t nrVertices() const;
156
157    /**
158     * @return The number of Edges in the Graph.
159     */
160    size_t nrEdges() const;
161
162    /**
163     * @return The number of Nodes in the LineGraph.
164     */
165    size_t nrNodes() const;
166
167    /**
```

```
168     * @return The number of Nodes in the LineGraph.
169     */
170     size_t                nrLines() const;
171
172     /** Builds graph if necessary before returning.
173     * @return The Boost Graph representation of the Graph.
174     * @throws GraphException if something goes wrong building the graph.
175     */
176     const GraphType&      getBoostGraph();
177
178     /** Get a reference to the line graph.
179     * @return The Boost Graph representation of the LineGraph.
180     * @throws GraphException if something goes wrong building the graph.
181     */
182     LineGraphType&       getBoostLineGraph();
183     const LineGraphType& getBoostLineGraph() const;
184
185     /** Get access to the topology that is the base for the graph.
186     * @return The Topology
187     */
188     const Topology&       getTopology() const;
189
190 // INQUIRY
191 /**
192  * @return true If graph has a vertex with given id.
193  */
194     bool                hasVertex(VertexIdType vertexId) const;
195
196 /**
197  * @return true If LineGraph has a node with given id.
198  */
199     bool                hasNode(EdgeIdType nodeId) const;
200
201 /** Get an already existing Node from the LineGraph.
202  * @param id The Edge id (== the Node id).
203  * @param The LineGraph Node.
204  * @throw GraphException if there is no Node with that id.
205  */
206     const NodeType&      getLineGraphNode(NodeIdType id) const;
207
208 /**
209  * @return true If graph was built with restrictions.
210  */
211     bool                isRestricted() const;
212
213 /** Output information about # vertices, edges, nodes, lines.
214  */
215     void                printGraphInformation(std::ostream& os) const;
216
217 protected:
218
219 private:
220 // HELPERS
221
222 // buildGraph() -----
223 // Used when constructing the internal Boost graph representation
224 // from the Topology.
```

```
225
226     /** Build the graph by adding vertices and edges from the topology. */
227     void                buildGraph();
228
229     /** Add the topology vertices to the graph, respecting restrictions.
230      * Helper for 'buildGraph()'.
231      */
232     void                addTopoVerticesToGraph();
233
234     /** Add the topology edges to the graph, respecting restrictions.
235      * Helper for 'buildGraph()'.
236      */
237     void                addTopoEdgesToGraph();
238
239     /** Check if an edge is restricted
240      * @param   rEdge   Reference to edge
241      * @return  bool
242      */
243     bool                isEdgeRestricted(const Edge& rEdge) const;
244
245     /** Add the correct number of directed edges from the topo Edge.
246      * @param   rEdge       The topological graph data
247      * @param   rNewEdgeId  The running id for the graph's directed edges.
248      */
249     void                addDirectedGraphEdges(
250                         const Edge& rEdge,
251                         EdgeIdType& rNewEdgeId);
252
253     /** Add a directed edge from source to target.
254      * Helper for 'addTopoEdgesToGraph()'.
255      * @param   id        The edge's topology id.
256      * @param   source     The source vertex.
257      * @param   target     The target vertex.
258      * @param   e_ix      The running index amongst edges added to graph.
259      * @param   oppositeDirection
260      *                  If the directed edge runs opposite of the original
261      *                  edge direction as specified in the topology.
262      */
263     void                addDirectedEdge(
264                         EdgeIdType id,
265                         const VertexType& source,
266                         const VertexType& target,
267                         EdgeIdType ix,
268                         bool oppositeDirection);
269
270     /** Get the graph vertex corresponding to a given id.
271      * @param   id        The vertex' topology id.
272      * @return  Reference to the Graph vertex corresponding to id.
273      * @throw   GraphException if there is no corresponding vertex to id.
274      */
275     const VertexType&   getGraphVertex(VertexIdType id) const;
276
277     // buidlLineGraph() -----
278     // Used when transforming the Graph to a LineGraph
279
280     /** Start converting the GraphBuilder to a LineGraph.
281      */
```

```
282     void                buildLineGraph();
283
284     /** Add Edges from the graph as Nodes in the Linegraph.
285      * Helper for 'buildLineGraph()'
286      */
287     void                addGraphEdgesToLineGraph();
288
289     /** Actually add a graph edge as a linegraph node, checking if it already
290      * exists or not.
291      * @param   rGraphEdge  The Edge to add to the LineGraph as Node.
292      * @param   rNode       The Node corresponding to the edge returned here.
293      */
294     void                addGraphEdgeAsLineGraphNode(
295                         const EdgeType& rGraphEdge,
296                         NodeType&      rNode);
297
298
299     /** Connect the newly added Node to all Nodes it should be connected to,
300      * that is look up which outgoing edges there are from the Edge's (node's)
301      * target vertex, and if there are no restrictions: add the Edge as a Node
302      * to the LineGraph and add a Line between the Nodes.
303      * @param   rSourceNode  The Node to add Lines from.
304      * @param   rViaVertex   Are there any restrictions in the vertex?
305      * @throw    GraphException
306      */
307     void                connectSourceNodeToTargetNodesViaVertex(
308                         const NodeType& rSourceNode,
309                         const VertexType& rViaVertex);
310
311     /** Extract LineGraphNode data from the LineGraph.
312      * @param   rNode       The descriptor in the LineGraph
313      * @return  a LineGraphNode
314      */
315     LineGraphNode       getLineGraphNodeData(const NodeType& rNode) const;
316
317     /** Add a line in the LineGraph, connecting the source and target nodes.
318      * @param   rSourceNode
319      * @param   rTargetNode
320      * @return  the added line
321      * @throw    GraphException
322      */
323     LineType            addLineGraphLine(
324                         const NodeType& rSourceNode,
325                         const NodeType& rTargetNode);
326
327     /** Add meta data ids for source, target and vertex to the newly added Line.
328      * @param   rLine
329      * @param   sourceId
330      * @param   targetId
331      * @param   viaVertexId
332      */
333     void                addLineMetaIds(
334                         const LineType& rLine,
335                         EdgeIdType sourceId,
336                         EdgeIdType targetId,
337                         VertexIdType viaVertexId);
338
```

```
339     /** Add the meta information about the cost to the new line.
340     * @param   rLine
341     * @param   rSourceEdge    The Source Edge
342     * @param   targetId       The id of the target edge in topology
343     */
344     void addLineMetaCost(
345         const LineType& rLine,
346         const Edge&     rSourceEdge,
347         EdgeIdType      targetId);
348
349     /** Calculate the cost for making a turn from source edge to target.
350     * Helper to 'connectSourceNodeToTargetNodesViaVertex()'.
351     * @param   sourceEdgeId    The edge (and node) id of the source.
352     * @param   targetEdgeId    The edge (and node) id of the target.
353     */
354     double calculateTurnCost(
355         EdgeIdType sourceEdgeId,
356         EdgeIdType targetEdgeId) const;
357
358     /**
359     * @param   edgeId  Id to edge to look up.
360     * @return   true if this edge has no exits, meaning it is no use adding it.
361     */
362     bool edgeHasNoExit(EdgeIdType edgeId);
363
364     /**
365     * @return A vector of all Edges going out from a vertex.
366     */
367     std::vector<EdgeIdType>
368         getOutEdges(VertexIdType vertexId) const;
369
370     /**
371     * @param   rSourceNode    The LineGraph Node
372     * @return   A vector of all restricted edges from this Edge.
373     */
374     std::vector<EdgeIdType>
375         getRestrictedTargets(
376             const LineGraphNode& rSourceNode) const;
377
378     /** Look through the targets from a source to find which are restricted
379     * and add them to a collection of restricted.
380     * @param   rSourceEdge    The source edge.
381     * @param   rTargets       Targets from that source.
382     * @param   rRestrictedTargets  A collection to build up.
383     */
384     void findRestrictedTargets(
385         const Edge&          rSourceEdge,
386         const std::vector<EdgeIdType>& rTargets,
387         std::vector<EdgeIdType>&     rRestrictedTargets) const;
388
389     /** Add the turning restricted targets to the other restricted targets.
390     * @param   rSourceEdge    The source edge.
391     * @param   rRestrictedTargets  The collection of restricted targets.
392     */
393     void addTurningRestrictedTargets(
394         const Edge&          rSource,
395         std::vector<EdgeIdType>& rRestrictedTargets) const;
```

```

396
397     /**
398     * @return true if this target edge has restricted access from the source.
399     */
400     bool                isTargetRestricted(
401                         const std::vector<EdgeIdType>& rRestrictedTargets,
402                         EdgeIdType                    targetId) const;
403
404     void                printVertices(std::ostream& os) const;
405     void                printEdges(std::ostream& os)   const;
406     void                printNodes(std::ostream& os)   const;
407     void                printLines(std::ostream& os)   const;
408
409     // ATTRIBUTES
410     GraphType           mGraph;
411     LineGraphType       mLineGraph;
412     TopoVertexIdToGraphVertexMapType mIdToVertexMap;    // map original id to GraphVertex
413     TopoEdgeIdToGraphEdgeMapType     mIdToEdgeMap;    // map original id to GraphEdge
414     GraphEdgeIdToNodeMapType          mEdgeIdToNodeMap; // map GraphEdge.id to LineGraphNode
415     Topology&                          mrTopology;
416     const Configuration&               mrConfiguration;
417     mutable boost::log::sources::severity_logger
418         <boost::log::trivial::severity_level>
419         mLog;
420     bool                mUseRestrictions;
421
422     // CONSTANTS
423 };
424
425     // INLINE METHODS
426     //
427
428     // EXTERNAL REFERENCES
429     //
430
431 #endif /* GRAPH_GRAPHBUILDER_H_ */

```

D.7.9 GraphBuilder.cc

```

1  /*
2   * GraphBuilder.cc
3   *
4   * @author Jonas Bergman
5   */
6
7  #include "GraphBuilder.h" // class implemented
8
9  #include <typeinfo>
10
11  ////////////////////////////////// PUBLIC //////////////////////////////////
12
13  //===== LIFECYCLE =====
14  GraphBuilder::GraphBuilder(
15      Topology& rTopology,
16      const Configuration& rConfig,
17      bool useRestrictions)
18      : mGraph(),

```

```

19     mLineGraph(),
20     mIdToVertexMap(),
21     mIdToEdgeMap(),
22     mrTopology(rTopology),
23     mrConfiguration(rConfig),
24     mLog(),
25     mUseRestrictions(useRestrictions)
26 {
27     Logging::initLogging();
28     boost::log::add_common_attributes();
29
30     buildGraph();
31     buildLineGraph();
32 }
33
34 GraphBuilder::~GraphBuilder()
35 {
36 }
37
38 //===== OPERATORS =====
39 std::ostream&
40 operator<<(std::ostream& os, const GraphBuilder& rGraph)
41 {
42     rGraph.printGraphInformation(os);
43
44     os << std::endl << "Vertices: " << std::endl;
45     rGraph.printVertices(os);
46
47     os << std::endl << "Edges: " << std::endl;
48     rGraph.printEdges(os);
49
50     os << std::endl << "Nodes: " << std::endl;
51     rGraph.printNodes(os);
52
53     os << std::endl << "Lines: " << std::endl;
54     rGraph.printLines(os);
55
56     return os;
57 }
58 //===== OPERATIONS =====
59 //===== ACCESS =====
60 size_t
61 GraphBuilder::nrVertices() const
62 {
63     return mIdToVertexMap.size();
64 }
65
66 size_t
67 GraphBuilder::nrEdges() const
68 {
69     return mIdToEdgeMap.size();
70 }
71
72 size_t
73 GraphBuilder::nrNodes() const
74 {
75     return boost::num_vertices(mLineGraph);

```

```
76 }
77
78 size_t
79 GraphBuilder::nrLines() const
80 {
81     return boost::num_edges(mLineGraph);
82 }
83
84 const GraphType&
85 GraphBuilder::getBoostGraph()
86 {
87     return mGraph;
88 }
89
90 LineGraphType&
91 GraphBuilder::getBoostLineGraph()
92 {
93     return mLineGraph;
94 }
95
96 const LineGraphType&
97 GraphBuilder::getBoostLineGraph() const
98 {
99     return mLineGraph;
100 }
101
102 const Topology&
103 GraphBuilder::getTopology() const
104 {
105     return mrTopology;
106 }
107
108 //===== INQUIRY =====
109 bool
110 GraphBuilder::hasVertex(VertexIdType vertexId) const
111 {
112     const auto& it = mIdToVertexMap.find(vertexId);
113     return (it != mIdToVertexMap.end());
114 }
115
116 bool
117 GraphBuilder::hasNode(EdgeIdType nodeId) const
118 {
119     const auto& it = mEdgeIdToNodeMap.find(nodeId);
120     return (it != mEdgeIdToNodeMap.end());
121 }
122
123 const NodeType&
124 GraphBuilder::getLineGraphNode(NodeIdType id) const
125 {
126     const auto& res = mEdgeIdToNodeMap.find(id);
127     if(res == mEdgeIdToNodeMap.end())
128     {
129         throw GraphException("Graph:getLineGraphNode: Missing node: "
130                               + std::to_string(id));
131     }
132     return res->second;
```



```
133 }
134
135 bool
136 GraphBuilder::isRestricted() const
137 {
138     return mUseRestrictions;
139 }
140
141 ////////////////////////////////// PROTECTED //////////////////////////////////
142
143 ////////////////////////////////// PRIVATE //////////////////////////////////
144 void
145 GraphBuilder::buildGraph()
146 {
147     addTopoVerticesToGraph();
148     addTopoEdgesToGraph();
149 }
150
151 void
152 GraphBuilder::addTopoVerticesToGraph()
153 {
154     VertexIdType v_ix = 0;
155     for(const auto& vertexpair : mrTopology.mVertexMap)
156     {
157         VertexType v = boost::add_vertex(mGraph);
158         mIdToVertexMap.insert({vertexpair.second.id(), v});
159         mGraph[v].graphVertexId = v_ix;
160         mGraph[v].topoVertexId = vertexpair.second.id();
161         ++v_ix;
162     }
163 }
164
165 void
166 GraphBuilder::addTopoEdgesToGraph()
167 {
168     EdgeIdType e_ix = 0;
169
170     for(const auto& edgepair : mrTopology.mEdgeMap)
171     {
172         const Edge& e = edgepair.second;
173
174         if(isEdgeRestricted(e))
175         {
176             continue;
177         }
178
179         addDirectedGraphEdges(e, e_ix);
180     }
181 }
182
183
184 bool
185 GraphBuilder::isEdgeRestricted(const Edge& rEdge) const
186 {
187     if(mUseRestrictions && rEdge.isRestricted(mrConfiguration))
188     {
189         BOOST_LOG_SEV(mLog, boost::log::trivial::info)
```

```
190         << "Graph:addTopoEdgeToGraph(): "
191         << "Restricted Edge id " << rEdge.id();
192     return true;
193 }
194 return false;
195 }
196
197 void
198 GraphBuilder::addDirectedGraphEdges(const Edge& rEdge, EdgeIdType& rNewEdgeId)
199 {
200     const VertexType& s = getGraphVertex(rEdge.sourceId());
201     const VertexType& t = getGraphVertex(rEdge.targetId());
202
203     // add all lanes in forward direction
204     if(rEdge.roadData().direction == Edge::DirectionType::FROM_TO
205        || rEdge.roadData().direction == Edge::DirectionType::BOTH)
206     {
207         for(size_t lane = 1; lane <= rEdge.roadData().nrLanes; ++lane) {
208             addDirectedEdge(rEdge.id(), s, t, rNewEdgeId, false);
209             ++rNewEdgeId;
210         }
211     }
212
213     // add all lanes in backward direction
214     if(rEdge.roadData().direction == Edge::DirectionType::TO_FROM
215        || rEdge.roadData().direction == Edge::DirectionType::BOTH)
216     {
217         for(size_t lane = 1; lane <= rEdge.roadData().nrLanes; ++lane) {
218             addDirectedEdge(rEdge.id(), t, s, rNewEdgeId, true);
219             ++rNewEdgeId;
220         }
221     }
222 }
223
224 void
225 GraphBuilder::addDirectedEdge(
226     EdgeIdType      id,
227     const VertexType& source,
228     const VertexType& target,
229     EdgeIdType      e_ix,
230     bool            oppositeDirection)
231 {
232     const auto& res = boost::add_edge(source, target, mGraph);
233     if(res.second == true)
234     {
235         mIdToEdgeMap.insert({id, res.first});
236         mGraph[res.first].graphEdgeId = e_ix;
237         mGraph[res.first].topoEdgeId = id;
238         mGraph[res.first].oppositeDirection = oppositeDirection;
239     }
240     else
241     {
242         throw GraphException("Graph:addDirectedEdge: cannot add edge: "
243                               + std::to_string(id));
244     }
245 }
246
```

```
247 const VertexType&
248 GraphBuilder::getGraphVertex(VertexIdType id) const
249 {
250     const auto& res = mIdToVertexMap.find(id);
251     if(res == mIdToVertexMap.end())
252     {
253         throw GraphException("Graph:getGraphVertex: Missing vertex: "
254             + std::to_string(id));
255     }
256     return res->second;
257 }
258
259 void
260 GraphBuilder::buildLineGraph()
261 {
262     mLineGraph.clear();
263     addGraphEdgesToLineGraph();
264 }
265
266 void
267 GraphBuilder::addGraphEdgesToLineGraph()
268 {
269     // iterate through edges: add as Node.
270     for(auto e_it = boost::edges(mGraph);
271         e_it.first != e_it.second;
272         ++e_it.first)
273     {
274         const EdgeType& edge = *(e_it.first);
275
276         NodeType node;
277         addGraphEdgeAsLineGraphNode(edge, node);
278
279         // look up targetId vertex.
280         VertexType via_vertex = boost::target(edge, mGraph);
281
282         // connect all possible travels from 'edge' via the vertex
283         connectSourceNodeToTargetNodesViaVertex(node, via_vertex);
284     }
285 }
286
287 void
288 GraphBuilder::addGraphEdgeAsLineGraphNode(const EdgeType& rGraphEdge,
289                                           NodeType& rNode)
290 {
291     EdgeIdType e_graph_id =
292         boost::get(&GraphEdge::graphEdgeId, mGraph, rGraphEdge);
293     EdgeIdType e_topo_id =
294         boost::get(&GraphEdge::topoEdgeId, mGraph, rGraphEdge);
295
296     if(!hasNode(e_graph_id))
297     {
298         rNode = boost::add_vertex(mLineGraph);
299         mLineGraph[rNode].graphEdgeId = e_graph_id;
300         mLineGraph[rNode].topoEdgeId = e_topo_id;
301         mEdgeIdToNodeMap.insert({e_graph_id, rNode});
302     }
303     else
```

```
304     {
305         rNode = getLineGraphNode(e_graph_id);
306     }
307 }
308
309
310 void
311 GraphBuilder::connectSourceNodeToTargetNodesViaVertex(
312     const NodeType& rSourceNode,
313     const VertexType& rViaVertex)
314 {
315     // SOURCE
316     LineGraphNode source_node = getLineGraphNodeData(rSourceNode);
317
318     if(edgeHasNoExit(source_node.topoEdgeId))
319     {
320         return;
321     }
322
323     // get the edge corresponding to the node
324     Edge& source_edge = mrTopology.getEdge(source_node.topoEdgeId);
325
326     // VIA
327     VertexIdType via_topo_vertex_id =
328         boost::get(&GraphVertex::topoVertexId, mGraph, rViaVertex);
329
330     // TARGET
331     // get targets that are restricted
332     std::vector<EdgeIdType> restricted_targets =
333         getRestrictedTargets(source_node);
334
335     // look at all out edges from the via-vertex
336     for(auto target_it = boost::out_edges(rViaVertex, mGraph);
337         target_it.first != target_it.second;
338         ++target_it.first)
339     {
340         const EdgeType& target = *(target_it.first);
341         EdgeIdType target_topo_id =
342             boost::get(&GraphEdge::topoEdgeId, mGraph, target);
343
344         if(!isTargetRestricted(restricted_targets, target_topo_id))
345         {
346             // add nodes to LineGraph
347             NodeType target_node;
348             addGraphEdgeAsLineGraphNode(target, target_node);
349
350             NodeIdType target_edge_id =
351                 boost::get(&LineGraphNode::graphEdgeId, mLineGraph, target_node);
352
353             // add Line between Nodes to the LineGraph
354             try
355             {
356                 LineType line = addLineGraphLine(rSourceNode, target_node);
357                 addLineMetaIds(
358                     line,
359                     source_node.graphEdgeId,
360                     target_edge_id,
```

```
361         via_topo_vertex_id);
362         addLineMetaCost(line, source_edge, target_topo_id);
363     }
364     catch (GraphException& ge)
365     {
366         throw GraphException(
367             "Graph:connectSourceNodeToTargetNodesViaVertex: source: "
368             + std::to_string(source_node.graphEdgeId)
369             + ", target: " + std::to_string(target_edge_id));
370     }
371 }
372 else // log restricted targetId
373 {
374     Edge& s = mrTopology.getEdge(source_node.topoEdgeId);
375     Edge& t = mrTopology.getEdge(target_topo_id);
376     BOOST_LOG_SEV(mLog, boost::log::trivial::info)
377     << "Graph:connectSourceNodeToTargetNodesViaVertex(): Restricted: "
378     << "Source: " << source_node.topoEdgeId << " (osm: " << s.osmId()
379     << ") , Target: " << target_topo_id << " (osm: " << t.osmId() << "));
380 }
381 }
382 }
383
384 LineGraphNode
385 GraphBuilder::getLineGraphNodeData(const NodeType& rNode) const
386 {
387     LineGraphNode node;
388     node.topoEdgeId = boost::get(&LineGraphNode::topoEdgeId, mLineGraph, rNode);
389     node.graphEdgeId = boost::get(&LineGraphNode::graphEdgeId, mLineGraph, rNode);
390     node.oppositeDirection =
391         boost::get(&LineGraphNode::oppositeDirection, mLineGraph, rNode);
392
393     return node;
394 }
395
396 LineType
397 GraphBuilder::addLineGraphLine(const NodeType& rSourceNode,
398                               const NodeType& rTargetNode)
399 {
400     const auto& line_add =
401         boost::add_edge(rSourceNode, rTargetNode, mLineGraph);
402     if(line_add.second == true)
403     {
404         return line_add.first;
405     }
406     else // could not add the line to the linegraph
407     {
408         throw GraphException("GraphBuilder:addLineGraphLine");
409     }
410 }
411
412 void
413 GraphBuilder::addLineMetaIds(
414     const LineType& rLine,
415     EdgeIdType      sourceId,
416     EdgeIdType      targetId,
417     VertexIdType    viaVertexId)
```

```
418 {
419     mLineGraph[rLine].lgSourceNodeId = sourceId;
420     mLineGraph[rLine].lgTargetNodeId = targetId;
421     mLineGraph[rLine].topoViaVertexId = viaVertexId;
422 }
423
424 void
425 GraphBuilder::addLineMetaCost(
426     const LineType& rLine,
427     const Edge&      rSourceEdge,
428     EdgeIdType       targetId)
429 {
430     mLineGraph[rLine].cost =
431         rSourceEdge.cost() +
432         calculateTurnCost(rSourceEdge.id(), targetId);
433 }
434
435 double
436 GraphBuilder::calculateTurnCost(EdgeIdType sourceEdgeId,
437                                 EdgeIdType targetEdgeId) const
438 {
439     const Edge& source = mrTopology.getEdge(sourceEdgeId);
440     const Edge& target = mrTopology.getEdge(targetEdgeId);
441     return TurnCostCalculator::getTurnCost(source, target, mrConfiguration);
442 }
443
444 bool
445 GraphBuilder::edgeHasNoExit(EdgeIdType edgeId)
446 {
447     Edge& e = mrTopology.getEdge(edgeId);
448     if(e.hasRestrictions() && e.restrictions().hasNoExitRestriction())
449     {
450         return true;
451     }
452     return false;
453 }
454
455 std::vector<EdgeIdType>
456 GraphBuilder::getOutEdges(VertexIdType vertexId) const
457 {
458     std::vector<EdgeIdType> out_edges;
459     VertexType graphVertex = getGraphVertex(vertexId);
460     auto edge_iterators = boost::out_edges(graphVertex, mGraph);
461     while(edge_iterators.first != edge_iterators.second) {
462         const EdgeType& e = *(edge_iterators.first);
463         EdgeIdType edgeId = boost::get(&GraphEdge::topoEdgeId, mGraph, e);
464         out_edges.push_back(edgeId);
465         ++edge_iterators.first;
466     }
467     return out_edges;
468 }
469
470 std::vector<EdgeIdType>
471 GraphBuilder::getRestrictedTargets(const LineGraphNode& rSourceNode) const
472 {
473     std::vector<EdgeIdType> restricted_targets;
474 }
```

```
475     // Find all out edges from the targetId vertex of the edge,
476     // which depends on if the edge is the opposite direction of the topo edge.
477     Edge& sourceEdge = mrTopology.getEdge(rSourceNode.topoEdgeId);
478
479     VertexIdType target_vertex =
480         rSourceNode.oppositeDirection ?
481         sourceEdge.sourceId() : sourceEdge.targetId();
482
483     std::vector<EdgeIdType> out_edges = getOutEdges(target_vertex);
484     std::vector<EdgeIdType> targets;
485     targets.insert(targets.end(), out_edges.begin(), out_edges.end());
486
487     // build map of restricted targets
488     findRestrictedTargets(sourceEdge, targets, restricted_targets);
489
490     return restricted_targets;
491 }
492
493 void
494 GraphBuilder::findRestrictedTargets(
495     const Edge&          rSourceEdge,
496     const std::vector<EdgeIdType>& rTargets,
497     std::vector<EdgeIdType>&      rRestrictedTargets) const
498 {
499     for(EdgeIdType e_id : rTargets)
500     {
501         // don't add self to targetId
502         if(e_id == rSourceEdge.id())
503         {
504             continue;
505         }
506
507         Edge& e = mrTopology.getEdge(e_id);
508
509         if(e.isRestricted(mrConfiguration))
510         {
511             BOOST_LOG_SEV(mLog, boost::log::trivial::info)
512                 << "Graph:getRestrictedTargets(): "
513                 << "Source id " << rSourceEdge.id()
514                 << " has restricted target: " << e_id;
515             rRestrictedTargets.push_back(e_id);
516         }
517     }
518
519     addTurningRestrictedTargets(rSourceEdge, rRestrictedTargets);
520 }
521
522 void
523 GraphBuilder::addTurningRestrictedTargets(
524     const Edge& rSourceEdge,
525     std::vector<EdgeIdType>& rRestrictedTargets) const
526 {
527     if(rSourceEdge.hasRestrictions() &&
528         rSourceEdge.restrictions().hasTurningRestriction())
529     {
530         BOOST_LOG_SEV(mLog, boost::log::trivial::info)
531             << "Graph:getRestrictedTargets(): "
```

```
532         << "Source id " << rSourceEdge.id()
533         << " has TURN restricted targets. ";
534     std::vector<EdgeIdType> turn_restricted_targets =
535         rSourceEdge.restrictions().restrictedTargetEdges();
536     rRestrictedTargets.insert(rRestrictedTargets.end(),
537         turn_restricted_targets.begin(), turn_restricted_targets.end());
538 }
539 }
540
541 bool
542 GraphBuilder::isTargetRestricted(
543     const std::vector<EdgeIdType>& rRestrictedTargets,
544     EdgeIdType targetId) const
545 {
546     if(mUseRestrictions && rRestrictedTargets.size() > 0)
547     {
548         const auto& restr_it = std::find(
549             rRestrictedTargets.begin(),
550             rRestrictedTargets.end(),
551             targetId);
552         if(restr_it != rRestrictedTargets.end())
553         {
554             BOOST_LOG_SEV(mLog, boost::log::trivial::info)
555                 << "Graph:isTargetRestricted(): "
556                 << "Restricted target id " << targetId;
557             return true;
558         }
559     }
560     return false;
561 }
562
563 void
564 GraphBuilder::printGraphInformation(std::ostream& os) const
565 {
566     os << "Graph: #vertices: " << nrVertices()
567         << ", #edges: " << nrEdges()
568         << ". LineGraph: #nodes: " << nrNodes()
569         << ", #lines: " << nrLines()
570         << std::endl;
571 }
572
573 void
574 GraphBuilder::printVertices(std::ostream& os) const
575 {
576     for(auto v_it = boost::vertices(mGraph);
577         v_it.first != v_it.second;
578         ++v_it.first)
579     {
580         const VertexType& v = *v_it.first;
581         VertexIdType graph_vertex_id =
582             boost::get(&GraphVertex::graphVertexId, mGraph, v);
583         VertexIdType topo_vertex_id =
584             boost::get(&GraphVertex::topoVertexId, mGraph, v);
585         const Vertex& vertex = mrTopology.getVertex(topo_vertex_id);
586
587         os << "    graph_vertex_id: " << graph_vertex_id
588             << ", topo_vertex_id: " << topo_vertex_id
```



```
589         << "\n          v: " << v
590         << " " << vertex << std::endl;
591     }
592 }
593
594 void
595 GraphBuilder::printEdges(std::ostream& os) const
596 {
597     for(auto e_it = boost::edges(mGraph);
598         e_it.first != e_it.second;
599         ++e_it.first)
600     {
601         const EdgeType& e = *(e_it.first);
602         EdgeIdType graph_edge_id =
603             boost::get(&GraphEdge::graphEdgeId, mGraph, e);
604         EdgeIdType topo_edge_id =
605             boost::get(&GraphEdge::topoEdgeId, mGraph, e);
606         const Edge& edge = mrTopology.getEdge(topo_edge_id);
607
608         os << "    graph_edge_id: " << graph_edge_id
609            << ", e_topo_id: " << topo_edge_id
610            << "\n          e: " << e
611            << " " << edge << std::endl;
612     }
613 }
614
615 void
616 GraphBuilder::printNodes(std::ostream& os) const
617 {
618     for(auto n_it = boost::vertices(mLineGraph);
619         n_it.first != n_it.second;
620         ++n_it.first)
621     {
622         const NodeType& node = *(n_it.first);
623         NodeIdType lg_node_id =
624             boost::get(&LineGraphNode::graphEdgeId, mLineGraph, node);
625         EdgeIdType topo_edge_id =
626             boost::get(&LineGraphNode::graphEdgeId, mLineGraph, node);
627
628         os << "    lg_node_id (graph_edge_id): " << lg_node_id
629            << ", topo_edge_id: " << topo_edge_id << std::endl;
630     }
631 }
632
633 void
634 GraphBuilder::printLines(std::ostream& os) const
635 {
636     for(auto line_it = boost::edges(mLineGraph);
637         line_it.first != line_it.second;
638         ++line_it.first)
639     {
640         const LineType& line = *(line_it.first);
641         NodeIdType lg_source_id =
642             boost::get(&LineGraphLine::lgSourceNodeId, mLineGraph, line);
643         NodeIdType lg_target_id =
644             boost::get(&LineGraphLine::lgTargetNodeId, mLineGraph, line);
645         VertexIdType topo_via_vertex_id =
```

```
646         boost::get(&LineGraphLine::topoViaVertexId, mLineGraph, line);
647
648         os << "    lg_source_id: " << lg_source_id
649         << ", lg_target_id: " << lg_target_id
650         << ", topo_via_vertex_id: " << topo_via_vertex_id << std::endl;
651     }
652 }
```

D.7.10 Cost.h

```
1  /* The Cost type.
2   *
3   * Cost.h
4   *
5   * @author Jonas Bergman
6   */
7
8  #ifndef GRAPH_COST_H_
9  #define GRAPH_COST_H_
10
11  typedef double Cost;
12
13  #endif /* GRAPH_COST_H_ */
```

D.7.11 Speed.h

```
1  /** The Speed type.
2   * Speed.h
3   *
4   * @author Jonas Bergman
5   */
6
7  #ifndef GRAPH_SPEED_H_
8  #define GRAPH_SPEED_H_
9
10
11  typedef unsigned Speed;
12
13
14  #endif /* GRAPH_SPEED_H_ */
```

D.7.12 EdgeCost.h

```
1  /** The Costs for an Edge.
2   * The cost or weight can be thought of as seconds, with the time to travel
3   * the edge as a base, and different obstacles as additional costs.
4   *
5   * #include "EdgeCost.h"
6   *
7   * @author Jonas Bergman
8   */
9  #ifndef GRAPH_EDGE_COST_H_
10 #define GRAPH_EDGE_COST_H_
11
12 // SYSTEM INCLUDES
13 //
14 #include <map>
```

```
15
16 // PROJECT INCLUDES
17 //
18
19 // LOCAL INCLUDES
20 //
21 #include "Cost.h"
22
23 // FORWARD REFERENCES
24 //
25 //typedef double Cost;
26
27 /** Costs for edges:
28  * - speed (either set explicitly or default from road category)
29  * - barriers (should be imported from the EdgeRestriction)
30  * - incline (not implemented yet)
31  * - surface
32  * - traffic_calming
33  * - highway => bus_stop
34  * - highway => crossing
35  * - highway => give_way
36  * - highway => mini_roundabout
37  * - highway => stop
38  * - highway => traffic_signals
39  * - public_transport => stop_position
40  * - railway => level_crossing
41  */
42 class EdgeCost
43 {
44 public:
45 // TYPES
46     enum CostType
47     {
48         TRAVEL_TIME,
49         BARRIER,
50         OTHER
51     };
52
53 // LIFECYCLE
54
55     /** Default constructor.
56     */
57     EdgeCost() = default;
58
59
60     /** Copy constructor.
61     *
62     * @param from The value to copy to this object.
63     */
64     EdgeCost(const EdgeCost& from) = delete;
65
66
67     /** Destructor.
68     */
69     ~EdgeCost() = default;
70
71
```

```
72 // OPERATORS
73
74 /** Accumulate a cost of a certain type, except `travel` which can not
75     * be accumulated.
76     * @param type The type of cost
77     * @param cost The value of the cost in seconds.
78     */
79 void addCost(CostType type, Cost cost);
80
81 /** Clear out all costs.
82     */
83 void clearCosts();
84
85 // OPERATIONS
86 // ACCESS
87
88 /**
89     * @return The sum of all costs
90     */
91 Cost getCost() const;
92
93 /**
94     * @return The accumulated costs of a CostType
95     */
96 Cost getCost(CostType type) const;
97
98 // INQUIRY
99 /** Find out if there are costs of a certain type
100     * @return True if there is such a cost
101     */
102 bool hasCost(CostType type) const;
103
104 protected:
105 private:
106     std::map<CostType, Cost> costs;
107 };
108
109 // INLINE METHODS
110 //
111
112 // EXTERNAL REFERENCES
113 //
114
115 #endif /* GRAPH_EDGE_COST_H_ */
```

D.7.13 EdgeCost.cc

```
1 /*
2  * EdgeCost.cc
3  *
4  * @author Jonas Bergman
5  */
6
7 #include "EdgeCost.h" // class implemented
8
9 ////////////////////////////////// PUBLIC //////////////////////////////////
10 //===== LIFECYCLE =====
```

```

11 //===== OPERATORS =====
12 void
13 EdgeCost::addCost(CostType type, Cost cost)
14 {
15     if(hasCost(type))
16     {
17         if(type != EdgeCost::TRAVEL_TIME)
18         {
19             cost += getCost(type);
20         }
21         costs.erase(type);
22     }
23     costs.insert({type, cost});
24 }
25
26 void
27 EdgeCost::clearCosts()
28 {
29     costs.clear();
30 }
31 //===== OPERATIONS =====
32 //===== ACCESS =====
33 Cost
34 EdgeCost::getCost() const
35 {
36     Cost sum {0};
37     for(const auto& pair : costs)
38     {
39         sum += pair.second;
40     }
41     return sum;
42 }
43
44 Cost
45 EdgeCost::getCost(EdgeCost::CostType type) const
46 {
47     const auto& it = costs.find(type);
48     if(it != costs.end())
49     {
50         return it->second;
51     }
52     return 0;
53 }
54
55 //===== INQUIRY =====
56 bool
57 EdgeCost::hasCost(EdgeCost::CostType type) const
58 {
59     return costs.find(type) != costs.end();
60 }
61 ////////////////////////////////// PROTECTED //////////////////////////////////
62 ////////////////////////////////// PRIVATE //////////////////////////////////

```

D.7.14 EdgeRestriction.h

```

1 /** The EdgeRestriction class contains different restrictions for edges
2  * in the graph such as dimensions, access, turn restrictions.

```

```
3  *
4  * #include "EdgeRestriction.h"
5  *
6  * @author Jonas Bergman
7  */
8
9  #ifndef GRAPH_EDGERESTRICTION_H_
10 #define GRAPH_EDGERESTRICTION_H_
11
12 // SYSTEM INCLUDES
13 //
14 #include <limits>
15 #include <map>
16 #include <set>
17
18 // PROJECT INCLUDES
19 //
20
21 // LOCAL INCLUDES
22 //
23 #include "Edge.h"
24 #include "RestrictionsException.h"
25 #include "Speed.h"
26 #include "Vertex.h"
27 #include "../config/Configuration.h"
28 #include "../osm/OsmAccess.h"
29 #include "../osm/OsmBarrier.h"
30 #include "../osm/OsmTurningRestriction.h"
31 #include "../osm/OsmVehicle.h"
32
33 // FORWARD REFERENCES
34 //
35 //class OsmTurningRestriction;
36
37 /**
38  * EdgeRestriction are:
39  * - vehicle properties
40  * - General access to an edge
41  * - vehicle type specific access
42  * - barriers
43  * - turn restrictions
44  * - disused roads
45  * - no-exit roads
46  */
47 class EdgeRestriction
48 {
49 public:
50 // TYPES
51 /** EdgeRestrictions on Vehicles to travel an Edge.
52  * Dimensions in meters.
53  * Speed in km/h
54  */
55 struct VehicleProperties
56 {
57     static double DEFAULT_DIMENSION_MAX;
58     static Speed DEFAULT_SPEED_MAX;
59     static Speed DEFAULT_SPEED_MIN;
```

```
60
61     double    maxHeight    {DEFAULT_DIMENSION_MAX};
62     double    maxLength    {DEFAULT_DIMENSION_MAX};
63     double    maxWeight    {DEFAULT_DIMENSION_MAX};
64     double    maxWidth     {DEFAULT_DIMENSION_MAX};
65
66     Speed      maxSpeed     {DEFAULT_SPEED_MAX};
67     Speed      minSpeed     {DEFAULT_SPEED_MIN};
68
69     /** Look if the vehicle properties restricts
70     * vehicle with given configuration.
71     * @return True if these vehicle properties restricts access.
72     */
73     bool    restrictsAccess(const VehicleConfig& rVehicleConfig) const
74     {
75         return (maxHeight <= rVehicleConfig.height)
76             || (maxLength <= rVehicleConfig.length)
77             || (maxWeight <= rVehicleConfig.weight)
78             || (maxWidth <= rVehicleConfig.width)
79             || (minSpeed >= rVehicleConfig.maxspeed);
80     }
81 };
82
83 /** Types of restrictions.
84 */
85 enum RestrictionType
86 {
87     VEHICLE_PROPERTIES,
88     GENERAL_ACCESS,
89     VEHICLE_TYPE_ACCESS,
90     BARRIER,
91     TURNING,
92     DISUSED,
93     NO_EXIT,
94
95     NR_RESTRICTION_TYPES
96 };
97
98 // LIFECYCLE
99
100 /** Default constructor.
101 */
102 EdgeRestriction() = default;
103
104
105 /** Copy constructor.
106 *
107 * @param from The value to copy to this object.
108 */
109 EdgeRestriction(const EdgeRestriction& from) = delete;
110
111
112 /** Destructor.
113 */
114 ~EdgeRestriction();
115
116
```

```
117 // OPERATORS
118 // OPERATIONS
119
120 /** Check if this Restriction restricts when the Configuration is applied.
121  * @param rConfig Configuration
122  * @throw RestrictionsException
123  */
124 bool restricts(const Configuration& rConfig) const;
125
126 /** Set vehicle properties for the specified edge.
127  * Replacing any existing properties with the new ones.
128  * @param pVehicleProperties The properties to install for the edge.
129  */
130 void setVehiclePropertyRestriction(
131     VehicleProperties* pVehicleProperties);
132
133 /** Set access restrictions for this edge, that is restrictions for all.
134  * @param pGeneralAccess The access to set.
135  */
136 void setGeneralAccessRestriction(
137     OsmAccess* pGeneralAccess);
138
139 /** Set access restrictions for this edge, that is restrictions for all.
140  * @param generalAccessType The access type to set.
141  */
142 void setGeneralAccessRestriction(
143     OsmAccess::AccessType generalAccessType);
144
145 /** Set access restrictions for edge based on vehicle type.
146  * There can be several vehicle restrictions for each edge.
147  * @param vehicleType The type of vehicle to restrict on the edge.
148  * @param pAccess The access restriction for that vehicle type
149  * on this edge.
150  */
151 void addVehicleTypeAccessRestriction(
152     OsmVehicle::VehicleType vehicleType,
153     OsmAccess* pAccess);
154
155 /** Set access restrictions for edge based on vehicle type.
156  * There can be several vehicle restrictions for each edge.
157  * @param vehicleType The type of vehicle to restrict on the edge.
158  * @param accessType The access restriction for that vehicle type
159  * on this edge.
160  */
161 void addVehicleTypeAccessRestriction(
162     OsmVehicle::VehicleType vehicleType,
163     OsmAccess::AccessType accessType);
164
165 /** Set barrier restricting this edge.
166  * @param pBarrier The barrier to set.
167  */
168 void setBarrierRestriction(
169     OsmBarrier* pBarrier);
170
171 /** Set barrier restricting this edge.
172  * @param barrierType The barrier type to set.
173  */
```



```
174     void                setBarrierRestriction(  
175         OsmBarrier::BarrierType barrierType);  
176  
177     /** Add turning restrictions from this edge.  
178     * Actually just adds the restriction without checking if there already is  
179     * a restriction between those two edges.  
180     * @param pTurningRestriction The turning restriction to set.  
181     */  
182     void                addTurningRestriction(  
183         OsmTurningRestriction* pTurningRestriction);  
184  
185     /** Set disused flag on this edge.  
186     */  
187     void                setDisusedRestriction();  
188  
189     /** Set no exit flag on this edge.  
190     */  
191     void                setNoExitRestriction();  
192  
193     /** Flag this edge as part of a via way restriction that needs attention  
194     * when routing.  
195     */  
196     void                setViaWayRestriction();  
197  
198     // ACCESS  
199     /** Get which kinds of restrictions this edge has.  
200     * @return A vector with all types of restrictions.  
201     */  
202     std::vector<RestrictionType>  
203         restrictionTypes() const;  
204  
205     /** Try to fetch the vehicle property restrictions for an Edge.  
206     * @return The Vehicle properties  
207     * @throw RestrictionsException if no entry exists for Edge.  
208     */  
209     const VehicleProperties&  
210         vehicleProperties() const;  
211  
212     /** Try to fetch the vehicle property restrictions for an Edge.  
213     * @return The Vehicle properties  
214     * @throw RestrictionsException if no entry exists for Edge.  
215     */  
216     VehicleProperties& vehicleProperties();  
217  
218     /** Fetch the max speed for this edge. If no explicit speed is set it  
219     * returns `VehicleProperties::DEFAULT_SPEED_MAX`. One can query to see if  
220     * if there exists an explicit limit with `hasMaxSpeedRestriction()`  
221     * @return Either the explicit speed limit or a default if not set.  
222     */  
223     Speed                maxSpeed() const;  
224  
225     /** Try to fetch the general access restrictions for this edge.  
226     * @param edgeId The id of the edge.  
227     * @return reference to the OsmAccess object.  
228     * @throw RestrictionsException if no entry exists for Edge.  
229     */  
230     const OsmAccess&     generalAccess() const;
```

```
231
232 /** Try to fetch the general access restrictions for this edge.
233  * @param   edgeId   The id of the edge.
234  * @return  reference to the OsmAccess object.
235  * @throw   RestrictionsException if no entry exists for Edge.
236  */
237 OsmAccess&          generalAccess();
238
239 /** Try to fetch the vehicle type specific access restrictions for this edge.
240  * @param   vehicleType   The type of Vehicle to get access restriction
241  * @return  reference to the OsmAccess object.
242  * @throw   RestrictionsException if no entry exists for Edge.
243  */
244 const OsmAccess&    vehicleTypeAccess(
245                     OsmVehicle::VehicleType vehicleType) const;
246
247 /** Try to fetch the vehicle type specific access restrictions for this edge.
248  * @param   vehicleType   The type of Vehicle to get access restriction
249  * @return  reference to the OsmAccess object.
250  * @throw   RestrictionsException if no entry exists for Edge.
251  */
252 OsmAccess&          vehicleTypeAccess(
253                     OsmVehicle::VehicleType vehicleType);
254
255 /** Get a list of the types of vehicles with restrictions on this edge.
256  * @return  a Vector with restriction types.
257  */
258 std::vector<OsmVehicle::VehicleType>
259         vehicleTypesWithRestrictions() const;
260
261 /** Fetch the barrier restricting this edge.
262  * @return  reference to a OsmBarrier object.
263  * @throw   RestrictionsException if no entry exists for this Edge.
264  */
265 const OsmBarrier&    barrier() const;
266
267 /** Get a list of the turning restrictions from this edge.
268  * @return  a Vector with turning restrictions.
269  * @throw   RestrictionsException if edge has no turning restrictions.
270  */
271 const std::vector<OsmTurningRestriction*>&
272         turningRestrictions() const;
273
274 /** Get a list of all edge id's to which travel from edge is not allowed.
275  * @return  A vector of edgeIds to which travel is not allowed.
276  */
277 std::vector<EdgeIdType>
278         restrictedTargetEdges() const;
279
280 // INQUIRY
281
282 /** Ask if an Edge has restriction of a certain type.
283  * @param   restrictionType   The type of restriction
284  * @return  true if there is a restriction of that type, false if not.
285  */
286 bool          hasRestriction(
287                     RestrictionType restrictionType) const;
```

```
288     /**
289      * @return true if there is a VehicleProperty restriction for edge.
290      */
291     bool                hasVehiclePropertyRestriction() const;
292
293     /** Convenience method to query for max speed.
294      * @return true if there is a max speed restriction for the edge.
295      */
296     bool                hasMaxSpeedRestriction() const;
297
298     /**
299      * @return true if there is a General Access restriction for the edge.
300      */
301     bool                hasGeneralAccessRestriction() const;
302
303     /**
304      * @return true if there are any Vehicle Type Access restrictions for the edge.
305      */
306     bool                hasVehicleTypeAccessRestriction() const;
307
308     /**
309      * @return true if there are Vehicle Type Access restrictions for the edge
310      *         for that specific type of vehicle.
311      */
312     bool                hasVehicleTypeAccessRestriction(
313                         OsmVehicle::VehicleType vehicleType) const;
314
315     /**
316      * @return true if there are any barriers restricting access to the edge.
317      */
318     bool                hasBarrierRestriction() const;
319
320     /**
321      * @return true if there are any turning restrictions traveling from edge.
322      */
323     bool                hasTurningRestriction() const;
324
325     /**
326      * @return true if the edge is 'disused'.
327      */
328     bool                hasDisusedRestriction() const;
329
330     /**
331      * @return true if the edge has no exit.
332      */
333     bool                hasNoExitRestriction() const;
334
335     /**
336      * @return true if the edge is part of a turning restriction via another way.
337      */
338     bool                hasViaWayRestriction() const;
339
340
341     protected:
342     private:
343         VehicleProperties*    mpVehicleProperties {nullptr};
344         OsmAccess*           mpGeneralAccess {nullptr};
```

```
345     std::map<OsmVehicle::VehicleType, OsmAccess*>
346                                     mVehicleTypeAccessMap;
347     OsmBarrier*                      mpBarrier {nullptr};
348     std::vector<OsmTurningRestriction*>
349                                     mTurningRestrictions;
350     bool                             mIsDisusedEdge {false};
351     bool                             mIsNoExitEdge {false};
352     bool                             mHasViaWayRestriction {false};
353 };
354
355 // INLINE METHODS
356 //
357
358 // EXTERNAL REFERENCES
359 //
360
361 #endif /* GRAPH_EDGERESTRICTION_H_ */
```

D.7.15 EdgeRestriction.cc

```
1  /*
2   * EdgeRestriction.cc
3   *
4   * @author Jonas Bergman
5   */
6
7  #include "EdgeRestriction.h" // class implemented
8
9  // STATIC INITIALIZATION
10 /*static*/ double EdgeRestriction::VehicleProperties::DEFAULT_DIMENSION_MAX
11     = std::numeric_limits<double>::max();
12
13 /*static*/ Speed EdgeRestriction::VehicleProperties::DEFAULT_SPEED_MAX
14     = std::numeric_limits<unsigned>::max();
15
16 /*static*/ Speed EdgeRestriction::VehicleProperties::DEFAULT_SPEED_MIN
17     = 0;
18
19 ////////////////////////////////// PUBLIC //////////////////////////////////
20 //===== LIFECYCLE =====
21 EdgeRestriction::~EdgeRestriction()
22 {
23     delete mpVehicleProperties;
24     delete mpGeneralAccess;
25     delete mpBarrier;
26     for(auto it : mVehicleTypeAccessMap)
27     {
28         delete it.second;
29     }
30     for(auto it : mTurningRestrictions)
31     {
32         delete it;
33     }
34 }
35 //===== OPERATORS =====
36 //===== OPERATIONS =====
37 bool
```

```
38 EdgeRestriction::restricts(const Configuration& rConfig) const
39 {
40     bool is_restricted = false;
41     bool is_generally_restricted = false;
42     bool is_vehicle_banned = false;
43
44     for(const auto& r : restrictionTypes())
45     {
46         switch (r)
47         {
48             case EdgeRestriction::DISUSED:
49                 is_restricted = true; break;
50             case EdgeRestriction::VEHICLE_PROPERTIES:
51                 if(vehicleProperties()
52                     .restrictsAccess(rConfig.getVehicleConfig()))
53                 {
54                     is_restricted = true;
55                 }
56                 break;
57             case EdgeRestriction::BARRIER:
58                 if(barrier()
59                     .restrictsAccess(rConfig.getBarrierRestrictionsRule()))
60                 {
61                     is_restricted = true;
62                 }
63                 break;
64             case EdgeRestriction::GENERAL_ACCESS:
65                 if(!generalAccess()
66                     .allowsAccess(rConfig.getAccessRule()))
67                 {
68                     is_generally_restricted = true;
69                 }
70                 continue;
71             case EdgeRestriction::VEHICLE_TYPE_ACCESS:
72                 {
73                     OsmVehicle::VehicleType type =
74                         rConfig.getVehicleConfig().category;
75                     if(hasVehicleTypeAccessRestriction(type))
76                     {
77                         if(!vehicleTypeAccess(type)
78                             .allowsAccess(rConfig.getAccessRule()))
79                         {
80                             is_vehicle_banned = true;
81                         }
82                     }
83                 }
84                 continue;
85             default:
86                 continue;
87         }
88     }
89
90     if(is_restricted
91         || (is_generally_restricted && is_vehicle_banned)
92         || is_vehicle_banned)
93     {
94         return true;
95     }
```

```
95     }
96     return false;
97 }
98
99 void
100 EdgeRestriction::setVehiclePropertyRestriction(
101     EdgeRestriction::VehicleProperties* pVehicleProperties)
102 {
103     delete mpVehicleProperties;
104     mpVehicleProperties = pVehicleProperties;
105 }
106
107 void
108 EdgeRestriction::setGeneralAccessRestriction(
109     OsmAccess* pGeneralAccess)
110 {
111     delete mpGeneralAccess;
112     mpGeneralAccess = pGeneralAccess;
113 }
114
115 void
116 EdgeRestriction::setGeneralAccessRestriction(
117     OsmAccess::AccessType generalAccessType)
118 {
119     delete mpGeneralAccess;
120     mpGeneralAccess = new OsmAccess(generalAccessType);
121 }
122
123 void
124 EdgeRestriction::addVehicleTypeAccessRestriction(
125     OsmVehicle::VehicleType vehicleType,
126     OsmAccess* pAccess)
127 {
128     if(hasVehicleTypeAccessRestriction(vehicleType))
129     {
130         auto old_access = mVehicleTypeAccessMap.find(vehicleType);
131         delete old_access->second;
132         mVehicleTypeAccessMap.erase(vehicleType);
133     }
134     mVehicleTypeAccessMap.insert({vehicleType, pAccess});
135 }
136
137 void
138 EdgeRestriction::addVehicleTypeAccessRestriction(
139     OsmVehicle::VehicleType vehicleType,
140     OsmAccess::AccessType accessType)
141 {
142     addVehicleTypeAccessRestriction(vehicleType, new OsmAccess(accessType));
143 }
144
145 void
146 EdgeRestriction::setBarrierRestriction(
147     OsmBarrier* pBarrier)
148 {
149     delete mpBarrier;
150     mpBarrier = pBarrier;
151 }
```

```
152
153 void
154 EdgeRestriction::setBarrierRestriction(
155     OsmBarrier::BarrierType barrierType)
156 {
157     delete mpBarrier;
158     mpBarrier = new OsmBarrier(barrierType);
159 }
160
161 void
162 EdgeRestriction::addTurningRestriction(
163     OsmTurningRestriction* pTurningRestriction)
164 {
165     mTurningRestrictions.push_back(pTurningRestriction);
166 }
167
168 void
169 EdgeRestriction::setDisusedRestriction()
170 {
171     mIsDisusedEdge = true;
172 }
173
174 void
175 EdgeRestriction::setNoExitRestriction()
176 {
177     mIsNoExitEdge = true;
178 }
179
180 void
181 EdgeRestriction::setViaWayRestriction()
182 {
183     mHasViaWayRestriction = true;
184 }
185 //===== ACCESS =====
186 std::vector<EdgeRestriction::RestrictionType>
187 EdgeRestriction::restrictionTypes() const
188 {
189     std::vector<EdgeRestriction::RestrictionType> rest_types;
190
191     for(int i = EdgeRestriction::VEHICLE_PROPERTIES;
192         i < EdgeRestriction::NR_RESTRICTION_TYPES;
193         ++i)
194     {
195         RestrictionType type = static_cast<RestrictionType>(i);
196         if(hasRestriction(type))
197         {
198             rest_types.push_back(type);
199         }
200     }
201
202     return rest_types;
203 }
204
205 const EdgeRestriction::VehicleProperties&
206 EdgeRestriction::vehicleProperties() const
207 {
208     if(!hasVehiclePropertyRestriction())
```

```
209     {
210         throw RestrictionsException(
211             "Restrictions:vehicleProperties: no restriction for edge");
212     }
213     return *mpVehicleProperties;
214 }
215
216 EdgeRestriction::VehicleProperties&
217 EdgeRestriction::vehicleProperties()
218 {
219     if(!hasVehiclePropertyRestriction())
220     {
221         throw RestrictionsException(
222             "Restrictions:vehicleProperties: no restriction for edge");
223     }
224     return *mpVehicleProperties;
225 }
226
227 Speed
228 EdgeRestriction::maxSpeed() const
229 {
230     if(hasVehiclePropertyRestriction())
231     {
232         return mpVehicleProperties->maxSpeed;
233     }
234     return VehicleProperties::DEFAULT_SPEED_MAX;
235 }
236
237 const OsmAccess&
238 EdgeRestriction::generalAccess() const
239 {
240     if(!hasGeneralAccessRestriction())
241     {
242         throw RestrictionsException(
243             "Restrictions:generalAccess: no restriction for edge");
244     }
245     return *mpGeneralAccess;
246 }
247
248 OsmAccess&
249 EdgeRestriction::generalAccess()
250 {
251     if(!hasGeneralAccessRestriction())
252     {
253         throw RestrictionsException(
254             "Restrictions:generalAccess: no restriction for edge");
255     }
256     return *mpGeneralAccess;
257 }
258
259 const OsmAccess&
260 EdgeRestriction::vehicleTypeAccess(
261     OsmVehicle::VehicleType vehicleType) const
262 {
263     if(!hasVehicleTypeAccessRestriction(vehicleType))
264     {
265         throw RestrictionsException(
```



```
266         std::string("Restrictions:vehicleTypeAccess: no restriction for")
267         + " vehicle type " + OsmVehicle::toString(vehicleType)
268         + " for edge ");
269     }
270     return *(mVehicleTypeAccessMap.find(vehicleType)->second);
271 }
272
273 OsmAccess&
274 EdgeRestriction::vehicleTypeAccess(
275     OsmVehicle::VehicleType vehicleType)
276 {
277     return const_cast<OsmAccess&>
278         (static_cast<const EdgeRestriction&>
279          (*this).vehicleTypeAccess(vehicleType)
280         );
281 }
282
283 std::vector<OsmVehicle::VehicleType>
284 EdgeRestriction::vehicleTypesWithRestrictions() const
285 {
286     std::vector<OsmVehicle::VehicleType> types;
287
288     for( int i = 0; i < OsmVehicle::NR_VEHICLE_TYPES; ++i)
289     {
290         OsmVehicle::VehicleType type = static_cast<OsmVehicle::VehicleType>(i);
291
292         if(hasVehicleTypeAccessRestriction(type))
293         {
294             types.push_back(type);
295         }
296     }
297
298     return types;
299 }
300
301 const OsmBarrier&
302 EdgeRestriction::barrier() const
303 {
304     if(!hasBarrierRestriction())
305     {
306         throw RestrictionsException(
307             "Restrictions:barrier: no restriction for edge");
308     }
309     return *mpBarrier;
310 }
311
312 const std::vector<OsmTurningRestriction*>&
313 EdgeRestriction::turningRestrictions() const
314 {
315     if(!hasTurningRestriction())
316     {
317         throw RestrictionsException(
318             "Restriction:turningRestriction: no turning restriction for edge");
319     }
320     return mTurningRestrictions;
321 }
322
```

```
323 std::vector<EdgeIdType>
324 EdgeRestriction::restrictedTargetEdges() const
325 {
326     std::vector<EdgeIdType> restricted_targets;
327
328     try
329     {
330         const auto& r_vec = this->turningRestrictions();
331
332         for(const auto& restr : r_vec)
333         {
334             restricted_targets.push_back(restr->toEdgeId());
335         }
336     }
337     catch (RestrictionsException& re)
338     {
339         // never mind
340     }
341     return restricted_targets;
342 }
343
344 //===== INQUIRY =====
345 bool
346 EdgeRestriction::hasRestriction(
347     EdgeRestriction::RestrictionType type) const
348 {
349     switch (type)
350     {
351         case VEHICLE_PROPERTIES:
352             return hasVehiclePropertyRestriction(); break;
353         case GENERAL_ACCESS:
354             return hasGeneralAccessRestriction(); break;
355         case VEHICLE_TYPE_ACCESS:
356             return hasVehicleTypeAccessRestriction(); break;
357         case BARRIER:
358             return hasBarrierRestriction(); break;
359         case TURNING:
360             return hasTurningRestriction(); break;
361         case DISUSED:
362             return hasDisusedRestriction(); break;
363         case NO_EXIT:
364             return hasNoExitRestriction(); break;
365         default:
366             return false;
367     }
368 }
369
370 bool
371 EdgeRestriction::hasVehiclePropertyRestriction() const
372 {
373     return mpVehicleProperties != nullptr;
374 }
375
376 bool
377 EdgeRestriction::hasMaxSpeedRestriction() const
378 {
379     if(hasVehiclePropertyRestriction())
```

```
380     {
381         return mpVehicleProperties->maxSpeed != VehicleProperties::DEFAULT_SPEED_MAX;
382     }
383     return false;
384 }
385
386 bool
387 EdgeRestriction::hasGeneralAccessRestriction() const
388 {
389     return mpGeneralAccess != nullptr;
390 }
391
392 bool
393 EdgeRestriction::hasVehicleTypeAccessRestriction() const
394 {
395     return mVehicleTypeAccessMap.size() > 0;
396 }
397
398 bool
399 EdgeRestriction::hasVehicleTypeAccessRestriction(
400     OsmVehicle::VehicleType vehicleType) const
401 {
402     auto it = mVehicleTypeAccessMap.find(vehicleType);
403     if (it != mVehicleTypeAccessMap.end())
404     {
405         return true;
406     }
407     return false;
408 }
409
410 bool
411 EdgeRestriction::hasBarrierRestriction() const
412 {
413     return mpBarrier != nullptr;
414 }
415
416 bool
417 EdgeRestriction::hasTurningRestriction() const
418 {
419     return mTurningRestrictions.size() > 0;
420 }
421
422 bool
423 EdgeRestriction::hasDisusedRestriction() const
424 {
425     return mIsDisusedEdge;
426 }
427
428 bool
429 EdgeRestriction::hasNoExitRestriction() const
430 {
431     return mIsNoExitEdge;
432 }
433
434 bool
435 EdgeRestriction::hasViaWayRestriction() const
436 {
```

```
437     return mHasViaWayRestriction;
438 }
439 ////////////////////////////////////////////////// PROTECTED ///////////////////////////////////
440
441 ////////////////////////////////////////////////// PRIVATE ///////////////////////////////////
```

D.7.16 TurnCostCalculator.h

```
1  /** Calculate the turn cost for making a turn between to edges (roads).
2   *
3   * #include "TurnCostCalculator.h"
4   *
5   * @author Jonas Bergman
6   */
7
8  #ifndef GRAPH_TURNCOSTCALCULATOR_H_
9  #define GRAPH_TURNCOSTCALCULATOR_H_
10
11 // SYSTEM INCLUDES
12 //
13 #include <initializer_list>
14 #include <cstdlib> // abs()
15
16 // PROJECT INCLUDES
17 //
18
19 // LOCAL INCLUDES
20 //
21 #include "Cost.h"
22 #include "Edge.h"
23 #include "Speed.h"
24 #include "../config/Configuration.h"
25
26 // FORWARD REFERENCES
27 //
28
29 // TYPES
30 //
31
32 /**
33  * Calculate the cost for making turns.
34  * Based on "Route Planning in Road Networks with Turn Costs"
35  * by Lars Volker. Universitat Karlsruhe 2008.
36  * http://algo2.iti.kit.edu/documents/routeplanning/volker\_sa.pdf
37  *
38  * The cost is dependent on
39  * - angle between roads
40  * - size of vehicle
41  * - road category precedence
42  */
43 class TurnCostCalculator
44 {
45 public:
46 // LIFECYCLE
47     TurnCostCalculator() = delete;
48     virtual ~TurnCostCalculator() = delete;
49 }
```

```
50 // OPERATORS
51 // OPERATIONS
52 // ACCESS
53 /**
54  * @return The cost of the turn.
55  */
56 static double getTurnCost(
57     const Edge& rSource,
58     const Edge& rTarget,
59     const Configuration& rConfig);
60 // INQUIRY
61 private:
62 // HELPERS
63 /**
64  * @param rSource Source edge.
65  * @param rTarget Target edge.
66  * @return The speed dependent on the angle between edges.
67  */
68 static Speed getAngleSpeed(
69     const Edge& rSource,
70     const Edge& rTarget);
71
72 /**
73  * @param rSource Source edge.
74  * @param rTarget Target edge.
75  * @param vehicle_length Length of the vehicle.
76  * @param angleSpeed The angle dependent speed
77  * @return The speed dependent on the size of the routed vehicle.
78  */
79 static Speed getVehicleSizeSpeed(
80     const Edge& rSource,
81     const Edge& rTarget,
82     double vehicle_length,
83     Speed angleSpeed);
84
85 /**
86  * @param speeds A set of speeds.
87  * @return The smallest speed
88  */
89 static Speed getSmallestSpeed(std::initializer_list<Speed> speeds);
90
91 /** Get the angle between source and target as
92  * -180 < angle < 180
93  * That means that 0 is straight ahead, > 0 to the right
94  * and < 0 to the left.
95  */
96 static int getTurnAngle(
97     const Edge& rSource,
98     const Edge& rTarget);
99
100 /** Calculate a penalty for making sharp right turns with long vehicles.
101  * @param turnAngle The turning angle in degrees (-180 < a < 180).
102  * @param vehicleLength The length of the vehicle.
103  * @return A factor 0.33 - 1.0
104  */
105 static double calculateLengthPenaltyFactor(
106     int turnAngle,
```

```
107         double vehicleLength);
108
109     /** Look if target is of a more important highway type than the source,
110     * in that case we must add a penalty for giving way when entering
111     * the target road.
112     * @param rSource    The source edge.
113     * @param rTarget    The target edge.
114     * @return A cost for giving way.
115     */
116     static Cost    giveWayToHigherRoadCategoryCost(
117         const Edge& rSource,
118         const Edge& rTarget);
119
120     // ATTRIBUTES
121     // CONSTANTS
122     static constexpr double VEHICLE_PENALTY_LENGTH = 4.5;
123
124 };
125
126 // INLINE METHODS
127 //
128
129 // EXTERNAL REFERENCES
130 //
131
132 #endif /* GRAPH_TURN_COST_CALCULATOR_H_ */
```

D.7.17 TurnCostCalculator.cc

```
1  /*
2   * TurnCostCalculator.cc
3   */
4
5  #include "TurnCostCalculator.h" // class implemented
6
7  ////////////////////////////////// PUBLIC //////////////////////////////////
8  //===== LIFECYCLE =====
9  //===== OPERATORS =====
10 //===== OPERATIONS =====
11 //===== ACCESS =====
12 /* static */
13 double
14 TurnCostCalculator::getTurnCost(
15     const Edge& rSource,
16     const Edge& rTarget,
17     const Configuration& rConfig)
18 {
19     double vehicle_length = rConfig.getVehicleConfig().length;
20
21     Speed angle_speed = getAngleSpeed(rSource, rTarget);
22     Speed size_speed =
23         getVehicleSizeSpeed(rSource, rTarget, vehicle_length, angle_speed);
24     Speed turn_speed = getSmallestSpeed({angle_speed, size_speed});
25
26     double decel_factor = rConfig.getVehicleConfig().acceleration / 100.0;
27     double accel_factor = rConfig.getVehicleConfig().deceleration / 100.0;
28 }
```

```
29     Cost deceleration_cost = decel_factor * (rSource.speed() - turn_speed);
30     Cost acceleration_cost = accel_factor * (rTarget.speed() - turn_speed);
31     Cost additional_cost = giveWayToHigherRoadCategoryCost(rSource, rTarget);
32
33     Cost turn_cost = deceleration_cost + acceleration_cost + additional_cost;
34
35     return static_cast<double>(turn_cost);
36 }
37 //===== INQUIRY =====
38 ////////////////////////////////////////////////// PROTECTED //////////////////////////////////////
39
40 ////////////////////////////////////////////////// PRIVATE //////////////////////////////////////
41 /* static */
42 Speed
43 TurnCostCalculator::getAngleSpeed(const Edge& rSource, const Edge& rTarget)
44 {
45     int turn_angle = getTurnAngle(rSource, rTarget);
46     // make sure there is some speed and not 0
47     if(abs(turn_angle) > 175)
48     {
49         turn_angle = 175;
50     }
51     double reduction_factor(1 - (abs(turn_angle)/180.0));
52     double speed =
53         reduction_factor * getSmallestSpeed({rSource.speed(), rTarget.speed()});
54     return static_cast<Speed>(speed);
55 }
56
57 /* static */
58 Speed
59 TurnCostCalculator::getVehicleSizeSpeed(
60     const Edge& rSource,
61     const Edge& rTarget,
62     double      vehicle_length,
63     Speed       angleSpeed)
64 {
65     int turn_angle (getTurnAngle(rSource, rTarget));
66     double length_penalty_factor =
67         calculateLengthPenaltyFactor(turn_angle, vehicle_length);
68
69     Speed speed = angleSpeed
70         * (VEHICLE_PENALTY_LENGTH / vehicle_length)
71         * length_penalty_factor;
72     return speed;
73 }
74
75 /* static */
76 Speed
77 TurnCostCalculator::getSmallestSpeed(std::initializer_list<Speed> speeds)
78 {
79     Speed min {1000};
80
81     if(speeds.size() > 0)
82     {
83         for(const auto& s : speeds)
84         {
85             if(s < min)
```

```
86         {
87             min = s;
88         }
89     }
90 }
91 return min;
92 }
93
94 /* static */
95 int
96 TurnCostCalculator::getTurnAngle(const Edge& rSource, const Edge& rTarget)
97 {
98     int angle =
99         rSource.geomData().targetBearing - rTarget.geomData().sourceBearing;
100     if(angle < -180)
101     {
102         angle += 360;
103     }
104     if(angle > 180)
105     {
106         angle -= 360;
107     }
108     return angle;
109 }
110
111 /* static */
112 double
113 TurnCostCalculator::calculateLengthPenaltyFactor(
114     int turnAngle,
115     double vehicleLength)
116 {
117     double factor(1.0);
118
119     if(vehicleLength > VEHICLE_PENALTY_LENGTH)
120     {
121         if(turnAngle > 0)
122         {
123             factor = 1.0 - ((2.0/3.0) * (turnAngle/180.0));
124         }
125     }
126     return factor;
127 }
128
129 /* static */
130 Cost
131 TurnCostCalculator::giveWayToHigherRoadCategoryCost(
132     const Edge& rSource,
133     const Edge& rTarget)
134 {
135     if(rSource.roadData().roadType > rTarget.roadData().roadType)
136     {
137         return 5;
138     }
139     return 0;
140 }
```


D.7.18 GraphException.h

```
1  /** Exception thrown by the Graph package.
2   *
3   * #include "GraphException.h"
4   *
5   * @author Jonas Bergman
6   */
7
8  #ifndef GRAPH_GRAPHEXCEPTION_H_
9  #define GRAPH_GRAPHEXCEPTION_H_
10
11 // SYSTEM INCLUDES
12 //
13 #include <exception>
14 #include <string>
15
16 // PROJECT INCLUDES
17 //
18
19 // LOCAL INCLUDES
20 //
21
22 // FORWARD REFERENCES
23 //
24
25 /**
26  * Exception to throw from the 'graph' package.
27  * More information of the type of exception is given in the 'what()' message.
28  */
29 class GraphException : public std::exception
30 {
31 public:
32 // LIFECYCLE
33     /** Default constructor.
34      */
35     GraphException() = delete;
36
37     /** Constructor taking a message to display.
38      *
39      * @param message The message to prepend when 'what()' is called.
40      */
41     GraphException(const std::string& rMessage) noexcept
42         : std::exception(), mMessage(rMessage)
43     {}
44
45 // OPERATORS
46 // OPERATIONS
47 // ACCESS
48 // INQUIRY
49     const char* what() const noexcept
50     { return mMessage.c_str(); }
51
52 protected:
53 private:
54 // ATTRIBUTES
55     std::string mMessage;
56 };
```

```
57
58 // INLINE METHODS
59 //
60
61 // EXTERNAL REFERENCES
62 //
63
64 #endif /* GRAPH_GRAPHEXCEPTION_H_ */
```

D.7.19 RestrictionsException.h

```
1 /** Exception thrown by the Restrictions.
2  *
3  * #include "RestrictionsException.h"
4  *
5  * @author Jonas Bergman
6  */
7
8 #ifndef GRAPH_RESTRICTIONSEXCEPTION_H_
9 #define GRAPH_RESTRICTIONSEXCEPTION_H_
10
11 // SYSTEM INCLUDES
12 //
13 #include <exception>
14 #include <string>
15
16 // PROJECT INCLUDES
17 //
18
19 // LOCAL INCLUDES
20 //
21
22 // FORWARD REFERENCES
23 //
24
25 /**
26  * Exception to throw from Restrictions class.
27  * More information of the type of exception is given in the 'what()' message.
28  */
29 class RestrictionsException : public std::exception
30 {
31 public:
32 // LIFECYCLE
33     /** Default constructor.
34     */
35     RestrictionsException() = delete;
36
37     /** Constructor taking a message to display.
38     *
39     * @param message The message to prepend when 'what()' is called.
40     */
41     RestrictionsException(const std::string& rMessage) noexcept
42         : std::exception(), mMessage(rMessage)
43     {}
44
45 // OPERATORS
46     void addEdgeId(std::string edgeIdString) { mMessage += edgeIdString; }
```

```
47 // OPERATIONS
48 // ACCESS
49 // INQUIRY
50     const char* what() const noexcept
51     { return mMessage.c_str(); }
52
53 protected:
54 private:
55 // ATTRIBUTES
56     std::string      mMessage;
57 };
58
59 // INLINE METHODS
60 //
61
62 // EXTERNAL REFERENCES
63 //
64
65 #endif /* GRAPH_RESTRICTIONSEXCEPTION_H_ */
```

D.7.20 TopologyException.h

```
1 /** Exception thrown by the Topology package.
2  *
3  * #include "TopologyException.h"
4  *
5  * @author Jonas Bergman
6  */
7
8 #ifndef GRAPH_TOPOLOGYEXCEPTION_H_
9 #define GRAPH_TOPOLOGYEXCEPTION_H_
10
11 // SYSTEM INCLUDES
12 //
13 #include <exception>
14 #include <string>
15
16 // PROJECT INCLUDES
17 //
18
19 // LOCAL INCLUDES
20 //
21
22 // FORWARD REFERENCES
23 //
24
25 /**
26  * Exception to throw from the 'topology' package.
27  * More information of the type of exception is given in the 'what()' message.
28  */
29 class TopologyException : public std::exception
30 {
31 public:
32 // LIFECYCLE
33     /** Default constructor.
34     */
35     TopologyException() = delete;
```

```
36
37     /** Constructor taking a message to display.
38     *
39     * @param    message    The message to prepend when 'what()' is called.
40     */
41     TopologyException(const std::string& rMessage) noexcept
42         : std::exception(), mMessage(rMessage)
43     {}
44
45     // OPERATORS
46     // OPERATIONS
47     // ACCESS
48     // INQUIRY
49     const char* what() const noexcept
50     { return mMessage.c_str(); }
51
52 protected:
53 private:
54     // ATTRIBUTES
55     std::string      mMessage;
56 };
57
58 // INLINE METHODS
59 //
60
61 // EXTERNAL REFERENCES
62 //
63
64 #endif /* GRAPH_TOPOLOGYEXCEPTION_H_ */
```

D.7.21 EdgeCost_test.cc

```
1  /* Tests for EdgeCost class
2   * EdgeCost_test.cc
3   *
4   * @author  Jonas Bergman
5   */
6
7  #include "../catchtest/catch.hpp"
8
9  #include "../EdgeCost.h"
10
11  SCENARIO ("Keeping track of costs for an Edge", "[graph][edgcost]")
12  {
13      EdgeCost costs;
14
15      GIVEN ("an EdgeCost object")
16      {
17          WHEN ("no costs are added")
18          {
19              THEN ("there should be no costs")
20              {
21                  REQUIRE (costs.getCost() == 0);
22                  REQUIRE (costs.hasCost(EdgeCost::TRAVEL_TIME) == false);
23                  REQUIRE (costs.getCost(EdgeCost::BARRIER) == 0);
24              }
25          }
26      }
27  }
```

```
26
27     WHEN ("travel cost is added")
28     {
29         costs.addCost(EdgeCost::TRAVEL_TIME, 10);
30
31         THEN ("there should be costs")
32         {
33             REQUIRE (costs.getCost() > 0);
34             REQUIRE (costs.hasCost(EdgeCost::TRAVEL_TIME) == true);
35             REQUIRE (costs.getCost(EdgeCost::TRAVEL_TIME) == Approx(10.0));
36             REQUIRE (costs.getCost(EdgeCost::BARRIER) == 0);
37         }
38     }
39
40     WHEN ("two travel costs are added")
41     {
42         costs.addCost(EdgeCost::TRAVEL_TIME, 10);
43         costs.addCost(EdgeCost::TRAVEL_TIME, 20);
44
45         THEN ("only the last should be reported")
46         {
47             REQUIRE (costs.hasCost(EdgeCost::TRAVEL_TIME) == true);
48             REQUIRE (costs.getCost(EdgeCost::TRAVEL_TIME) == Approx(20.0));
49         }
50     }
51
52     WHEN ("travel a travel and a barrier cost are added")
53     {
54         costs.addCost(EdgeCost::TRAVEL_TIME, 10);
55         costs.addCost(EdgeCost::BARRIER, 20);
56
57         THEN ("the costs should be added")
58         {
59             REQUIRE (costs.getCost() == Approx(30.0));
60             REQUIRE (costs.hasCost(EdgeCost::TRAVEL_TIME) == true);
61             REQUIRE (costs.hasCost(EdgeCost::BARRIER) == true);
62             REQUIRE (costs.hasCost(EdgeCost::OTHER) == false);
63         }
64     }
65 }
66 }
```

D.7.22 GraphBuilder_test.cc

```
1  /*
2   * Graph_test.cc
3   *
4   * @author Jonas Bergman
5   */
6
7  #include <iostream>
8
9  #include "../GraphBuilder.h"
10 #include "../Topology.h"
11 #include "../../catchtest/catch.hpp"
12 #include "../../config/ConfigurationReader.h"
13 #include "../../mapprovider/postgis/PostGisProvider.h"
```

```
14
15 SCENARIO ("Building a small graph", "[graph][basic]")
16 {
17     // -----
18     GIVEN ("Three points and two edges for a topology")
19     {
20         size_t nr_vertices = 3;
21         size_t nr_edges = 2;
22         OsmIdType osm_id(1);
23
24         Topology topology;
25         const Vertex& v1 = topology.addVertex(1, Point(0,0));
26         const Vertex& v2 = topology.addVertex(2, Point(1,2));
27         const Vertex& v3 = topology.addVertex(3, Point(3,1));
28         Edge& e1 = topology.addEdge(1,osm_id,1,2);
29         Edge& e2 = topology.addEdge(2,osm_id,2,3);
30
31         Configuration config;
32
33         // .....
34         WHEN ("we try create a Graph from the Topology")
35         {
36             THEN ("we should not get an Exception")
37             {
38                 INFO ("calling Graph constructor");
39                 REQUIRE_NOTHROW (GraphBuilder g(topology, config));
40             }
41         }
42
43         // .....
44         WHEN ("building a graph from the topology")
45         {
46             GraphBuilder g(topology, config);
47             const auto& boost_graph = g.getBoostGraph();
48             LineGraphType& r_boost_line_graph = g.getBoostLineGraph();
49
50             // .....
51             THEN ("the # of vertices in the graph representation"
52                  " should be as in the topology"
53                  " and the # edges the double") // default is bidirectional
54             {
55                 REQUIRE (boost::num_vertices(boost_graph) == nr_vertices);
56                 REQUIRE (boost::num_edges(boost_graph) == nr_edges * 2);
57             }
58
59             // .....
60             THEN ("the number of nodes in the LineGraph"
61                  " should be as many as edges in the graph")
62             {
63                 REQUIRE (boost::num_vertices(r_boost_line_graph) ==
64                         boost::num_edges(boost_graph));
65             }
66         }
67
68         // .....
69         WHEN ("we try print out a Graph from the Topology")
70         {
```

```
71         GraphBuilder g(topology, config);
72
73         THEN ("we should get a print out")
74         {
75             INFO (g);
76             REQUIRE (true);
77         }
78     }
79
80     // .....
81     WHEN ("adding unidirectional information to edges before"
82           " building graph")
83     {
84
85         Edge::RoadData rd1;
86         rd1.direction = Edge::DirectionType::FROM_TO;
87         e1.setRoadData(rd1);
88
89         Edge::RoadData rd2;
90         rd2.direction = Edge::DirectionType::FROM_TO;
91         e2.setRoadData(rd2);
92
93         GraphBuilder g2(topology, config);
94
95         THEN ("the # of edges in the graph representation"
96               " should as many as in the topology")
97         {
98             INFO (g2);
99             const auto& boost_graph = g2.getBoostGraph();
100             REQUIRE (boost::num_edges(boost_graph) == topology.nrEdges());
101         }
102     }
103
104     // .....
105     WHEN ("adding an extra lane to an edge before"
106           " building graph")
107     {
108
109         Edge::RoadData rd1;
110         rd1.direction = Edge::DirectionType::FROM_TO;
111         rd1.nrLanes = 2;
112         e1.setRoadData(rd1);
113
114         Edge::RoadData rd2;
115         rd2.direction = Edge::DirectionType::FROM_TO;
116         e2.setRoadData(rd2);
117
118         GraphBuilder g2(topology, config);
119
120         THEN ("the # of edges in the graph representation"
121               " should be one more than in the topology")
122         {
123             INFO (g2);
124             const auto& boost_graph = g2.getBoostGraph();
125             REQUIRE (boost::num_edges(boost_graph) == topology.nrEdges() + 1);
126         }
127     }
```

```
128     }
129 }
130
131 SCENARIO ("Building graph with restrictions", "[graph][restrictions]")
132 {
133     try
134     {
135
136         // =====
137         GIVEN ("Configuration to build a Graph with restrictions ")
138         {
139             std::string config_file(
140                 "catchtest/testsettings/mikh_restr_0617-testsettings.json");
141             ConfigurationReader config_reader(config_file);
142             Configuration config;
143             config_reader.fillConfiguration(config);
144
145             PostGisProvider pgp(config);
146
147             Topology topology;
148             pgp.getTopology(topology);
149             pgp.setRestrictionsAndCosts(topology);
150
151             GraphBuilder graph_restr(topology, config);
152
153             GraphBuilder graph_unrestr(topology, config, false);
154
155             // .....
156             WHEN ("Adding a turning restriction and a point restriction (barrier)")
157             {
158
159                 THEN ("there should be equally many vertices "
160                     "in restricted and unrestricted")
161                 {
162                     INFO (" Restricted # Vertices: " << graph_restr.nrVertices());
163                     INFO ("UNRestricted # Vertices: " << graph_unrestr.nrVertices());
164                     REQUIRE (graph_restr.nrVertices() == graph_unrestr.nrVertices());
165                 }
166
167                 THEN ("there should be 2 less edges "
168                     "in restricted and unrestricted")
169                 {
170                     INFO (" Restricted # Edges:      " << graph_restr.nrEdges());
171                     INFO ("UNRestricted # Edges:      " << graph_unrestr.nrEdges());
172                     REQUIRE (graph_restr.nrEdges() == graph_unrestr.nrEdges() - 2);
173                 }
174
175                 THEN ("there should be 2 less nodes "
176                     "in restricted and unrestricted")
177                 {
178                     INFO (" Restricted # Nodes:      " << graph_restr.nrNodes());
179                     INFO ("UNRestricted # Nodes:      " << graph_unrestr.nrNodes());
180                     REQUIRE (graph_restr.nrNodes() == graph_unrestr.nrNodes() - 2);
181                 }
182                 THEN ("there should be 9 lines less "
183                     "in restricted than unrestricted")
184                 {
```



```
185         // 1 turn restriction
186         // 3*2 where target is restricted by barrier (lift gate)
187         // 2 u-turns on restricted edge
188         INFO ("  Restricted # Lines:    " << graph_restr.nrLines());
189         INFO ("UNRestricted # Lines:    " << graph_unrestr.nrLines());
190         REQUIRE (graph_restr.nrLines() == graph_unrestr.nrLines() - 9);
191     }
192     THEN ("we can print the info for an edge and it should have a cost")
193     {
194         EdgeIdType id = 270;
195         const Edge& edge = topology.getEdge(id);
196         INFO ("Edge " << id << ": " << edge);
197         REQUIRE (true);
198     }
199 }
200 }
201 }
202 catch (ConfigurationException& e)
203 {
204     INFO(e.what());
205     REQUIRE (false);    // force output of error and failure
206 }
207 catch (MapProviderException& dbe)
208 {
209     INFO(dbe.what());
210     REQUIRE (false);    // force output of error and failure
211 }
212 }
213 }
```

D.7.23 RestrictionsAndCosts_test.cc

```
1  /* Tests for the different kind of restrictions
2   *
3   * Graph_test.cc
4   * @author Jonas Bergman
5   */
6
7  #include <iostream>
8
9  #include "../catchtest/catch.hpp"
10
11 #include "../Topology.h"
12 #include "../config/ConfigurationReader.h"
13 #include "../mapprovider/postgis/PostGisProvider.h"
14 #include "../GraphBuilder.h"
15
16 // TURN RESTRICTION //////////////////////////////////////
17
18 SCENARIO ("Building graph of Mikhailovsk with turn restriction",
19         "[graph][r_and_c][turn][mikhailovsk]")
20 {
21     // block on node 1706164751 on way 158421713
22     try
23     {
24         std::string orig_config_file("catchtest/testsettings/"
25                                     "restrictions/mikhailovsk-original.json");
```

```
26     ConfigurationReader orig_config_reader(orig_config_file);
27     Configuration orig_config;
28     orig_config_reader.fillConfiguration(orig_config);
29     PostGisProvider orig_pgp(orig_config);
30     Topology orig_topology;
31     orig_pgp.getTopology(orig_topology);
32     orig_pgp.setRestrictionsAndCosts(orig_topology);
33     GraphBuilder orig_graph(orig_topology, orig_config);
34
35     // =====
36     GIVEN ("Configuration to build a Graph with turn restriction ")
37     {
38         std::string config_file("catchtest/testsettings/"
39                                "restrictions/mikhailovsk-turn_no_right.json");
40         ConfigurationReader config_reader(config_file);
41         Configuration config;
42         config_reader.fillConfiguration(config);
43
44         PostGisProvider pgp(config);
45
46         Topology topology;
47         pgp.getTopology(topology);
48         pgp.setRestrictionsAndCosts(topology);
49
50         GraphBuilder graph(topology, config);
51
52         // .....
53         WHEN ("Comparing original to graph with turn restrictions")
54         {
55
56             THEN ("there should be equally many vertices "
57                  "in original and restricted")
58             {
59                 INFO (" Original # Vertices: " << orig_graph.nrVertices());
60                 INFO ("Restricted # Vertices: " << graph.nrVertices());
61                 REQUIRE (orig_graph.nrVertices() == graph.nrVertices());
62             }
63
64             THEN ("there should be equally many edges "
65                  "in original as in restricted")
66             {
67                 INFO (" Original # Edges: " << orig_graph.nrEdges());
68                 INFO ("Restricted # Edges: " << graph.nrEdges());
69                 REQUIRE ((orig_graph.nrEdges() == graph.nrEdges()));
70             }
71
72             THEN ("there should be equally many nodes "
73                  "in original as in restricted")
74             {
75                 INFO (" Original # Nodes: " << orig_graph.nrNodes());
76                 INFO ("Restricted # Nodes: " << graph.nrNodes());
77                 REQUIRE ((orig_graph.nrNodes() == graph.nrNodes()));
78             }
79
80             THEN ("there should be 1 less line "
81                  "in original than in restricted")
82             {
```

```
83         // 1 right turn
84         INFO (" Original # Lines:  " << orig_graph.nrLines());
85         INFO ("Restricted # Lines:  " << graph.nrLines());
86         REQUIRE ((orig_graph.nrLines() - 1) == graph.nrLines());
87     }
88 }
89 }
90 }
91 catch (ConfigurationException& e)
92 {
93     INFO(e.what());
94     REQUIRE (false);    // force output of error and failure
95 }
96 catch (MapProviderException& dbp)
97 {
98     INFO(dbp.what());
99     REQUIRE (false);    // force output of error and failure
100 }
101 }
102 }
103
104 SCENARIO ("Building graph of Partille with turn restriction",
105          "[graph][r_and_c][turn][partille]")
106 {
107     // block on node 1706164751 on way 158421713
108     try
109     {
110         std::string orig_config_file("catchtest/testsettings/"
111                                     "restrictions/partille-original.json");
112         ConfigurationReader orig_config_reader(orig_config_file);
113         Configuration orig_config;
114         orig_config_reader.fillConfiguration(orig_config);
115         PostGisProvider orig_pgp(orig_config);
116         Topology orig_topology;
117         orig_pgp.getTopology(orig_topology);
118         orig_pgp.setRestrictionsAndCosts(orig_topology);
119         GraphBuilder orig_graph(orig_topology, orig_config);
120
121         // =====
122         GIVEN ("Configuration to build a Graph with turn restriction ")
123         {
124             std::string config_file("catchtest/testsettings/"
125                                   "restrictions/partille-turn_no_left.json");
126             ConfigurationReader config_reader(config_file);
127             Configuration config;
128             config_reader.fillConfiguration(config);
129
130             PostGisProvider pgp(config);
131
132             Topology topology;
133             pgp.getTopology(topology);
134             pgp.setRestrictionsAndCosts(topology);
135
136             GraphBuilder graph(topology, config);
137
138             // .....
139             WHEN ("Comparing original to graph with turn restrictions")
```

```
140         {
141
142             THEN ("there should be equally many vertices "
143                 "in original and restricted")
144             {
145                 INFO (" Original # Vertices: " << orig_graph.nrVertices());
146                 INFO ("Restricted # Vertices: " << graph.nrVertices());
147                 REQUIRE (orig_graph.nrVertices() == graph.nrVertices());
148             }
149
150             THEN ("there should be equally many edges "
151                 "in original as in restricted")
152             {
153                 INFO (" Original # Edges: " << orig_graph.nrEdges());
154                 INFO ("Restricted # Edges: " << graph.nrEdges());
155                 REQUIRE ((orig_graph.nrEdges()) == graph.nrEdges());
156             }
157
158             THEN ("there should be equally many nodes "
159                 "in original as in restricted")
160             {
161                 INFO (" Original # Nodes:      " << orig_graph.nrNodes());
162                 INFO ("Restricted # Nodes:      " << graph.nrNodes());
163                 REQUIRE ((orig_graph.nrNodes()) == graph.nrNodes());
164             }
165
166             THEN ("there should be 1 less line "
167                 "in original than in restricted")
168             {
169                 // 1 right turn
170                 INFO (" Original # Lines:      " << orig_graph.nrLines());
171                 INFO ("Restricted # Lines:      " << graph.nrLines());
172                 REQUIRE ((orig_graph.nrLines() - 1) == graph.nrLines());
173             }
174         }
175     }
176 }
177 catch (ConfigurationException& e)
178 {
179     INFO(e.what());
180     REQUIRE (false);    // force output of error and failure
181 }
182 catch (MapProviderException& dbe)
183 {
184     INFO(dbe.what());
185     REQUIRE (false);    // force output of error and failure
186 }
187 }
188 }
189
190 // BARRIER BLOCK //////////////////////////////////////
191
192 SCENARIO ("Building graph of Mikhailovsk with barrier block",
193     "[graph][r_and_c][block][mikhailovsk]")
194 {
195     // block on node 1706164751 on way 158421713
196     try
```

```
197 {
198     std::string orig_config_file("catchtest/testsettings/"
199     "restrictions/mikhailovsk-original.json");
200     ConfigurationReader orig_config_reader(orig_config_file);
201     Configuration orig_config;
202     orig_config_reader.fillConfiguration(orig_config);
203     PostGisProvider orig_pgp(orig_config);
204     Topology orig_topology;
205     orig_pgp.getTopology(orig_topology);
206     orig_pgp.setRestrictionsAndCosts(orig_topology);
207     GraphBuilder orig_graph(orig_topology, orig_config);
208
209     // =====
210     GIVEN ("Configuration that restricts barrier block ")
211     {
212         std::string config_file("catchtest/testsettings/"
213         "restrictions/mikhailovsk-barrier_block.json");
214         ConfigurationReader config_reader(config_file);
215         Configuration config;
216         config_reader.fillConfiguration(config);
217
218         PostGisProvider pgp(config);
219
220         Topology topology;
221         pgp.getTopology(topology);
222         pgp.setRestrictionsAndCosts(topology);
223
224         GraphBuilder graph(topology, config);
225
226         // .....
227         WHEN ("Comparing original to graph with barrier block")
228         {
229
230             THEN ("there should be equally many vertices "
231             "in original and restricted")
232             {
233                 INFO (" Original # Vertices: " << orig_graph.nrVertices());
234                 INFO ("Restricted # Vertices: " << graph.nrVertices());
235                 REQUIRE (orig_graph.nrVertices() == graph.nrVertices());
236             }
237
238             THEN ("there should be 2 more edges "
239             "in original than in restricted")
240             {
241                 INFO (" Original # Edges: " << orig_graph.nrEdges());
242                 INFO ("Restricted # Edges: " << graph.nrEdges());
243                 REQUIRE ((orig_graph.nrEdges() - 2) == graph.nrEdges());
244             }
245
246             THEN ("there should be 2 more nodes "
247             "in original than in restricted")
248             {
249                 INFO (" Original # Nodes: " << orig_graph.nrNodes());
250                 INFO ("Restricted # Nodes: " << graph.nrNodes());
251                 REQUIRE ((orig_graph.nrNodes() - 2) == graph.nrNodes());
252             }
253         }
```

```
254         THEN ("there should be 10 more lines "  
255             "in original than in restricted")  
256     {  
257         // 4 bidirectional edges connecting = 8 lines  
258         // 2 u-turns = 2 lines  
259         INFO (" Original # Lines:      " << orig_graph.nrLines());  
260         INFO ("Restricted # Lines:      " << graph.nrLines());  
261         REQUIRE ((orig_graph.nrLines() - 10) == graph.nrLines());  
262     }  
263 }  
264 }  
265 }  
266 catch (ConfigurationException& e)  
267 {  
268     INFO(e.what());  
269     REQUIRE (false);    // force output of error and failure  
270 }  
271 catch (MapProviderException& dbe)  
272 {  
273     INFO(dbe.what());  
274     REQUIRE (false);    // force output of error and failure  
275 }  
276 }  
277 }  
278  
279 SCENARIO ("Building graph of Partille with barrier block",  
280     "[graph][r_and_c][block][partille]")  
281 {  
282     // block on node 249292683 on way 28050664  
283     try  
284     {  
285         std::string orig_config_file("catchtest/testsettings/"  
286             "restrictions/partille-original.json");  
287         ConfigurationReader orig_config_reader(orig_config_file);  
288         Configuration orig_config;  
289         orig_config_reader.fillConfiguration(orig_config);  
290         PostGisProvider orig_pgp(orig_config);  
291         Topology orig_topology;  
292         orig_pgp.getTopology(orig_topology);  
293         orig_pgp.setRestrictionsAndCosts(orig_topology);  
294         GraphBuilder orig_graph(orig_topology, orig_config);  
295  
296         // =====  
297         GIVEN ("Configuration that restricts barrier block ")  
298         {  
299             std::string config_file("catchtest/testsettings/"  
300                 "restrictions/partille-barrier_block.json");  
301             ConfigurationReader config_reader(config_file);  
302             Configuration config;  
303             config_reader.fillConfiguration(config);  
304  
305             PostGisProvider pgp(config);  
306  
307             Topology topology;  
308             pgp.getTopology(topology);  
309             pgp.setRestrictionsAndCosts(topology);  
310
```

```
311     GraphBuilder graph(topology, config);
312
313     // .....
314     WHEN ("Comparing original to graph with barrier block")
315     {
316
317         THEN ("there should be equally many vertices "
318             "in original and restricted")
319         {
320             INFO (" Original # Vertices: " << orig_graph.nrVertices());
321             INFO ("Restricted # Vertices: " << graph.nrVertices());
322             REQUIRE (orig_graph.nrVertices() == graph.nrVertices());
323         }
324
325         THEN ("there should be 2 more edges "
326             "in original than in restricted")
327         {
328             INFO (" Original # Edges: " << orig_graph.nrEdges());
329             INFO ("Restricted # Edges: " << graph.nrEdges());
330             REQUIRE ((orig_graph.nrEdges() - 2) == graph.nrEdges());
331         }
332
333         THEN ("there should be 2 more nodes "
334             "in original than in restricted")
335         {
336             INFO (" Original # Nodes: " << orig_graph.nrNodes());
337             INFO ("Restricted # Nodes: " << graph.nrNodes());
338             REQUIRE ((orig_graph.nrNodes() - 2) == graph.nrNodes());
339         }
340
341         THEN ("there should be 8 more lines "
342             "in original than in restricted")
343         {
344             // 3 bidirectional edges connecting = 6 lines
345             // (1 cycleway = 0 lines)
346             // 2 u-turns = 2 lines
347             INFO (" Original # Lines: " << orig_graph.nrLines());
348             INFO ("Restricted # Lines: " << graph.nrLines());
349             REQUIRE ((orig_graph.nrLines() - 8) == graph.nrLines());
350         }
351     }
352 }
353
354 catch (ConfigurationException& e)
355 {
356     INFO(e.what());
357     REQUIRE (false);    // force output of error and failure
358 }
359 catch (MapProviderException& dbe)
360 {
361     INFO(dbe.what());
362     REQUIRE (false);    // force output of error and failure
363 }
364 }
365 }
366
367
```

```
368 // BARRIER BOLLARD //////////////////////////////////////
369
370 SCENARIO ("Building graph of Mikhailovsk with barrier bollard",
371         "[graph][r_and_c][bollard][mikhailovsk]")
372 {
373     // block on node 1706164751 on way 158421713
374     try
375     {
376         std::string orig_config_file("catchtest/testsettings/"
377                                     "restrictions/mikhailovsk-original.json");
378         ConfigurationReader orig_config_reader(orig_config_file);
379         Configuration orig_config;
380         orig_config_reader.fillConfiguration(orig_config);
381         PostGisProvider orig_pgp(orig_config);
382         Topology orig_topology;
383         orig_pgp.getTopology(orig_topology);
384         orig_pgp.setRestrictionsAndCosts(orig_topology);
385         GraphBuilder orig_graph(orig_topology, orig_config);
386
387         // =====
388         GIVEN ("Configuration that restricts barrier bollard ")
389         {
390             std::string config_file("catchtest/testsettings/"
391                                    "restrictions/mikhailovsk-barrier_bollard.json");
392             ConfigurationReader config_reader(config_file);
393             Configuration config;
394             config_reader.fillConfiguration(config);
395
396             PostGisProvider pgp(config);
397
398             Topology topology;
399             pgp.getTopology(topology);
400             pgp.setRestrictionsAndCosts(topology);
401
402             GraphBuilder graph(topology, config);
403
404             // .....
405             WHEN ("Comparing original to graph with barrier bollard")
406             {
407
408                 THEN ("there should be equally many vertices "
409                     "in original and restricted")
410                 {
411                     INFO (" Original # Vertices: " << orig_graph.nrVertices());
412                     INFO ("Restricted # Vertices: " << graph.nrVertices());
413                     REQUIRE (orig_graph.nrVertices() == graph.nrVertices());
414                 }
415
416                 THEN ("there should be 2 more edges "
417                     "in original than in restricted")
418                 {
419                     INFO (" Original # Edges: " << orig_graph.nrEdges());
420                     INFO ("Restricted # Edges: " << graph.nrEdges());
421                     REQUIRE ((orig_graph.nrEdges() - 2) == graph.nrEdges());
422                 }
423
424                 THEN ("there should be 2 more nodes ")

```



```

425         "in original than in restricted")
426     {
427         INFO (" Original # Nodes:      " << orig_graph.nrNodes());
428         INFO ("Restricted # Nodes:      " << graph.nrNodes());
429         REQUIRE ((orig_graph.nrNodes() - 2) == graph.nrNodes());
430     }
431
432     THEN ("there should be 10 more lines "
433          "in original than in restricted")
434     {
435         // 4 bidirectional edges connecting = 8 lines
436         // 2 u-turns = 2 lines
437         INFO (" Original # Lines:      " << orig_graph.nrLines());
438         INFO ("Restricted # Lines:      " << graph.nrLines());
439         REQUIRE ((orig_graph.nrLines() - 10) == graph.nrLines());
440     }
441 }
442 }
443 }
444 catch (ConfigurationException& e)
445 {
446     INFO(e.what());
447     REQUIRE (false);    // force output of error and failure
448 }
449 catch (MapProviderException& dbp)
450 {
451     INFO(dbp.what());
452     REQUIRE (false);    // force output of error and failure
453 }
454 }
455 }
456
457 SCENARIO ("Building graph of Partille with barrier bollard",
458          "[graph][r_and_c][bollard][partille]")
459 {
460     // block on node 249292683 on way 28050664
461     try
462     {
463         std::string orig_config_file("catchtest/testsettings/"
464                                     "restrictions/partille-original.json");
465         ConfigurationReader orig_config_reader(orig_config_file);
466         Configuration orig_config;
467         orig_config_reader.fillConfiguration(orig_config);
468         PostGisProvider orig_pgp(orig_config);
469         Topology orig_topology;
470         orig_pgp.getTopology(orig_topology);
471         orig_pgp.setRestrictionsAndCosts(orig_topology);
472         GraphBuilder orig_graph(orig_topology, orig_config);
473
474         // =====
475         GIVEN ("Configuration that restricts barrier bollard ")
476         {
477             std::string config_file("catchtest/testsettings/"
478                                   "restrictions/partille-barrier_bollard.json");
479             ConfigurationReader config_reader(config_file);
480             Configuration config;
481             config_reader.fillConfiguration(config);

```

```
482
483     PostGisProvider pgp(config);
484
485     Topology topology;
486     pgp.getTopology(topology);
487     pgp.setRestrictionsAndCosts(topology);
488
489     GraphBuilder graph(topology, config);
490
491     // .....
492     WHEN ("Comparing original to graph with barrier bollard")
493     {
494
495         THEN ("there should be equally many vertices "
496             "in original and restricted")
497         {
498             INFO (" Original # Vertices: " << orig_graph.nrVertices());
499             INFO ("Restricted # Vertices: " << graph.nrVertices());
500             REQUIRE (orig_graph.nrVertices() == graph.nrVertices());
501         }
502
503         THEN ("there should be 2 more edges "
504             "in original than in restricted")
505         {
506             INFO (" Original # Edges: " << orig_graph.nrEdges());
507             INFO ("Restricted # Edges: " << graph.nrEdges());
508             REQUIRE ((orig_graph.nrEdges() - 2) == graph.nrEdges());
509         }
510
511         THEN ("there should be 2 more nodes "
512             "in original than in restricted")
513         {
514             INFO (" Original # Nodes: " << orig_graph.nrNodes());
515             INFO ("Restricted # Nodes: " << graph.nrNodes());
516             REQUIRE ((orig_graph.nrNodes() - 2) == graph.nrNodes());
517         }
518
519         THEN ("there should be 8 more lines "
520             "in original than in restricted")
521         {
522             // 3 bidirectional edges connecting = 6 lines
523             // (1 cycleway = 0 lines)
524             // 2 u-turns = 2 lines
525             INFO (" Original # Lines: " << orig_graph.nrLines());
526             INFO ("Restricted # Lines: " << graph.nrLines());
527             REQUIRE ((orig_graph.nrLines() - 8) == graph.nrLines());
528         }
529     }
530 }
531 }
532 catch (ConfigurationException& e)
533 {
534     INFO(e.what());
535     REQUIRE (false);    // force output of error and failure
536 }
537 catch (MapProviderException& dbe)
538 {
```

```
539         INFO(dbe.what());
540         REQUIRE (false);    // force output of error and failure
541     }
542 }
543
544
545 // BARRIER LIFT GATE //////////////////////////////////////
546
547 SCENARIO ("Building graph of Mikhailovsk with barrier lift gate",
548     "[graph][r_and_c][lift_gate][mikhailovsk]")
549 {
550     // block on node 1706164751 on way 158421713 (topo edge 649)
551     try
552     {
553         std::string orig_config_file("catchtest/testsettings/"
554             "restrictions/mikhailovsk-original.json");
555         ConfigurationReader orig_config_reader(orig_config_file);
556         Configuration orig_config;
557         orig_config_reader.fillConfiguration(orig_config);
558         PostGisProvider orig_pgp(orig_config);
559         Topology orig_topology;
560         orig_pgp.getTopology(orig_topology);
561         orig_pgp.setRestrictionsAndCosts(orig_topology);
562         GraphBuilder orig_graph(orig_topology, orig_config);
563
564         // =====
565         GIVEN ("Configuration that does not restrict barrier lift gate ")
566         {
567             std::string config_file("catchtest/testsettings/"
568                 "restrictions/mikhailovsk-barrier_lift_gate.json");
569             ConfigurationReader config_reader(config_file);
570             Configuration config;
571             config_reader.fillConfiguration(config);
572
573             PostGisProvider pgp(config);
574
575             Topology topology;
576             pgp.getTopology(topology);
577             pgp.setRestrictionsAndCosts(topology);
578
579             GraphBuilder graph(topology, config);
580
581             // .....
582             WHEN ("Comparing original to graph with barrier lift gate")
583             {
584
585                 THEN ("there should be equally many vertices "
586                     "in original and restricted")
587                 {
588                     INFO (" Original # Vertices: " << orig_graph.nrVertices());
589                     INFO ("Restricted # Vertices: " << graph.nrVertices());
590                     REQUIRE (orig_graph.nrVertices() == graph.nrVertices());
591                 }
592
593                 THEN ("there should be equally many edges "
594                     "in original as in restricted")
595                 {
```

```
596         INFO (" Original # Edges: " << orig_graph.nrEdges());
597         INFO ("Restricted # Edges: " << graph.nrEdges());
598         REQUIRE ((orig_graph.nrEdges()) == graph.nrEdges());
599     }
600
601     THEN ("there should be equally many nodes "
602           "in original as in restricted")
603     {
604         INFO (" Original # Nodes:      " << orig_graph.nrNodes());
605         INFO ("Restricted # Nodes:      " << graph.nrNodes());
606         REQUIRE ((orig_graph.nrNodes()) == graph.nrNodes());
607     }
608
609     THEN ("there should be equally many lines "
610           "in original as in restricted")
611     {
612         INFO (" Original # Lines:      " << orig_graph.nrLines());
613         INFO ("Restricted # Lines:      " << graph.nrLines());
614         REQUIRE ((orig_graph.nrLines()) == graph.nrLines());
615     }
616
617     THEN ("there should be an extra cost of 60 on edge 649")
618     {
619         EdgeIdType id = 649;
620         Cost orig_cost = orig_topology.getEdge(id).cost();
621         Cost rest_cost = topology.getEdge(id).cost();
622         INFO (" Original cost:      " << orig_cost);
623         INFO ("Restricted cost:      " << rest_cost);
624         REQUIRE (60.0 == Approx((rest_cost - orig_cost)));
625     }
626 }
627
628 }
629 catch (ConfigurationException& e)
630 {
631     INFO(e.what());
632     REQUIRE (false);    // force output of error and failure
633 }
634 catch (MapProviderException& dbe)
635 {
636     INFO(dbe.what());
637     REQUIRE (false);    // force output of error and failure
638 }
639 }
640 }
641
642
643 SCENARIO ("Building graph of Partille with barrier lift gate",
644           "[graph][r_and_c][lift_gate][partille]")
645 {
646     // lift gate on node 249292683 on way 28050664 (topo edge 267)
647     try
648     {
649         std::string orig_config_file("catchtest/testsettings/"
650                                     "restrictions/partille-original.json");
651         ConfigurationReader orig_config_reader(orig_config_file);
652         Configuration orig_config;
```

```
653 orig_config_reader.fillConfiguration(orig_config);
654 PostGisProvider orig_pgp(orig_config);
655 Topology orig_topology;
656 orig_pgp.getTopology(orig_topology);
657 orig_pgp.setRestrictionsAndCosts(orig_topology);
658 GraphBuilder orig_graph(orig_topology, orig_config);
659
660 // =====
661 GIVEN ("Configuration that does not restrict barrier lift gate ")
662 {
663     std::string config_file("catchtest/testsettings/"
664                             "restrictions/partille-barrier_lift_gate.json");
665     ConfigurationReader config_reader(config_file);
666     Configuration config;
667     config_reader.fillConfiguration(config);
668
669     PostGisProvider pgp(config);
670
671     Topology topology;
672     pgp.getTopology(topology);
673     pgp.setRestrictionsAndCosts(topology);
674
675     GraphBuilder graph(topology, config);
676
677 // .....
678 WHEN ("Comparing original to graph with barrier lift gate")
679 {
680
681     THEN ("there should be equally many vertices "
682           "in original and restricted")
683     {
684         INFO (" Original # Vertices: " << orig_graph.nrVertices());
685         INFO ("Restricted # Vertices: " << graph.nrVertices());
686         REQUIRE (orig_graph.nrVertices() == graph.nrVertices());
687     }
688
689     THEN ("there should be equally many edges "
690           "in original as in restricted")
691     {
692         INFO (" Original # Edges: " << orig_graph.nrEdges());
693         INFO ("Restricted # Edges: " << graph.nrEdges());
694         REQUIRE ((orig_graph.nrEdges() == graph.nrEdges());
695     }
696
697     THEN ("there should be equally many nodes "
698           "in original as in restricted")
699     {
700         INFO (" Original # Nodes: " << orig_graph.nrNodes());
701         INFO ("Restricted # Nodes: " << graph.nrNodes());
702         REQUIRE ((orig_graph.nrNodes() == graph.nrNodes());
703     }
704
705     THEN ("there should be equally many lines "
706           "in original as in restricted")
707     {
708         INFO (" Original # Lines: " << orig_graph.nrLines());
709         INFO ("Restricted # Lines: " << graph.nrLines());
```

```
710         REQUIRE ((orig_graph.nrLines()) == graph.nrLines());
711     }
712
713     THEN ("there should be an extra cost of 60 on edge 267")
714     {
715         EdgeIdType id = 267;
716         Cost orig_cost = orig_topology.getEdge(id).cost();
717         Cost rest_cost = topology.getEdge(id).cost();
718         INFO (" Original cost:    " << orig_cost);
719         INFO ("Restricted cost:    " << rest_cost);
720         REQUIRE (60.0 == Approx((rest_cost - orig_cost)));
721     }
722 }
723
724 }
725 catch (ConfigurationException& e)
726 {
727     INFO(e.what());
728     REQUIRE (false);    // force output of error and failure
729 }
730 catch (MapProviderException& dbe)
731 {
732     INFO(dbe.what());
733     REQUIRE (false);    // force output of error and failure
734 }
735 }
736 }
737
738 // TRAFFIC LIGHTS //////////////////////////////////////
739
740 SCENARIO ("Building graph of Mikhailovsk with traffic signals",
741     "[graph][r_and_c][traffic_signals][mikhailovsk]")
742 {
743     // additional node on way 158421713 (topo edge id 649)
744     try
745     {
746         std::string orig_config_file("catchtest/testsettings/"
747             "restrictions/mikhailovsk-original.json");
748         ConfigurationReader orig_config_reader(orig_config_file);
749         Configuration orig_config;
750         orig_config_reader.fillConfiguration(orig_config);
751         PostGisProvider orig_pgp(orig_config);
752         Topology orig_topology;
753         orig_pgp.getTopology(orig_topology);
754         orig_pgp.setRestrictionsAndCosts(orig_topology);
755         GraphBuilder orig_graph(orig_topology, orig_config);
756
757         // =====
758         GIVEN ("Configuration that has cost for traffic signals ")
759         {
760             std::string config_file("catchtest/testsettings/"
761                 "restrictions/mikhailovsk-highway_traffic_signals.json");
762             ConfigurationReader config_reader(config_file);
763             Configuration config;
764             config_reader.fillConfiguration(config);
765
766             PostGisProvider pgp(config);
```

```
767
768     Topology topology;
769     pgp.getTopology(topology);
770     pgp.setRestrictionsAndCosts(topology);
771
772     GraphBuilder graph(topology, config);
773
774     // .....
775     WHEN ("Comparing original to graph with traffic lights")
776     {
777
778         THEN ("there should be equally many vertices "
779             "in original and restricted")
780         {
781             INFO (" Original # Vertices: " << orig_graph.nrVertices());
782             INFO ("Restricted # Vertices: " << graph.nrVertices());
783             REQUIRE (orig_graph.nrVertices() == graph.nrVertices());
784         }
785
786         THEN ("there should be equally many edges "
787             "in original as in restricted")
788         {
789             INFO (" Original # Edges: " << orig_graph.nrEdges());
790             INFO ("Restricted # Edges: " << graph.nrEdges());
791             REQUIRE ((orig_graph.nrEdges()) == graph.nrEdges());
792         }
793
794         THEN ("there should be equally many nodes "
795             "in original as in restricted")
796         {
797             INFO (" Original # Nodes:      " << orig_graph.nrNodes());
798             INFO ("Restricted # Nodes:      " << graph.nrNodes());
799             REQUIRE ((orig_graph.nrNodes()) == graph.nrNodes());
800         }
801
802         THEN ("there should be equally many lines "
803             "in original as in restricted")
804         {
805             INFO (" Original # Lines:      " << orig_graph.nrLines());
806             INFO ("Restricted # Lines:      " << graph.nrLines());
807             REQUIRE ((orig_graph.nrLines()) == graph.nrLines());
808         }
809
810         THEN ("there should be an extra cost of 30 on edge 649")
811         {
812             EdgeIdType id = 649;
813             Cost orig_cost = orig_topology.getEdge(id).cost();
814             Cost rest_cost = topology.getEdge(id).cost();
815             INFO (" Original cost:      " << orig_cost);
816             INFO ("Restricted cost:      " << rest_cost);
817             REQUIRE (30.0 == Approx((rest_cost - orig_cost)));
818         }
819     }
820 }
821 }
822 catch (ConfigurationException& e)
823 {
```

```
824         INFO(e.what());
825         REQUIRE (false);    // force output of error and failure
826     }
827     catch (MapProviderException& dbe)
828     {
829         INFO(dbe.what());
830         REQUIRE (false);    // force output of error and failure
831     }
832 }
833 }
834
835 SCENARIO ("Building graph of Partille with traffic signals",
836          "[graph][r_and_c][traffic_signals][partille]")
837 {
838     // additional node on way 28050664 (topo edge id 267)
839     try
840     {
841         std::string orig_config_file("catchtest/testsettings/"
842                                     "restrictions/partille-original.json");
843         ConfigurationReader orig_config_reader(orig_config_file);
844         Configuration orig_config;
845         orig_config_reader.fillConfiguration(orig_config);
846         PostGisProvider orig_pgp(orig_config);
847         Topology orig_topology;
848         orig_pgp.getTopology(orig_topology);
849         orig_pgp.setRestrictionsAndCosts(orig_topology);
850         GraphBuilder orig_graph(orig_topology, orig_config);
851
852         // =====
853         GIVEN ("Configuration that has cost for traffic signals ")
854         {
855             std::string config_file("catchtest/testsettings/"
856                                   "restrictions/partille-highway_traffic_signals.json");
857             ConfigurationReader config_reader(config_file);
858             Configuration config;
859             config_reader.fillConfiguration(config);
860
861             PostGisProvider pgp(config);
862
863             Topology topology;
864             pgp.getTopology(topology);
865             pgp.setRestrictionsAndCosts(topology);
866
867             GraphBuilder graph(topology, config);
868
869             // .....
870             WHEN ("Comparing original to graph with traffic lights")
871             {
872
873                 THEN ("there should be equally many vertices "
874                     "in original and restricted")
875                 {
876                     INFO (" Original # Vertices: " << orig_graph.nrVertices());
877                     INFO ("Restricted # Vertices: " << graph.nrVertices());
878                     REQUIRE (orig_graph.nrVertices() == graph.nrVertices());
879                 }
880             }
881         }
882     }
883 }
```



```
881         THEN ("there should be equally many edges "
882              "in original as in restricted")
883     {
884         INFO (" Original # Edges: " << orig_graph.nrEdges());
885         INFO ("Restricted # Edges: " << graph.nrEdges());
886         REQUIRE ((orig_graph.nrEdges()) == graph.nrEdges());
887     }
888
889     THEN ("there should be equally many nodes "
890          "in original as in restricted")
891     {
892         INFO (" Original # Nodes:  " << orig_graph.nrNodes());
893         INFO ("Restricted # Nodes:  " << graph.nrNodes());
894         REQUIRE ((orig_graph.nrNodes()) == graph.nrNodes());
895     }
896
897     THEN ("there should be equally many lines "
898          "in original as in restricted")
899     {
900         INFO (" Original # Lines:  " << orig_graph.nrLines());
901         INFO ("Restricted # Lines:  " << graph.nrLines());
902         REQUIRE ((orig_graph.nrLines()) == graph.nrLines());
903     }
904
905     THEN ("there should be an extra cost of 30 on edge 267")
906     {
907         EdgeIdType id = 267;
908         Cost orig_cost = orig_topology.getEdge(id).cost();
909         Cost rest_cost = topology.getEdge(id).cost();
910         INFO (" Original cost:    " << orig_cost);
911         INFO ("Restricted cost:    " << rest_cost);
912         REQUIRE (30.0 == Approx((rest_cost - orig_cost)));
913     }
914 }
915 }
916 }
917 catch (ConfigurationException& e)
918 {
919     INFO(e.what());
920     REQUIRE (false);    // force output of error and failure
921 }
922 catch (MapProviderException& dbe)
923 {
924     INFO(dbe.what());
925     REQUIRE (false);    // force output of error and failure
926 }
927 }
928 }
929
930 // STOP NODE ////////////////////////////////////////
931
932 SCENARIO ("Building graph of Mikhailovsk with stop at node before crossing",
933          "[graph][r_and_c][stop_node][mikhailovsk]")
934 {
935     // additional node on way 158421713 (topo edge id 649)
936     try
937     {
```

```
938     std::string orig_config_file("catchtest/testsettings/"
939     "restrictions/mikhailovsk-original.json");
940     ConfigurationReader orig_config_reader(orig_config_file);
941     Configuration orig_config;
942     orig_config_reader.fillConfiguration(orig_config);
943     PostGisProvider orig_pgp(orig_config);
944     Topology orig_topology;
945     orig_pgp.getTopology(orig_topology);
946     orig_pgp.setRestrictionsAndCosts(orig_topology);
947     GraphBuilder orig_graph(orig_topology, orig_config);
948
949     // =====
950     GIVEN ("Configuration that has cost for stops ")
951     {
952         std::string config_file("catchtest/testsettings/"
953         "restrictions/mikhailovsk-highway_stop_node.json");
954         ConfigurationReader config_reader(config_file);
955         Configuration config;
956         config_reader.fillConfiguration(config);
957
958         PostGisProvider pgp(config);
959
960         Topology topology;
961         pgp.getTopology(topology);
962         pgp.setRestrictionsAndCosts(topology);
963
964         GraphBuilder graph(topology, config);
965
966         // .....
967         WHEN ("Comparing original to graph with stop signs")
968         {
969             THEN ("there should be equally many lines "
970             "in original as in restricted")
971             {
972                 INFO (" Original # Lines:  " << orig_graph.nrLines());
973                 INFO ("Restricted # Lines:  " << graph.nrLines());
974                 REQUIRE ((orig_graph.nrLines() == graph.nrLines()));
975             }
976
977             THEN ("there should be an extra cost of 30 on edge 649")
978             {
979                 EdgeIdType id = 649;
980                 Cost orig_cost = orig_topology.getEdge(id).cost();
981                 Cost rest_cost = topology.getEdge(id).cost();
982                 INFO (" Original cost:    " << orig_cost);
983                 INFO ("Restricted cost:    " << rest_cost);
984                 REQUIRE (30.0 == Approx((rest_cost - orig_cost)));
985             }
986         }
987     }
988 }
989 catch (ConfigurationException& e)
990 {
991     INFO(e.what());
992     REQUIRE (false);    // force output of error and failure
993 }
994 catch (MapProviderException& dbe)
```

```
995     {
996         INFO(dbe.what());
997         REQUIRE (false);    // force output of error and failure
998     }
999 }
1000
1001
1002 SCENARIO ("Building graph of Partille with stop at node before crossing",
1003          "[graph][r_and_c][stop_node][partille]")
1004 {
1005     // additional node on way 28050664 (topo edge id 267)
1006     try
1007     {
1008         std::string orig_config_file("catchtest/testsettings/"
1009                                     "restrictions/partille-original.json");
1010         ConfigurationReader orig_config_reader(orig_config_file);
1011         Configuration orig_config;
1012         orig_config_reader.fillConfiguration(orig_config);
1013         PostGisProvider orig_pgp(orig_config);
1014         Topology orig_topology;
1015         orig_pgp.getTopology(orig_topology);
1016         orig_pgp.setRestrictionsAndCosts(orig_topology);
1017         GraphBuilder orig_graph(orig_topology, orig_config);
1018
1019         // =====
1020         GIVEN ("Configuration that has cost for traffic signals ")
1021         {
1022             std::string config_file("catchtest/testsettings/"
1023                                   "restrictions/partille-highway_stop_node.json");
1024             ConfigurationReader config_reader(config_file);
1025             Configuration config;
1026             config_reader.fillConfiguration(config);
1027
1028             PostGisProvider pgp(config);
1029
1030             Topology topology;
1031             pgp.getTopology(topology);
1032             pgp.setRestrictionsAndCosts(topology);
1033
1034             GraphBuilder graph(topology, config);
1035
1036             // .....
1037             WHEN ("Comparing original to graph with stop signs")
1038             {
1039                 THEN ("there should be equally many lines "
1040                     "in original as in restricted")
1041                 {
1042                     INFO (" Original # Lines:  " << orig_graph.nrLines());
1043                     INFO ("Restricted # Lines:  " << graph.nrLines());
1044                     REQUIRE ((orig_graph.nrLines() == graph.nrLines()));
1045                 }
1046
1047                 THEN ("there should be an extra cost of 30 on edge 267")
1048                 {
1049                     EdgeIdType id = 267;
1050                     Cost orig_cost = orig_topology.getEdge(id).cost();
1051                     Cost rest_cost = topology.getEdge(id).cost();
```

```
1052             INFO (" Original cost:      " << orig_cost);
1053             INFO ("Restricted cost:      " << rest_cost);
1054             REQUIRE (30.0 == Approx((rest_cost - orig_cost)));
1055         }
1056     }
1057 }
1058 }
1059 catch (ConfigurationException& e)
1060 {
1061     INFO(e.what());
1062     REQUIRE (false);    // force output of error and failure
1063 }
1064 catch (MapProviderException& dbe)
1065 {
1066     INFO(dbe.what());
1067     REQUIRE (false);    // force output of error and failure
1068 }
1069 }
1070 }
1071
1072 // STOP ALL //////////////////////////////////////
1073
1074 SCENARIO ("Building graph of Mikhailovsk with stop for all at crossing",
1075     "[graph][r_and_c][stop_all][mikhailovsk]")
1076 {
1077     // stop at vertex 1706164758 (topo 460)
1078     // affecting edges with topo id 611, 649, 661
1079     try
1080     {
1081         std::string orig_config_file("catchtest/testsettings/"
1082             "restrictions/mikhailovsk-original.json");
1083         ConfigurationReader orig_config_reader(orig_config_file);
1084         Configuration orig_config;
1085         orig_config_reader.fillConfiguration(orig_config);
1086         PostGisProvider orig_pgp(orig_config);
1087         Topology orig_topology;
1088         orig_pgp.getTopology(orig_topology);
1089         orig_pgp.setRestrictionsAndCosts(orig_topology);
1090         GraphBuilder orig_graph(orig_topology, orig_config);
1091
1092         // =====
1093         GIVEN ("Configuration that has cost for stops ")
1094         {
1095             std::string config_file("catchtest/testsettings/"
1096                 "restrictions/mikhailovsk-highway_stop_all.json");
1097             ConfigurationReader config_reader(config_file);
1098             Configuration config;
1099             config_reader.fillConfiguration(config);
1100
1101             PostGisProvider pgp(config);
1102
1103             Topology topology;
1104             pgp.getTopology(topology);
1105             pgp.setRestrictionsAndCosts(topology);
1106
1107             GraphBuilder graph(topology, config);
1108
```

```
1109 // .....
1110 WHEN ("Comparing original to graph with stop signs")
1111 {
1112     THEN ("there should be equally many lines "
1113           "in original as in restricted")
1114     {
1115         INFO (" Original # Lines:    " << orig_graph.nrLines());
1116         INFO ("Restricted # Lines:    " << graph.nrLines());
1117         REQUIRE ((orig_graph.nrLines()) == graph.nrLines());
1118     }
1119
1120     THEN ("there should be an extra cost of 30 on edge 611")
1121     {
1122         EdgeIdType id = 611;
1123         Cost orig_cost = orig_topology.getEdge(id).cost();
1124         Cost rest_cost = topology.getEdge(id).cost();
1125         INFO (" Original cost:      " << orig_cost);
1126         INFO ("Restricted cost:      " << rest_cost);
1127         REQUIRE (30.0 == Approx((rest_cost - orig_cost)));
1128     }
1129
1130     THEN ("there should be an extra cost of 30 on edge 649")
1131     {
1132         EdgeIdType id = 649;
1133         Cost orig_cost = orig_topology.getEdge(id).cost();
1134         Cost rest_cost = topology.getEdge(id).cost();
1135         INFO (" Original cost:      " << orig_cost);
1136         INFO ("Restricted cost:      " << rest_cost);
1137         REQUIRE (30.0 == Approx((rest_cost - orig_cost)));
1138     }
1139
1140     THEN ("there should be an extra cost of 30 on edge 661")
1141     {
1142         EdgeIdType id = 661;
1143         Cost orig_cost = orig_topology.getEdge(id).cost();
1144         Cost rest_cost = topology.getEdge(id).cost();
1145         INFO (" Original cost:      " << orig_cost);
1146         INFO ("Restricted cost:      " << rest_cost);
1147         REQUIRE (30.0 == Approx((rest_cost - orig_cost)));
1148     }
1149 }
1150
1151 }
1152 catch (ConfigurationException& e)
1153 {
1154     INFO(e.what());
1155     REQUIRE (false);    // force output of error and failure
1156 }
1157 catch (MapProviderException& dbe)
1158 {
1159     INFO(dbe.what());
1160     REQUIRE (false);    // force output of error and failure
1161 }
1162 }
1163 }
1164
1165 SCENARIO ("Building graph of Partille with stop for all at crossing",
```

```
1166     "[graph][r_and_c][stop_all][partille]")
1167 {
1168     // stop at vertex 308018343 (topo 229)
1169     // affecting edges with topo id 265, 266, 267
1170     try
1171     {
1172         std::string orig_config_file("catchtest/testsettings/"
1173                                     "restrictions/partille-original.json");
1174         ConfigurationReader orig_config_reader(orig_config_file);
1175         Configuration orig_config;
1176         orig_config_reader.fillConfiguration(orig_config);
1177         PostGisProvider orig_pgp(orig_config);
1178         Topology orig_topology;
1179         orig_pgp.getTopology(orig_topology);
1180         orig_pgp.setRestrictionsAndCosts(orig_topology);
1181         GraphBuilder orig_graph(orig_topology, orig_config);
1182
1183         // =====
1184         GIVEN ("Configuration that has cost for traffic signals ")
1185         {
1186             std::string config_file("catchtest/testsettings/"
1187                                    "restrictions/partille-highway_stop_all.json");
1188             ConfigurationReader config_reader(config_file);
1189             Configuration config;
1190             config_reader.fillConfiguration(config);
1191
1192             PostGisProvider pgp(config);
1193
1194             Topology topology;
1195             pgp.getTopology(topology);
1196             pgp.setRestrictionsAndCosts(topology);
1197
1198             GraphBuilder graph(topology, config);
1199
1200             // .....
1201             WHEN ("Comparing original to graph with stop signs")
1202             {
1203                 THEN ("there should be equally many lines "
1204                      "in original as in restricted")
1205                 {
1206                     INFO (" Original # Lines:  " << orig_graph.nrLines());
1207                     INFO ("Restricted # Lines:  " << graph.nrLines());
1208                     REQUIRE ((orig_graph.nrLines() == graph.nrLines()));
1209                 }
1210
1211                 THEN ("there should be an extra cost of 30 on edge 265")
1212                 {
1213                     EdgeIdType id = 265;
1214                     Cost orig_cost = orig_topology.getEdge(id).cost();
1215                     Cost rest_cost = topology.getEdge(id).cost();
1216                     INFO (" Original cost:    " << orig_cost);
1217                     INFO ("Restricted cost:    " << rest_cost);
1218                     REQUIRE (30.0 == Approx((rest_cost - orig_cost)));
1219                 }
1220
1221                 THEN ("there should be an extra cost of 30 on edge 266")
1222                 {
```

```
1223         EdgeIdType id = 266;
1224         Cost orig_cost = orig_topology.getEdge(id).cost();
1225         Cost rest_cost = topology.getEdge(id).cost();
1226         INFO (" Original cost:      " << orig_cost);
1227         INFO ("Restricted cost:      " << rest_cost);
1228         REQUIRE (30.0 == Approx((rest_cost - orig_cost)));
1229     }
1230
1231     THEN ("there should be an extra cost of 30 on edge 267")
1232     {
1233         EdgeIdType id = 267;
1234         Cost orig_cost = orig_topology.getEdge(id).cost();
1235         Cost rest_cost = topology.getEdge(id).cost();
1236         INFO (" Original cost:      " << orig_cost);
1237         INFO ("Restricted cost:      " << rest_cost);
1238         REQUIRE (30.0 == Approx((rest_cost - orig_cost)));
1239     }
1240 }
1241 }
1242 }
1243 catch (ConfigurationException& e)
1244 {
1245     INFO(e.what());
1246     REQUIRE (false);    // force output of error and failure
1247 }
1248 catch (MapProviderException& dbe)
1249 {
1250     INFO(dbe.what());
1251     REQUIRE (false);    // force output of error and failure
1252 }
1253 }
1254 }
1255
1256 // TRAFFIC CALMING //////////////////////////////////////
1257
1258 SCENARIO ("Building graph of Mikhailovsk with speed bump at node",
1259     "[graph][r_and_c][traffic_calming][mikhailovsk]")
1260 {
1261     // additional node on way 158421713 (topo edge id 649)
1262     try
1263     {
1264         std::string orig_config_file("catchtest/testsettings/"
1265             "restrictions/mikhailovsk-original.json");
1266         ConfigurationReader orig_config_reader(orig_config_file);
1267         Configuration orig_config;
1268         orig_config_reader.fillConfiguration(orig_config);
1269         PostGisProvider orig_pgp(orig_config);
1270         Topology orig_topology;
1271         orig_pgp.getTopology(orig_topology);
1272         orig_pgp.setRestrictionsAndCosts(orig_topology);
1273         GraphBuilder orig_graph(orig_topology, orig_config);
1274
1275         // =====
1276         GIVEN ("Configuration that has cost for stops ")
1277         {
1278             std::string config_file("catchtest/testsettings/"
1279                 "restrictions/mikhailovsk-traffic_calming_bump.json");
```

```
1280      ConfigurationReader config_reader(config_file);
1281      Configuration config;
1282      config_reader.fillConfiguration(config);
1283
1284      PostGisProvider pgp(config);
1285
1286      Topology topology;
1287      pgp.getTopology(topology);
1288      pgp.setRestrictionsAndCosts(topology);
1289
1290      GraphBuilder graph(topology, config);
1291
1292      // .....
1293      WHEN ("Comparing original to graph with stop signs")
1294      {
1295          THEN ("there should be equally many lines "
1296              "in original as in restricted")
1297          {
1298              INFO (" Original # Lines:  " << orig_graph.nrLines());
1299              INFO ("Restricted # Lines:  " << graph.nrLines());
1300              REQUIRE ((orig_graph.nrLines() == graph.nrLines()));
1301          }
1302
1303          THEN ("there should be an extra cost of 10 on edge 649")
1304          {
1305              EdgeIdType id = 649;
1306              Cost orig_cost = orig_topology.getEdge(id).cost();
1307              Cost rest_cost = topology.getEdge(id).cost();
1308              INFO (" Original cost:  " << orig_cost);
1309              INFO ("Restricted cost:  " << rest_cost);
1310              REQUIRE (10.0 == Approx((rest_cost - orig_cost)));
1311          }
1312      }
1313  }
1314 }
1315 catch (ConfigurationException& e)
1316 {
1317     INFO(e.what());
1318     REQUIRE (false);    // force output of error and failure
1319 }
1320 catch (MapProviderException& dbe)
1321 {
1322     INFO(dbe.what());
1323     REQUIRE (false);    // force output of error and failure
1324 }
1325 }
1326 }
1327
1328 SCENARIO ("Building graph of Partille with speed bump at node",
1329     "[graph][r_and_c][traffic_calming][partille]")
1330 {
1331     // additional node on way 28050664 (topo edge id 267)
1332     try
1333     {
1334         std::string orig_config_file("catchtest/testsettings/"
1335             "restrictions/partille-original.json");
1336         ConfigurationReader orig_config_reader(orig_config_file);
```



```
1337     Configuration orig_config;
1338     orig_config_reader.fillConfiguration(orig_config);
1339     PostGisProvider orig_pgp(orig_config);
1340     Topology orig_topology;
1341     orig_pgp.getTopology(orig_topology);
1342     orig_pgp.setRestrictionsAndCosts(orig_topology);
1343     GraphBuilder orig_graph(orig_topology, orig_config);
1344
1345     // =====
1346     GIVEN ("Configuration that has cost for stops ")
1347     {
1348         std::string config_file("catchtest/testsettings/"
1349                                "restrictions/partille-traffic_calming_hump.json");
1350         ConfigurationReader config_reader(config_file);
1351         Configuration config;
1352         config_reader.fillConfiguration(config);
1353
1354         PostGisProvider pgp(config);
1355
1356         Topology topology;
1357         pgp.getTopology(topology);
1358         pgp.setRestrictionsAndCosts(topology);
1359
1360         GraphBuilder graph(topology, config);
1361
1362         // .....
1363         WHEN ("Comparing original to graph with stop signs")
1364         {
1365             THEN ("there should be equally many lines "
1366                  "in original as in restricted")
1367             {
1368                 INFO (" Original # Lines:  " << orig_graph.nrLines());
1369                 INFO ("Restricted # Lines:  " << graph.nrLines());
1370                 REQUIRE ((orig_graph.nrLines() == graph.nrLines()));
1371             }
1372
1373             THEN ("there should be an extra cost of 10 on edge 267")
1374             {
1375                 EdgeIdType id = 267;
1376                 Cost orig_cost = orig_topology.getEdge(id).cost();
1377                 Cost rest_cost = topology.getEdge(id).cost();
1378                 INFO (" Original cost:    " << orig_cost);
1379                 INFO ("Restricted cost:    " << rest_cost);
1380                 REQUIRE (10.0 == Approx((rest_cost - orig_cost)));
1381             }
1382         }
1383     }
1384 }
1385 catch (ConfigurationException& e)
1386 {
1387     INFO(e.what());
1388     REQUIRE (false);    // force output of error and failure
1389 }
1390 catch (MapProviderException& dbe)
1391 {
1392     INFO(dbe.what());
1393     REQUIRE (false);    // force output of error and failure
```

```
1394     }  
1395 }
```

D.7.24 Topology_test.cc

```
1  /*  
2   * Topology_test.cc  
3   *  
4   * @author  Jonas Bergman  
5   */  
6  
7  #include "../catchtest/catch.hpp"  
8  
9  #include "../Topology.h"  
10  
11  SCENARIO ("Storing topology edges and vertices in Topology", "[topology]")  
12  {  
13      OsmIdType osm_id(std::numeric_limits<OsmIdType>::max());  
14      // -----  
15      GIVEN ("a Topology object and data for a vertex")  
16      {  
17          Topology topo;  
18          const VertexIdType id(1);  
19          const double x(2);  
20          const double y(3);  
21          const Point point(x, y);  
22  
23          WHEN ("we try to add vertex to Topology")  
24          {  
25              const Vertex& r_vertex = topo.addVertex(id, point);  
26  
27              THEN ("we should get a reference to a TopologyVertex object")  
28              {  
29                  REQUIRE (r_vertex.id() == id);  
30                  REQUIRE (r_vertex.point() == point);  
31                  REQUIRE (r_vertex.point().x == Approx(x));  
32                  REQUIRE (r_vertex.point().y == Approx(y));  
33              }  
34          }  
35      }  
36  
37      // -----  
38      GIVEN ("a Topology object and data for 2 vertices with same id")  
39      {  
40          Topology topo;  
41          const VertexIdType v1(1);  
42          const Point p1(2,3);  
43          const Point p2(4,5);  
44  
45          WHEN ("we try to add second vertex to Topology")  
46          {  
47              const Vertex& r_v1 = topo.addVertex(v1, p1);  
48              const Vertex& r_v2 = topo.addVertex(v1, p2);  
49  
50              THEN ("we should get a reference to first TopologyVertex object")  
51              {  
52                  REQUIRE (r_v2 == r_v1);
```

```
53     }
54   }
55 }
56
57 // -----
58 GIVEN ("a Topology object and data for two vertices and an edge")
59 {
60   Topology topo;
61
62   const VertexIdType v1(1);
63   const Point p1(2,3);
64
65   const VertexIdType v2(2);
66   const Point p2(4,5);
67
68   const EdgeIdType e1(1);
69
70   WHEN ("we try to add edge to Topology with existing vertices")
71   {
72     const Vertex& r_v1 = topo.addVertex(v1, p1);
73     const Vertex& r_v2 = topo.addVertex(v2, p2);
74
75     const Edge& r_edge = topo.addEdge(e1, osm_id, v1, v2);
76
77     THEN ("we should get a reference to a TopologyEdge object")
78     {
79       REQUIRE (r_edge.id() == e1);
80       REQUIRE (r_edge.sourceId() == r_v1.id());
81       REQUIRE (r_edge.targetId() == r_v2.id());
82     }
83   }
84 }
85
86 // -----
87 GIVEN ("a Topology object and data for two vertices and an edge")
88 {
89   Topology topo;
90
91   const VertexIdType v1(1);
92   const Point p1(2,3);
93
94   const VertexIdType v2(2);
95   const Point p2(4,5);
96
97   const EdgeIdType e1(1);
98
99   WHEN ("we try to add edge to Topology with non-existing vertices")
100   {
101     THEN ("we should get a TopologyException")
102     {
103       REQUIRE_THROWS_AS(
104         const Edge& r_edge = topo.addEdge(e1, osm_id, v1, v2),
105         TopologyException&
106       );
107     }
108   }
109 }
```

```
110
111 // -----
112 GIVEN ("Three points and to edges for a topology")
113 {
114     Topology topology;
115     topology.addVertex(1, Point(0,0));
116     topology.addVertex(2, Point(1,2));
117     topology.addVertex(3, Point(3,4));
118     topology.addEdge(1,osm_id,1,2);
119     topology.addEdge(2,osm_id,2,3);
120
121     // .....
122     WHEN ("counting nr of edges")
123     {
124         size_t nr_edges = topology.nrEdges();
125
126         THEN ("we should get 2")
127         {
128             REQUIRE (nr_edges == 2);
129         }
130     }
131
132     // .....
133     WHEN ("counting nr of vertices")
134     {
135         size_t nr_vertices = topology.nrVertices();
136
137         THEN ("we should get 3")
138         {
139             REQUIRE (nr_vertices == 3);
140         }
141     }
142 }
143 }
```

D.7.25 TurnCostCalculator_test.cc

```
1  /* Tests for TurnCostCalculator class.
2   *
3   * To run these tests one needs to comment the
4   * `private` label in the TurnCostCalculator.
5   *
6   * TurnCostCalculator_test.cc
7   *
8   * @author Jonas Bergman
9   */
10
11 #include "../catchtest/catch.hpp"
12
13 #include "../TurnCostCalculator.h"
14 #include "../Edge.h"
15 #include "../config/ConfigurationReader.h"
16 #include "../config/Configuration.h"
17
18 SCENARIO ("Keeping track of costs for Turn", "[turncost]")
19 {
20     Edge source(1,1,1,1);
```

```
21     Edge target(2,2,2,2);
22
23     Edge::GeomData source_geom;
24     Edge::GeomData target_geom;
25
26     Edge::RoadData primary;
27     Edge::RoadData secondary;
28
29     primary.roadType = OsmHighway::HighwayType::PRIMARY;
30     secondary.roadType = OsmHighway::HighwayType::SECONDARY;
31
32
33     std::string config_file(
34         "catchtest/testsettings/mikh_restr_0617-testsettings.json");
35     ConfigurationReader config_reader(config_file);
36     Configuration config;
37     config_reader.fillConfiguration(config);
38
39     GIVEN ("two edges and a configuration")
40     {
41         WHEN ("asking for turn cost for turn between bearing 80 and 350")
42         {
43             source_geom.targetBearing = 80;
44             source.setGeomData(source_geom);
45             source.setSpeed(90);
46
47             target_geom.sourceBearing = 350;
48             target.setGeomData(target_geom);
49             target.setSpeed(60);
50
51             THEN ("we should get a cost")
52             {
53                 double cost =
54                     TurnCostCalculator::getTurnCost(
55                         source, target, config);
56                 INFO ("Turn cost " << cost);
57                 REQUIRE (cost > 0);
58             }
59         }
60
61         /*****
62          * Must comment the `private` part of the TurnCostCalculator class
63          * to run the following tests.
64          *****/
65         // WHEN ("getting cost for lower priority source turning into"
66         //     " higher priority target")
67         // {
68         //     source.setRoadData(secondary);
69         //     target.setRoadData(primary);
70         //
71         //     THEN ("we should get a cost")
72         //     {
73         //         double cost =
74         //             TurnCostCalculator::giveWayToHigherRoadCategoryCost(
75         //                 source, target);
76         //         REQUIRE (cost > 0);
77         //     }
78     }
```

```
78 //      }
79 //
80 //      WHEN ("getting cost for higher priority source turning into"
81 //          " lower priority target")
82 //      {
83 //          source.setRoadData(primary);
84 //          target.setRoadData(secondary);
85 //
86 //          THEN ("we should not get a cost")
87 //          {
88 //              double cost =
89 //                  TurnCostCalculator::giveWayToHigherRoadCategoryCost(
90 //                      source, target);
91 //              REQUIRE (cost == Approx(0.0));
92 //          }
93 //      }
94 //
95 //      WHEN ("getting cost for source turning into"
96 //          " equal priority target")
97 //      {
98 //          source.setRoadData(primary);
99 //          target.setRoadData(primary);
100 //
101 //          THEN ("we should not get a cost")
102 //          {
103 //              double cost =
104 //                  TurnCostCalculator::giveWayToHigherRoadCategoryCost(
105 //                      source, target);
106 //              REQUIRE (cost == Approx(0.0));
107 //          }
108 //      }
109 //
110 //      WHEN ("asking for angle between bearing 80 and bearing 20")
111 //      {
112 //          source_geom.targetBearing = 80;
113 //          source.setGeomData(source_geom);
114 //
115 //          target_geom.sourceBearing = 20;
116 //          target.setGeomData(target_geom);
117 //
118 //          THEN ("we should get an angle of 60")
119 //          {
120 //              int angle = TurnCostCalculator::getTurnAngle(source, target);
121 //              INFO ("turn angle in 80, out 20 = " << angle);
122 //              REQUIRE (angle == 60);
123 //          }
124 //      }
125 //
126 //      WHEN ("asking for angle between bearing 80 and bearing 350")
127 //      {
128 //          source_geom.targetBearing = 80;
129 //          source.setGeomData(source_geom);
130 //
131 //          target_geom.sourceBearing = 350;
132 //          target.setGeomData(target_geom);
133 //
134 //          THEN ("we should get an angle of 90")
```

```
135 //      {
136 //          int angle = TurnCostCalculator::getTurnAngle(source, target);
137 //          INFO ("turn angle in 80, out 350 = " << angle);
138 //          REQUIRE (angle == 90);
139 //      }
140 //  }
141 //
142 //  WHEN ("asking for angle between bearing 80 and bearing 125")
143 //  {
144 //      source_geom.targetBearing = 80;
145 //      source.setGeomData(source_geom);
146 //
147 //      target_geom.sourceBearing = 125;
148 //      target.setGeomData(target_geom);
149 //
150 //      THEN ("we should get an angle of -45")
151 //      {
152 //          int angle = TurnCostCalculator::getTurnAngle(source, target);
153 //          INFO ("turn angle in 80, out 125 = " << angle);
154 //          REQUIRE (angle == -45);
155 //      }
156 //  }
157 //
158 //  WHEN ("asking for angle between bearing 80 and bearing 260")
159 //  {
160 //      source_geom.targetBearing = 80;
161 //      source.setGeomData(source_geom);
162 //
163 //      target_geom.sourceBearing = 260;
164 //      target.setGeomData(target_geom);
165 //
166 //      THEN ("we should get an angle of -180")
167 //      {
168 //          int angle = TurnCostCalculator::getTurnAngle(source, target);
169 //          INFO ("turn angle in 80, out 260 = " << angle);
170 //          REQUIRE (angle == -180);
171 //      }
172 //  }
173 //
174 //  WHEN ("asking for length penalty factor for length 4.5 at angle 35 degrees")
175 //  {
176 //      int angle = 35;
177 //
178 //      THEN ("we should get a factor of 1")
179 //      {
180 //          double len = 4.5;
181 //          double factor =
182 //              TurnCostCalculator::calculateLengthPenaltyFactor(angle, len);
183 //          REQUIRE (factor == Approx(1.0));
184 //      }
185 //  }
186 //
187 //  WHEN ("asking for length penalty factor for length 6.0 at angle 35 degrees")
188 //  {
189 //      int angle = 35;
190 //
191 //      THEN ("we should get a factor less than 1")
```

```
192 //      {
193 //          double len = 6.0;
194 //          double factor =
195 //              TurnCostCalculator::calculateLengthPenaltyFactor(angle, len);
196 //          REQUIRE (factor < 1.0);
197 //      }
198 //  }
199 //
200 //  WHEN ("asking for length penalty factor for length 6.0 at angle -130 degrees")
201 //  {
202 //      int angle = -130;
203 //
204 //      THEN ("we should get a factor equal to 1")
205 //      {
206 //          double len = 6.0;
207 //          double factor =
208 //              TurnCostCalculator::calculateLengthPenaltyFactor(angle, len);
209 //          REQUIRE (factor == Approx(1.0));
210 //      }
211 //  }
212 //
213 //  WHEN ("asking for smallest speed of 20, 40, 60, 80")
214 //  {
215 //      THEN ("we should get 20")
216 //      {
217 //          Speed smallest = TurnCostCalculator::getSmallestSpeed({80,40,20,60});
218 //          REQUIRE (smallest == 20);
219 //      }
220 //  }
221 //
222 //  WHEN ("asking for angle speed between bearing 80 and 350")
223 //  {
224 //      source_geom.targetBearing = 80;
225 //      source.setGeomData(source_geom);
226 //      source.setSpeed(90);
227 //
228 //      target_geom.sourceBearing = 350;
229 //      target.setGeomData(target_geom);
230 //      target.setSpeed(60);
231 //
232 //      THEN ("we should get a speed")
233 //      {
234 //          Speed speed = TurnCostCalculator::getAngleSpeed(source, target);
235 //          INFO ("Angle speed " << speed);
236 //          REQUIRE ((speed > 0 && speed < 60));
237 //      }
238 //  }
239 //
240 //  WHEN ("asking for angle speed between bearing 80 and 260")
241 //  {
242 //      source_geom.targetBearing = 80;
243 //      source.setGeomData(source_geom);
244 //      source.setSpeed(90);
245 //
246 //      target_geom.sourceBearing = 260;
247 //      target.setGeomData(target_geom);
248 //      target.setSpeed(60);
```



```
249 //
250 //     THEN ("we should get a speed")
251 //     {
252 //         Speed speed = TurnCostCalculator::getAngleSpeed(source, target);
253 //         INFO ("Angle speed " << speed);
254 //         REQUIRE ((speed > 0 && speed < 60));
255 //     }
256 // }
257 //
258 // WHEN ("asking for angle speed between bearing 80 and 20")
259 // {
260 //     source_geom.targetBearing = 80;
261 //     source.setGeomData(source_geom);
262 //     source.setSpeed(90);
263 //
264 //     target_geom.sourceBearing = 20;
265 //     target.setGeomData(target_geom);
266 //     target.setSpeed(60);
267 //
268 //     THEN ("we should get a speed")
269 //     {
270 //         Speed speed = TurnCostCalculator::getAngleSpeed(source, target);
271 //         INFO ("Angle speed " << speed);
272 //         REQUIRE ((speed > 0 && speed < 60));
273 //     }
274 // }
275 //
276 // WHEN ("asking for vehicle size speed between bearing 80 and 20, vehicle_length 4.5")
277 // {
278 //     source_geom.targetBearing = 80;
279 //     source.setGeomData(source_geom);
280 //     source.setSpeed(90);
281 //
282 //     target_geom.sourceBearing = 20;
283 //     target.setGeomData(target_geom);
284 //     target.setSpeed(60);
285 //
286 //     double length {4.5};
287 //     int angle_speed {40};
288 //
289 //
290 //     THEN ("we should not get a speed reduction from angle speed")
291 //     {
292 //         Speed speed =
293 //             TurnCostCalculator::getVehicleSizeSpeed(
294 //                 source, target, length, angle_speed);
295 //         INFO ("Vehicle size speed " << speed);
296 //         REQUIRE (speed == angle_speed);
297 //     }
298 // }
299 //
300 // WHEN ("asking for vehicle size speed between bearing 80 and 20, vehicle_length 8.5")
301 // {
302 //     source_geom.targetBearing = 80;
303 //     source.setGeomData(source_geom);
304 //     source.setSpeed(90);
305 // }
```

```
306 //      target_geom.sourceBearing = 20;
307 //      target.setGeomData(target_geom);
308 //      target.setSpeed(60);
309 //
310 //      double length {8.5};
311 //      int angle_speed {40};
312 //
313 //
314 //      THEN ("we should get a speed reduction from angle speed")
315 //      {
316 //          Speed speed =
317 //              TurnCostCalculator::getVehicleSizeSpeed(
318 //                  source, target, length, angle_speed);
319 //          INFO ("Vehicle size speed " << speed);
320 //          REQUIRE (speed < angle_speed);
321 //      }
322 //  }
323 //
324 //  WHEN ("asking for turn cost for turn between bearing 80 and 20")
325 //  {
326 //      source_geom.targetBearing = 80;
327 //      source.setGeomData(source_geom);
328 //      source.setSpeed(90);
329 //
330 //      target_geom.sourceBearing = 20;
331 //      target.setGeomData(target_geom);
332 //      target.setSpeed(60);
333 //
334 //      THEN ("we should get a cost")
335 //      {
336 //          double cost =
337 //              TurnCostCalculator::getTurnCost(
338 //                  source, target, config);
339 //          INFO ("Turn cost " << cost);
340 //          REQUIRE (cost > 0);
341 //      }
342 //  }
343 }
344 }
```

D.8 Igu

D.8.1 README.md

Line Graph Utility
=====

The main class in this utility.

Given a configuration file it picks a `MapProvider` and fetches a `Topology`,
→ which is passed to the `GraphBuilder` along with the `Configuration`. The
→ goal is to fetch a linegraph that is built according to the data found in the
→ database and the configuration settings found in the configuration file.

A requirement for this utility was to be able to update data in the database
↪ which means this utility can also be requested to re-read the topology if
↪ there has been a change to them, or the restrictions and costs if there has
↪ been a change to them.

D.8.2 LineGraphUtility.h

```
1  /** The class to call to request a linegraph for routing.
2   *
3   * #include "LineGraphUtility.h"
4   *
5   * @author Jonas Bergman
6   */
7
8  #ifndef LGU_LINEGRAPHUTILITY_H_
9  #define LGU_LINEGRAPHUTILITY_H_
10
11 // SYSTEM INCLUDES
12 //
13
14 // PROJECT INCLUDES
15 //
16 #include <boost/graph/copy.hpp>
17
18 // LOCAL INCLUDES
19 //
20 #include "LineGraphUtilityException.h"
21 #include "../config/ConfigurationReader.h"
22 #include "../graph/GraphBuilder.h"
23 #include "../mapprovider/MapProvider.h"
24
25 // FORWARD REFERENCES
26 //
27
28
29 /** A class to run the fetching of data from database, through to complete
30  * weighted linegraph.
31  */
32 class LineGraphUtility
33 {
34 public:
35 // LIFECYCLE
36
37     /** Default constructor.
38     */
39     LineGraphUtility() = delete;
40
41     /** Constructor.
42     * @param rFilename The path to the configuration file.
43     */
44     LineGraphUtility(const std::string& rFilename);
45
46     /** Copy constructor.
47     *
48     * @param from The value to copy to this object.
49     */
50     LineGraphUtility(const LineGraphUtility& from) = delete;
```

```
51
52
53     /** Destructor.
54     */
55     ~LineGraphUtility(void);
56
57
58 // OPERATORS
59 // OPERATIONS
60     /** Return a LineGraph
61     */
62     LineGraphType*   getLineGraph();
63
64     /** Re-read the topology if there has been a change in the database.
65     */
66     void             updateTopology();
67
68     /** Re-apply restrictions and costs on the topology fi there has been changes.
69     */
70     void             updateRestrictionsAndCosts();
71
72     /** Save the LineGraph to storage.
73     * This is a hack to be able to demo the line graph in PostGis and JOSM.
74     */
75     void             persistLineGraph();
76
77     /** Output information about # vertices, edges, nodes, lines.
78     */
79     void             printGraphInformation(
80                     std::string prompt,
81                     std::ostream& os) const;
82
83 // ACCESS
84 // INQUIRY
85
86 protected:
87 private:
88 // HELPERS
89     void   init();
90     void   initConfiguration();
91     void   initMapProvider();
92     void   initTopology();
93     void   initRestrictionsAndCosts();
94     void   buildGraph();
95
96 // ATTRIBUTES
97     const std::string& mrSettingsfile;
98     Configuration      mConfig;
99     MapProvider*       mpMapProvider;
100    Topology            mTopology;
101    GraphBuilder*       mpGraphBuilder;
102
103 // CONSTANTS
104 };
105
106 // INLINE METHODS
107 //
```

```
108
109 // EXTERNAL REFERENCES
110 //
111
112 #endif /* LGU_LINEGRAPHUTILITY_H_ */
```

D.8.3 LineGraphUtility.cc

```
1  /*
2   * LineGraphUtility.cc
3   *
4   * @author Jonas Bergman
5   */
6
7  #include "../mapprovider/postgis/PostGisProvider.h"
8  #include "../mapprovider/jsontest/JsonTestProvider.h"
9
10 #include <string>
11 #include "LineGraphUtility.h" // class implemented
12
13 ////////////////////////////////// PUBLIC //////////////////////////////////
14
15 //===== LIFECYCLE =====
16 LineGraphUtility::LineGraphUtility(const std::string& rFilename)
17     : mrSettingsfile(rFilename),
18       mConfig(),
19       mpMapProvider(nullptr),
20       mTopology(),
21       mpGraphBuilder(nullptr)
22 {
23     try
24     {
25         init();
26     }
27     catch (const std::exception& e)
28     {
29         throw LineGraphUtilityException(
30             std::string("Error initializing LineGraphUtility: ") + e.what());
31     }
32 }
33
34 LineGraphUtility::~LineGraphUtility()
35 {
36     delete mpMapProvider;
37     delete mpGraphBuilder;
38 }
39
40 //===== OPERATORS =====
41 //===== OPERATIONS =====
42 LineGraphType*
43 LineGraphUtility::getLineGraph()
44 {
45     LineGraphType& r_orig = mpGraphBuilder->getBoostLineGraph();
46     LineGraphType* p_new = new LineGraphType();
47
48     // make a copy of the old graph into a new
49     boost::copy_graph(r_orig, *p_new);
```

```
50
51     return p_new;
52 }
53
54 void
55 LineGraphUtility::updateTopology()
56 {
57     mTopology.clearTopology();
58     initTopology();
59     initRestrictionsAndCosts();
60     buildGraph();
61 }
62
63 void
64 LineGraphUtility::updateRestrictionsAndCosts()
65 {
66     mTopology.clearEdgeCostAndRestrictions();
67     initRestrictionsAndCosts();
68     buildGraph();
69 }
70
71 void
72 LineGraphUtility::persistLineGraph()
73 {
74     try
75     {
76         mpMapProvider->persistLineGraph(*mpGraphBuilder);
77     }
78     catch(MapProviderException& mpe)
79     {
80         throw LineGraphUtilityException(mpe.what());
81     }
82 }
83
84 void
85 LineGraphUtility::printGraphInformation(
86     std::string prompt,
87     std::ostream& os) const
88 {
89     os << prompt;
90     mpGraphBuilder->printGraphInformation(os);
91 }
92 //===== ACCESS =====
93 //===== INQUIRY =====
94 ////////////////////////////////// PROTECTED //////////////////////////////////
95
96 ////////////////////////////////// PRIVATE //////////////////////////////////
97 void
98 LineGraphUtility::init()
99 {
100     initConfiguration();
101     initMapProvider();
102     initTopology();
103     initRestrictionsAndCosts();
104     buildGraph();
105 }
106
```

```
107 void
108 LineGraphUtility::initConfiguration()
109 {
110     try
111     {
112         ConfigurationReader config_reader(mrSettingsfile);
113         config_reader.fillConfiguration(mConfig);
114     }
115     catch (ConfigurationException& ce)
116     {
117         delete mpMapProvider;
118         delete mpGraphBuilder;
119         throw LineGraphUtilityException(
120             std::string("LineGraphUtility:initConfiguration: ") + ce.what());
121     }
122 }
123
124 void
125 LineGraphUtility::initMapProvider()
126 {
127     try
128     {
129         const TopologyConfig& r_topo_config = mConfig.getTopologyConfig();
130         const std::string& r_provider_name = r_topo_config.providerName;
131
132         if(r_provider_name == TopologyConfig::PROVIDER_POSTGIS)
133         {
134             mpMapProvider = new PostGisProvider(mConfig);
135         }
136         else if(r_provider_name == TopologyConfig::PROVIDER_JSONTEST)
137         {
138             mpMapProvider = new JsonTestProvider(mConfig);
139         }
140         else
141         {
142             throw MapProviderException("No valid MapProvider found");
143         }
144     }
145     catch (MapProviderException& mpe)
146     {
147         delete mpMapProvider;
148         delete mpGraphBuilder;
149
150         throw LineGraphUtilityException(
151             std::string("LineGraphUtility:initMapProvider: ") + mpe.what());
152     }
153 }
154
155 void
156 LineGraphUtility::initTopology()
157 {
158     try
159     {
160         mpMapProvider->getTopology(mTopology);
161     }
162     catch (MapProviderException& mpe)
163     {
```

```
164         delete mpMapProvider;
165         delete mpGraphBuilder;
166
167         throw LineGraphUtilityException(
168             std::string("LineGraphUtility:initTopology ") + mpe.what());
169     }
170 }
171
172 void
173 LineGraphUtility::initRestrictionsAndCosts()
174 {
175     try
176     {
177         mpMapProvider->setRestrictionsAndCosts(mTopology);
178     }
179     catch (MapProviderException& mpe)
180     {
181         delete mpMapProvider;
182         delete mpGraphBuilder;
183
184         throw LineGraphUtilityException(
185             std::string("LineGraphUtility:initRestrictionsAndCosts ") + mpe.what());
186     }
187 }
188
189 void
190 LineGraphUtility::buildGraph()
191 {
192     try
193     {
194         delete mpGraphBuilder;
195         mpGraphBuilder = new GraphBuilder(mTopology, mConfig);
196     }
197     catch (const std::exception& e)
198     {
199         delete mpMapProvider;
200         delete mpGraphBuilder;
201
202         throw LineGraphUtilityException(
203             std::string("LineGraphUtility:buildGraph: ") + e.what());
204     }
205 }
```

D.8.4 LineGraphUtilityException.h

```
1  /** Exception thrown by the 'lgu' package.
2   *
3   * #include "LineGraphUtilityException.h"
4   *
5   * @author Jonas Bergman
6   */
7
8  #ifndef LGU_LINEGRAPHUTILITYEXCEPTION_H_
9  #define LGU_LINEGRAPHUTILITYEXCEPTION_H_
10
11 // SYSTEM INCLUDES
12 //
```



```
13  #include <exception>
14  #include <string>
15
16  // PROJECT INCLUDES
17  //
18
19  // LOCAL INCLUDES
20  //
21
22  // FORWARD REFERENCES
23  //
24
25  /**
26   * Exception to throw from the 'graph' package.
27   * More information of the type of exception is given in the 'what()' message.
28   */
29  class LineGraphUtilityException : public std::exception
30  {
31  public:
32      // LIFECYCLE
33      /** Default constructor.
34       */
35      LineGraphUtilityException() = delete;
36
37      /** Constructor taking a message to display.
38       *
39       * @param message    The message to prepend when 'what()' is called.
40       */
41      LineGraphUtilityException(const std::string& rMessage) noexcept
42          : std::exception(), mMessage(rMessage)
43      {}
44
45      // OPERATORS
46      // OPERATIONS
47      // ACCESS
48      // INQUIRY
49      const char* what() const noexcept
50      { return (mMessage.c_str()); }
51
52  protected:
53  private:
54      // ATTRIBUTES
55      std::string    mMessage;
56  };
57
58  // INLINE METHODS
59  //
60
61  // EXTERNAL REFERENCES
62  //
63
64  #endif /* LGU_LINEGRAPHUTILITYEXCEPTION_H_ */
```

D.8.5 LineGraphUtility_test.cc

```
1  /*
2   * LineGraphUtility_test.cc
```

```
3  *
4  * @author Jonas Bergman
5  */
6
7  #include "../LineGraphUtility.h"
8
9  #include <chrono>
10
11 using namespace std::chrono;
12
13
14 #include "../../catchtest/catch.hpp"
15
16
17 SCENARIO ("LineGraphUtility construction", "[lgu][construction]")
18 {
19     try
20     {
21         GIVEN ("a valid config file set up to use jstest as provider")
22         {
23             std::string config_file(
24                 "catchtest/testsettings/mikh_restr_0617-testsettings.json");
25             //.....
26             WHEN ("creating a LineGraphUtility")
27             {
28                 THEN ("we should not receive an exception")
29                 {
30                     REQUIRE_NOTHROW(LineGraphUtility lgu(config_file));
31                 }
32             }
33         }
34     }
35     catch (LineGraphUtilityException& lgue)
36     {
37         INFO(lgue.what());
38         REQUIRE (false); // force output of error and failure
39     }
40     catch (const std::exception& e)
41     {
42         INFO(e.what());
43         REQUIRE (false); // force output of error and failure
44     }
45 }
46
47 SCENARIO ("LineGraphUtility operation", "[lgu][operation]")
48 {
49     try
50     {
51         GIVEN ("a valid config file")
52         {
53             std::string config_file(
54                 "catchtest/testsettings/mikh_restr_0617-testsettings.json");
55             LineGraphUtility lgu(config_file);
56
57             WHEN ("asking for a LineGraph")
58             {
59                 LineGraphType* p_lg = lgu.getLineGraph();
```

```
60
61     THEN ("we should have a line graph")
62     {
63         REQUIRE (p_lg != nullptr);
64         REQUIRE (boost::num_edges(*p_lg) > 0);
65     }
66
67     THEN ("we should be able to print info for lines")
68     {
69         int i = 0;
70         for(auto it = boost::edges(*p_lg);
71             (i < 10) && (it.first != it.second) ;
72             ++it.first, ++i)
73         {
74             const auto& line = *(it.first);
75             NodeIdType lg_source_id =
76                 boost::get(&LineGraphLine::lgSourceNodeId, *p_lg, line);
77             NodeIdType lg_target_id =
78                 boost::get(&LineGraphLine::lgTargetNodeId, *p_lg, line);
79             VertexIdType topo_via_vertex_id =
80                 boost::get(&LineGraphLine::topoViaVertexId, *p_lg, line);
81             double cost =
82                 boost::get(&LineGraphLine::cost, *p_lg, line);
83
84             INFO ("LINE:  lg_source_id: " << lg_source_id
85                  << ", lg_target_id: " << lg_target_id
86                  << ", topo_via_vertex_id: " << topo_via_vertex_id
87                  << ", cost: " << cost << "\n");
88             REQUIRE (true);
89         }
90     }
91
92     THEN ("we can try to persist line graph")
93     {
94         try
95         {
96             lgu.persistLineGraph();
97             INFO ("Persisted line graph");
98             REQUIRE (true);
99         }
100        catch (LineGraphUtilityException& lgue)
101        {
102            INFO (lgue.what());
103            REQUIRE (false);
104        }
105    }
106
107    delete p_lg;
108
109    }
110
111    WHEN ("asking to update restrictions and costs")
112    {
113        lgu.updateRestrictionsAndCosts();
114        LineGraphType* p_lg {nullptr};
115        p_lg = lgu.getLineGraph();
116    }
```

```
117         THEN ("we should still be able to have a line graph")
118         {
119             REQUIRE (p_lg != nullptr);
120             REQUIRE (boost::num_edges(*p_lg) > 0);
121         }
122
123         delete p_lg;
124     }
125
126     WHEN ("asking to update topology")
127     {
128         lgu.updateTopology();
129         LineGraphType* p_lg {nullptr};
130         p_lg = lgu.getLineGraph();
131
132         THEN ("we should still be able to have a line graph")
133         {
134             REQUIRE (p_lg != nullptr);
135             REQUIRE (boost::num_edges(*p_lg) > 0);
136         }
137
138         delete p_lg;
139     }
140 }
141
142 catch (LineGraphUtilityException& lgue)
143 {
144     INFO(lgue.what());
145     REQUIRE (false);    // force output of error and failure
146 }
147 catch (const std::exception& e)
148 {
149     INFO(e.what());
150     REQUIRE (false);    // force output of error and failure
151 }
152 }
153
154
155 SCENARIO ("LineGraphUtility timing", "[lgu][timing]")
156 {
157     try
158     {
159         GIVEN ("a valid config file for Mikhailovsk without temporary topology")
160         {
161             std::string config_file(
162                 "catchtest/testsettings/mikhailovsk-original.json");
163
164             WHEN ("when timing request for a LineGraph")
165             {
166                 // start timing
167                 std::chrono::high_resolution_clock::time_point t1 =
168                     std::chrono::high_resolution_clock::now();
169
170                 LineGraphType* p_lg;
171
172                 int nr_rounds = 10;
173                 for(int i = 0; i < nr_rounds; ++i)
```

```
174         {
175             LineGraphUtility lgu(config_file);
176             p_lg = lgu.getLineGraph();
177             delete p_lg;
178             p_lg = nullptr;
179         }
180
181         // end timing;
182         std::chrono::high_resolution_clock::time_point t2 =
183             std::chrono::high_resolution_clock::now();
184
185         auto duration =
186             std::chrono::duration_cast<std::chrono::microseconds>
187                 ( t2 - t1 ).count();
188
189
190         THEN ("we should have an average timing")
191         {
192             INFO ("Average duration over " << nr_rounds << " rounds for "
193                 "Mikhailovsk without temporary topology: "
194                 << duration / nr_rounds << " microseconds");
195             REQUIRE (true);
196         }
197
198         delete p_lg;
199     }
200 }
201
202 GIVEN ("a valid config file for Mikhailovsk WITH temporary topology")
203 {
204     std::string config_file(
205         "catchtest/testsettings/mikhailovsk-original-temp.json");
206
207     WHEN ("when timing request for a LineGraph")
208     {
209         // start timing
210         std::chrono::high_resolution_clock::time_point t1 =
211             std::chrono::high_resolution_clock::now();
212
213         LineGraphType* p_lg;
214
215         int nr_rounds = 10;
216         for(int i = 0; i < nr_rounds; ++i)
217         {
218             LineGraphUtility lgu(config_file);
219             p_lg = lgu.getLineGraph();
220             delete p_lg;
221             p_lg = nullptr;
222         }
223
224         // end timing;
225         std::chrono::high_resolution_clock::time_point t2 =
226             std::chrono::high_resolution_clock::now();
227
228         auto duration =
229             std::chrono::duration_cast<std::chrono::microseconds>
230                 ( t2 - t1 ).count();
```

```
231
232
233     THEN ("we should have an average timing")
234     {
235         INFO ("Average duration over " << nr_rounds << " rounds for "
236             "Mikhailovsk WITH temporary topology: "
237             << duration / nr_rounds << " microseconds");
238         REQUIRE (true);
239     }
240
241     delete p_lg;
242 }
243
244
245
246 GIVEN ("a valid config file for Partille without temporary topology")
247 {
248     std::string config_file(
249         "catchtest/testsettings/partille-original.json");
250
251     WHEN ("when timing request for a LineGraph")
252     {
253         // start timing
254         std::chrono::high_resolution_clock::time_point t1 =
255             std::chrono::high_resolution_clock::now();
256
257         LineGraphType* p_lg;
258
259         int nr_rounds = 10;
260         for(int i = 0; i < nr_rounds; ++i)
261         {
262             LineGraphUtility lgu(config_file);
263             p_lg = lgu.getLineGraph();
264             delete p_lg;
265             p_lg = nullptr;
266         }
267
268         // end timing;
269         std::chrono::high_resolution_clock::time_point t2 =
270             std::chrono::high_resolution_clock::now();
271
272         auto duration =
273             std::chrono::duration_cast<std::chrono::microseconds>
274             ( t2 - t1 ).count();
275
276
277         THEN ("we should have an average timing")
278         {
279             INFO ("Average duration over " << nr_rounds << " rounds for "
280                 "Partille without temporary topology: "
281                 << duration / nr_rounds << " microseconds");
282             REQUIRE (true);
283         }
284
285         delete p_lg;
286     }
287 }
```

```
288
289     GIVEN ("a valid config file for Partille WITH temporary topology")
290     {
291         std::string config_file(
292             "catchtest/testsettings/partille-original-temp.json");
293
294         WHEN ("when timing request for a LineGraph")
295         {
296             // start timing
297             std::chrono::high_resolution_clock::time_point t1 =
298                 std::chrono::high_resolution_clock::now();
299
300             LineGraphType* p_lg;
301
302             int nr_rounds = 10;
303             for(int i = 0; i < nr_rounds; ++i)
304             {
305                 LineGraphUtility lgu(config_file);
306                 p_lg = lgu.getLineGraph();
307                 delete p_lg;
308                 p_lg = nullptr;
309             }
310
311             // end timing;
312             std::chrono::high_resolution_clock::time_point t2 =
313                 std::chrono::high_resolution_clock::now();
314
315             auto duration =
316                 std::chrono::duration_cast<std::chrono::microseconds>
317                     ( t2 - t1 ).count();
318
319             THEN ("we should have an average timing")
320             {
321                 INFO ("Average duration over " << nr_rounds << " rounds for "
322                     "Partille WITH temporary topology: "
323                     << duration / nr_rounds << " microseconds");
324                 REQUIRE (true);
325             }
326
327             delete p_lg;
328         }
329     }
330
331 }
332 catch (LineGraphUtilityException& lgue)
333 {
334     INFO(lgue.what());
335     REQUIRE (false);    // force output of error and failure
336 }
337 catch (const std::exception& e)
338 {
339     INFO(e.what());
340     REQUIRE (false);    // force output of error and failure
341 }
342 }
343
344 SCENARIO ("LineGraphUtility size and order", "[lgu][print_size]")
```

```
345 {
346     try
347     {
348         GIVEN ("a valid config file for Mikhailovsk")
349         {
350             std::string config_file(
351                 "catchtest/testsettings/mikhailovsk-original.json");
352
353             WHEN ("asking for size and order of graphs")
354             {
355                 LineGraphUtility lgu(config_file);
356                 THEN ("we should get a print out of sizes")
357                 {
358                     lgu.printGraphInformation("Mikhailovsk: ", std::cout);
359                     REQUIRE(true);
360                 }
361             }
362         }
363
364         GIVEN ("a valid config file for Partille")
365         {
366             std::string config_file(
367                 "catchtest/testsettings/partille-original.json");
368
369             WHEN ("asking for size and order of graphs")
370             {
371                 LineGraphUtility lgu(config_file);
372                 THEN ("we should get a print out of sizes")
373                 {
374                     lgu.printGraphInformation("Partille: ", std::cout);
375                     REQUIRE(true);
376                 }
377             }
378         }
379     }
380     catch (LineGraphUtilityException& lgue)
381     {
382         INFO(lgue.what());
383         REQUIRE (false);    // force output of error and failure
384     }
385     catch (const std::exception& e)
386     {
387         INFO(e.what());
388         REQUIRE (false);    // force output of error and failure
389     }
390 }
```

D.9 mapprovider

D.9.1 README.md

MapProvider
=====

The `mapprovider` package exists to implement different classes that can provide
↪ access to OpenStreetMap data.

Background

There exists several solutions to import OpenStreetMap data into a database, and

- ↪ the different solutions all creates different schemas and tables. To keep the
- ↪ flexibility to change how we get the OSM data, the ``mapprovider`` exists to
- ↪ provide an abstract interface that providers must implement.

``jsonstest``

The ``JsonTestProvider`` is a small map provider that was implemented to be able to

- ↪ read in a small set of well-known edges and vertices (such as the [pgRouting
- ↪ sample
- ↪ data](<http://docs.pgrouting.org/dev/doc/src/developer/sampled.html>)), to
- ↪ be used under development of the ``Graph`` class.

``postgis``

The ``PostGisProvider`` exists for working with topologies built with the

- ↪ ``postgis_topology`` extension. This is the course taken during development of
- ↪ the ``LineGraphUtility`` so far. (Using ``pgRouting`` seemed to be useful only
- ↪ for building topology and not to get access to the other map data, and
- ↪ ``osm2po`` is not open source. But with the ``MapProvider`` interface it is
- ↪ possible to implement another if desirable.)

The ``PostGisProvider`` uses classes ``TopologyQueries`` and ``RestrictionQueries`` for

- ↪ querying the database.

Exceptions

Each subpackage throws its own exception: ``MapProviderException``, and

- ↪ ``PostGisProviderException``.

D.9.2 MapProvider.h

```
1  /** Abstract base class giving the interface for different sources of
2   * topology map data.
3   *
4   * #include "MapProvider.h"
5   *
6   * @author Jonas Bergman
7   */
8
9  #ifndef MAPPROVIDER_MAPPROVIDER_H_
10 #define MAPPROVIDER_MAPPROVIDER_H_
11
12 // SYSTEM INCLUDES
13 //
14 #include <map>
15
16 // PROJECT INCLUDES
17 //
18
19 // LOCAL INCLUDES
20 //
21 #include "MapProviderException.h"
22 #include "../graph/Topology.h"
23 #include "../config/Configuration.h"
24 #include "../graph/Edge.h"
25 #include "../graph/GraphBuilder.h"
26 #include "../graph/Vertex.h"
27
```

```
28 // FORWARD REFERENCES
29 //
30
31 /**
32  * Interface for getting map data from file or database.
33  */
34 class MapProvider
35 {
36 public:
37 // LIFECYCLE
38
39     /** Default constructor.
40     */
41     MapProvider() = delete;
42
43     /** Constructor.
44     * Construct a MapProvider based on the configurations given.
45     */
46     MapProvider(const Configuration& rConfig)
47         : mBuildTempTopology(false), mrConfig(rConfig)
48     {}
49
50     /** Copy constructor.
51     *
52     * @param from The value to copy to this object.
53     */
54     MapProvider(const MapProvider& from) = delete;
55
56
57     /** Destructor.
58     */
59     virtual ~MapProvider(void) {}
60
61
62 // OPERATORS
63 // OPERATIONS
64     /** Fill the topology with data from the MapProvider.
65     * @param rTopology The Topology to fill with data.
66     * @throws MapProviderException, TopologyException
67     */
68     virtual void    getTopology(Topology& rTopology) = 0;
69
70     /** Read tags that might impose restrictions and costs and add them to
71     * the edges in the topology.
72     * @param rTopology The Topology with edges to get updated.
73     * @throws MapProviderException, RestrictionsException
74     */
75     virtual void    setRestrictionsAndCosts(Topology& rTopology) = 0;
76
77     /** Save the line graph to persistent storage or throw exception if not
78     * implemented.
79     * @param rGraph The GraphBuilder with the LineGraph and topology to save.
80     * @throws MapProviderException
81     */
82     virtual void    persistLineGraph(const GraphBuilder& rGraph) = 0;
83
84 // ACCESS
```

```
85 // INQUIRY
86
87 protected:
88     bool                mBuildTempTopology;
89     const Configuration& mrConfig;
90 private:
91 };
92
93 // INLINE METHODS
94 //
95
96 // EXTERNAL REFERENCES
97 //
98
99 #endif /* MAPPROVIDER_MAPPROVIDER_H_ */
```

D.9.3 MapProviderException.h

```
1 /** Exception thrown by the MapProvider package.
2  *
3  * #include "MapProviderException.h"
4  *
5  * @author Jonas Bergman
6  */
7
8 #ifndef MAPPROVIDER_MAPPROVIDEREXCEPTION_H_
9 #define MAPPROVIDER_MAPPROVIDEREXCEPTION_H_
10
11 // SYSTEM INCLUDES
12 //
13 #include <exception>
14 #include <string>
15
16 // PROJECT INCLUDES
17 //
18
19 // LOCAL INCLUDES
20 //
21
22 // FORWARD REFERENCES
23 //
24
25 /**
26  * Exception to throw from the 'MapProvider' package.
27  * More information of the type of exception is given in the 'what()' message.
28  */
29 class MapProviderException : public std::exception
30 {
31 public:
32 // LIFECYCLE
33
34     /** Default constructor.
35     */
36     MapProviderException() = delete;
37
38     /** Constructor taking a message to display.
39     *
```

```
40     * @param    message    The message to prepend when 'what()' is called.
41     */
42     MapProviderException(const std::string& rMessage) noexcept
43         : std::exception(), mMessage(rMessage)
44     {}
45
46     // OPERATORS
47     // OPERATIONS
48     // ACCESS
49     // INQUIRY
50     const char* what() const noexcept
51     { return mMessage.c_str(); }
52
53 protected:
54 private:
55     // ATTRIBUTES
56     std::string      mMessage;
57 };
58
59 // INLINE METHODS
60 //
61
62 // EXTERNAL REFERENCES
63 //
64
65 #endif /* MAPPROVIDER_MAPPROVIDEREXCEPTION_H_ */
```

D.9.4 MapProvider_test.cc

```
1  /*
2   * MapProvider_test.cc
3   *
4   * @author  Jonas Bergman
5   */
6
7  #include "../MapProvider.h"
8
9  #include <string>
10 #include <map>
11
12 #include "../../catchtest/catch.hpp"
13 #include "../../config/ConfigurationReader.h"
14 #include "../../config/Configuration.h"
15 #include "../../config/DatabaseConfig.h"
16 #include "../postgis/PostGisProvider.h"
17 #include "../../graph/Edge.h"
18 #include "../../graph/Vertex.h"
19
20
21 SCENARIO ("MapProvider queries", "[mp-query]")
22 {
23     try
24     {
25         std::string config_file("catchtest/testsettings/testsettings.json");
26         ConfigurationReader config_reader(config_file);
27
28         GIVEN ("a valid database configuration structure and "
```

```

29         "name to existing topology")
30     {
31         Configuration config;
32         config_reader.fillConfiguration(config);
33         const DatabaseConfig& db_config = config.getDatabaseConfig();
34         std::string topo_name("test");
35
36         MapProvider* p_mp(nullptr);
37         if(config.getTopologyConfig().providerName ==
38             TopologyConfig::PROVIDER_POSTGIS)
39         {
40             p_mp = new PostGisProvider(config);
41         }
42
43         REQUIRE (p_mp != nullptr);
44
45         // .....
46         WHEN ("we try to fetch topology")
47         {
48             Topology topology;
49             p_mp->getTopology(topology);
50
51             THEN ("we should receive topology vertices and edges")
52             {
53                 REQUIRE (topology.nrVertices() > 0);
54                 REQUIRE (topology.nrEdges() > 0);
55             }
56         }
57         delete p_mp;
58     }
59 }
60 catch (ConfigurationException& e)
61 {
62     INFO(e.what());
63     REQUIRE (false);    // force output of error and failure
64 }
65 catch (MapProviderException& dbe)
66 {
67     INFO(dbe.what());
68     REQUIRE (false);    // force output of error and failure
69 }
70 }
71 }

```

D.10 jsontest

D.10.1 README.md

JsonTest
=====

This package exists for the sole purpose of testing in the initial stages of
 ↪ development, so that we easily could read in a small set of well-known edges
 ↪ and vertices.

But the test is now commented out, as it has not been updated to keep up with
 ↪ advances in the development.

Format of test file in json is:

```
``json
{
  "vertices": [
    [1,2,0],
    [2,2,1]
  ],
  "edges": [
    [1,1,2,0]
  ]
}
``
```

where each row in `vertices` are `[id,x,y]` and each row in `edges` are `[id,
→ source vertex id, target vertex id, direction]`. Values for `direction` is
→ `0 = BOTH`, `1 = FROM_TO`, `2 = TO_FROM`.

D.10.2 JsonTestProvider.h

```
1  /** Read in sample topology from a json file.
2   *
3   * #include "JsonTestProvider.h"
4   *
5   * @author Jonas Bergman
6   */
7  #ifndef MAPPROVIDER_JSONTEST_JSONTESTPROVIDER_H_
8  #define MAPPROVIDER_JSONTEST_JSONTESTPROVIDER_H_
9
10 // SYSTEM INCLUDES
11 //
12
13 // PROJECT INCLUDES
14 //
15
16 // LOCAL INCLUDES
17 //
18 #include "../MapProvider.h"
19
20 // FORWARD REFERENCES
21 //
22
23 /**
24  * Interface for getting map data from file or database.
25  */
26 class JsonTestProvider : public MapProvider
27 {
28 public:
29 // LIFECYCLE
30
31     /** Default constructor.
32     */
33     JsonTestProvider() = delete;
34
35     /** Constructor.
```

```
36     * Construct a MapProvider based on the configurations given.
37     */
38     JsonTestProvider(const Configuration& rConfig);
39
40     /** Copy constructor.
41     *
42     * @param from The value to copy to this object.
43     */
44     JsonTestProvider(const JsonTestProvider& from) = delete;
45
46
47     /** Destructor.
48     */
49     virtual ~JsonTestProvider(void);
50
51
52     // OPERATORS
53     // OPERATIONS
54     virtual void    getTopology(Topology& rTopology);
55
56     virtual void    setRestrictionsAndCosts(Topology& rTopology);
57
58     virtual void    persistLineGraph(const GraphBuilder& rGraph);
59
60     // ACCESS
61     // INQUIRY
62
63     protected:
64     private:
65     };
66
67     // INLINE METHODS
68     //
69
70     // EXTERNAL REFERENCES
71     //
72
73     #endif /* MAPPROVIDER_JSONTEST_JSONTESTPROVIDER_H_ */
```

D.10.3 JsonTestProvider.cc

```
1  /*
2  * JsonTestProvider.cc
3  *
4  * @author Jonas Bergman
5  */
6
7  #include "JsonTestProvider.h" // class implemented
8  #include "../graph/Vertex.h"
9  #include "../graph/Edge.h"
10
11 #include <string>
12 #include <boost/property_tree/ptree.hpp>
13 #include <boost/property_tree/json_parser.hpp>
14
15
16
```

```
17  ////////////////////////////////// PUBLIC //////////////////////////////////
18
19  //===== LIFECYCLE =====
20
21  JsonTestProvider::JsonTestProvider(const Configuration& rConfig)
22      : MapProvider(rConfig)
23  {
24  }
25
26  JsonTestProvider::~JsonTestProvider()
27  {
28  }
29
30  //===== OPERATORS =====
31
32  //===== OPERATIONS =====
33  void
34  JsonTestProvider::getTopology(Topology& rTopology)
35  {
36      using namespace boost::property_tree;
37
38      const std::string& filename = mrConfig.getTopologyConfig().testFile;
39      ptree pt;
40
41      try
42      {
43          read_json(filename, pt);
44
45          // vertices
46          int v_row[3];
47          for(auto& row : pt.get_child("vertices"))
48          {
49              int i = 0;
50              for(auto& item : row.second)
51              {
52                  v_row[i] = item.second.get_value<int>();
53                  ++i;
54              }
55              rTopology.addVertex(v_row[0], Point(v_row[1], v_row[2]));
56          }
57
58          // edges
59          int e_row[4];
60          for(auto& row : pt.get_child("edges"))
61          {
62              int i = 0;
63              for(auto& item : row.second)
64              {
65                  e_row[i] = item.second.get_value<int>();
66                  ++i;
67              }
68              Edge::DirectionType direction;
69              OsmIdType osm_id(std::numeric_limits<OsmIdType>::max());
70              switch(e_row[3])
71              {
72                  case 0:
73                      direction = Edge::DirectionType::BOTH; break;
```



```
74         case 1:
75             direction = Edge::DirectionType::FROM_TO; break;
76         case 2:
77             direction = Edge::DirectionType::TO_FROM; break;
78         default:
79             direction = Edge::DirectionType::BOTH;
80     }
81     Edge& e = rTopology.addEdge(e_row[0], osm_id, e_row[1], e_row[2]);
82     Edge::RoadData rd;
83     rd.direction = direction;
84     e.setRoadData(rd);
85 }
86 }
87 catch (boost::property_tree::ptree_error& e)
88 {
89     throw TopologyException("Could not read file " + filename);
90 }
91 }
92
93 void
94 JsonTestProvider::setRestrictionsAndCosts(Topology& rTopology)
95 {
96     //none
97 }
98
99 void
100 JsonTestProvider::persistLineGraph(const GraphBuilder& rGraph)
101 {
102     throw MapProviderException("JsonTestProvider has not "
103                               "implemented persisting a Line graph");
104 }
105
106 //===== ACCESS =====
107 //===== INQUIRY =====
108 ////////////////////////////////////////////////// PROTECTED //////////////////////////////////////////
109
110 ////////////////////////////////////////////////// PRIVATE //////////////////////////////////////////
```

D.10.4 JsonTestProvider_test.cc

```
1  /**
2  // * JsonTestProvider_test.cc
3  // *
4  // * @author Jonas Bergman
5  // */
6  //
7  // #include "../JsonTestProvider.h"
8  //
9  // #include <string>
10 // #include <vector>
11 //
12 // #include "../../catchtest/catch.hpp"
13 // #include "../../config/ConfigurationReader.h"
14 // #include "../../config/DatabaseConfig.h"
15 // #include "../../graph/Edge.h"
16 // #include "../../graph/Vertex.h"
17 // #include "../../graph/Graph.h"
```

```
18 //
19 //SCENARIO ("JsonTest topology handling", "[jsontest]")
20 //{
21 //    try
22 //    {
23 //        // =====
24 //        GIVEN ("a valid configuration structure with a jsontest filename")
25 //        {
26 //            std::string config_file("mapprovider/jsontest"
27 //                                   "/catchtest/jsontest-settings.json");
28 //            ConfigurationReader config_reader(config_file);
29 //            Configuration config;
30 //            config_reader.fillConfiguration(config);
31 //            JsonTestProvider* p_jt(nullptr);
32 //
33 //            // .....
34 //            WHEN ("we try to create topology")
35 //            {
36 //                THEN ("we should not receive an exception")
37 //                {
38 //                    REQUIRE_NOTHROW ( p_jt = new JsonTestProvider(config));
39 //                }
40 //            }
41 //
42 //            // .....
43 //            WHEN ("we try to fetch topology ")
44 //            {
45 //                Topology topology;
46 //                JsonTestProvider jtp(config);
47 //
48 //                // .....
49 //                THEN ("we should not receive an exception")
50 //                {
51 //                    REQUIRE_NOTHROW (jtp.getTopology(topology));
52 //                }
53 //            }
54 //            // .....
55 //            WHEN ("using topology")
56 //            {
57 //                Topology topology;
58 //                JsonTestProvider jtp(config);
59 //                jtp.getTopology(topology);
60 //
61 //                size_t nr_vertices = 13;
62 //                size_t nr_edges = 16;
63 //
64 //                Configuration config;
65 //
66 //                // .....
67 //                THEN ("we should have the right number of edges and vertices"
68 //                     " in the topology")
69 //                {
70 //                    REQUIRE (topology.nrVertices() == nr_vertices);
71 //                    REQUIRE (topology.nrEdges() == nr_edges);
72 //                }
73 //
74 //                // .....
```

```
75 //          THEN ("we should be able to create a graph from topology")
76 //          {
77 //              REQUIRE_NOTHROW (Graph graph(topology, config));
78 //          }
79 //
80 //          // . . . . .
81 //          THEN ("we should be able to create a graph from topology"
82 //              " and print out the graph")
83 //          {
84 //              Graph graph(topology, config);
85 //              INFO (graph);
86 //              REQUIRE (true);
87 //          }
88 //      }
89 //      delete p_jt;
90 //  }
91 //
92 //  }
93 //  catch (ConfigurationException& e) {
94 //      INFO(e.what());
95 //      REQUIRE (false);    // force output of error and failure
96 //  }
97 //}
98 //
99 //
```

D.10.5 jsontest-settings.json

```
1  {
2      "database":
3      {
4          "host":      "127.0.0.1",
5          "port":      5432,
6          "username":  "tester",
7          "password":  "tester",
8          "database":  "mikh_style"
9      },
10
11     "topology":
12     {
13         "provider":    "jsontest",
14
15         "postgis":
16         {
17
18             "topo_name":    "test",
19             "roads_prefix": "highways",
20             "schema_prefix": "topo",
21             "build": {
22                 "temp_topo_name": "epoch_ms",
23                 "srid":            900913,
24                 "tolerance":       1.0
25             },
26             "edge":
27             {
28                 "table":    "edge_data",
29                 "id_col":    "edge_id",
```

```
30         "source_col": "start_node",
31         "target_col": "end_node",
32         "geom_col": "geom"
33     },
34     "vertex":
35     {
36         "table": "node",
37         "id_col": "node_id",
38         "geom_col": "geom"
39     }
40 },
41
42 "pgrouting":
43 {
44 },
45
46 "jsontest":
47 {
48     "test_file": "mapprovider/jsontest/catchtest/test-topology.json"
49 }
50 },
51
52 "vehicle":
53 {
54     "category": "motorcar",
55     "motorcar":
56     {
57         "height": 1.6,
58         "length": 4.5,
59         "width": 1.9,
60         "weight": 2.0,
61         "maxspeed": 200
62     }
63 },
64
65 "cost":
66 {
67     "default_speed":
68     {
69         "motorway": {"high": 110, "low": 90},
70         "motorway_link": {"high": 90, "low": 90},
71         "trunk": {"high": 90, "low": 60},
72         "trunk_link": {"high": 90, "low": 60},
73         "primary": {"high": 90, "low": 60},
74         "primary_link": {"high": 90, "low": 60},
75         "secondary": {"high": 90, "low": 60},
76         "secondary_link": {"high": 90, "low": 60},
77         "tertiary": {"high": 90, "low": 60},
78         "tertiary_link": {"high": 90, "low": 60},
79         "unclassified": {"high": 90, "low": 60},
80         "residential": {"high": 90, "low": 60},
81         "living_street": {"high": 20, "low": 20}
82     }
83 }
84 }
```

D.10.6 test-topology.json

```
1  {
2      "vertices": [
3          [1,2,0],
4          [2,2,1],
5          [3,3,1],
6          [4,4,1],
7          [5,0,2],
8          [6,1,2],
9          [7,2,2],
10         [8,3,2],
11         [9,4,2],
12         [10,2,3],
13         [11,3,3],
14         [12,4,3],
15         [13,2,4]
16     ],
17     "edges": [
18         [1,1,2,0],
19         [2,2,3,1],
20         [3,3,4,1],
21         [4,2,7,0],
22         [5,3,8,2],
23         [6,5,6,0],
24         [7,6,7,0],
25         [8,7,8,0],
26         [9,8,9,0],
27         [10,7,10,0],
28         [11,8,11,2],
29         [12,10,11,2],
30         [13,11,12,2],
31         [14,10,13,0],
32         [15,9,12,0],
33         [16,4,9,0]
34     ]
35 }
```

D.11 postgis

D.11.1 README.md

PostGisProvider
=====

This is a concrete class that implements the MapProviders interface. It fetches
→ map data from a PostGis database where the OSM data has been imported with
→ `osm2pgsql`, and topology has been built with the `postgis_topology`
→ extension, converts it to valid `Vertex` and `Edge` types and stores them in
→ a `Topology`.

The handling of the queries are factored out in different static classes:

- `CostQueries` for handling costs.
- `RestrictionQueries` for handling restrictions.
- `TopologyQueries` for handling topology related stuff.
- `LineGraphSaveQueries` for persisting a LineGraph back to the database.

D.11.2 PostGisProvider.h

```
1  /** Handle connections with PostGis database to get map data.
2   *
3   * #include "PostGisProvider.h"
4   *
5   * @author Jonas Bergman
6   */
7
8  #ifndef MAPPROVIDER_POSTGIS_POSTGISPROVIDER_H_
9  #define MAPPROVIDER_POSTGIS_POSTGISPROVIDER_H_
10
11 // SYSTEM INCLUDES
12 //
13 #include <algorithm>
14 #include <sstream>
15 #include <string>
16 #include <vector>
17
18 // PROJECT INCLUDES
19 //
20 #include <pqxx/pqxx> // link with -lpqxx -lpq
21 #include <boost/algorithm/string.hpp>
22
23 // LOCAL INCLUDES
24 //
25 #include "CostQueries.h"
26 #include "RestrictionQueries.h"
27 #include "TopologyQueries.h"
28 #include "../MapProvider.h"
29 #include "../MapProviderException.h"
30 #include "../../config/DatabaseConfig.h"
31 #include "../../graph/Edge.h"
32 #include "../../graph/Topology.h"
33 #include "../../graph/Vertex.h"
34 #include "../../graph/Speed.h"
35 #include "../../osm/OsmAccess.h"
36 #include "../../osm/OsmHighway.h"
37 #include "../../osm/OsmVehicle.h"
38 #include "../../util/TimeToStringMaker.h"
39 #include "LineGraphSaveQueries.h"
40
41 // FORWARD REFERENCES
42 //
43
44 /**
45  * A class to handle the reading of data from the PostGis database.
46  * The configurations for the connection is given.
47  */
48 class PostGisProvider : public MapProvider
49 {
50 public:
51 // LIFECYCLE
52
53 // ** Default constructor.
54 //
55 PostGisProvider() = delete;
56
```

```
57     /** Constructor.
58      * Establish connection to database.
59      *
60      * @param      rConfig          The configuration.
61      * @throws      MapProviderException    If connection could not be established.
62      */
63     PostGisProvider(const Configuration& rConfig);
64
65     /** Destructor.
66      * Close connection to database
67      */
68     virtual ~PostGisProvider();
69
70
71     // OPERATORS
72     // OPERATIONS
73     virtual void    getTopology(Topology& rTopology);
74
75     virtual void    setRestrictionsAndCosts(Topology& rTopology);
76
77     virtual void    persistLineGraph(const GraphBuilder& rGraph);
78
79     // INQUIRY
80
81     protected:
82
83     private:
84     // HELPERS
85
86     /** Get edges from database.
87      * @param      rEdgeResult    Result of db query for Edges.
88      * @throws      MapProviderException
89      */
90     void    getTopologyEdges(pqxx::result& rEdgeResult);
91
92     /** Add edges to topology.
93      * @param      rEdgeResult    Result of db query for edges.
94      * @param      rTopology      Topology to fill with edges.
95      * @throws      TopologyException
96      */
97     void    addEdgeResultToTopology(const pqxx::result& rEdgeResult,
98                                     Topology& rTopology);
99
100     /** Get vertices from database.
101      * @throws      MapProviderException
102      */
103     void    getTopologyVertices(pqxx::result& rVertexResult);
104
105     /** Add vertices to topology.
106      * @throws      TopologyException
107      */
108     void    addVertexResultToTopology(
109             const pqxx::result& rResult,
110             Topology& rTopology);
111
112     // Helpers for constructor
113     /** Set the base name for the topology, either a string from config
```

```
114     * or a timestamp.
115     */
116     void      setTopoBaseName(std::string& rTopoBaseName);
117
118     /** Build a PostGIS topology with name given in constructor.
119     * @param      srid          The SRID for the projection to use
120     * @param      tolerance      The distance to look for merging vertices, unit of srid.
121     * @throws      MapProviderException
122     */
123     void      buildTopology(int srid, double tolerance);
124
125     /** Remove PostGIS topology (tables and schema) from the database.
126     * @throws      MapProviderException
127     */
128     void      removeTopology();
129
130
131     // Restriction helpers -----
132
133     /** Add restrictions to edges.
134     * @param      rTopology      Adding EdgeRestriction to Edges in topology.
135     * @throw      MapProviderException
136     */
137     void      addEdgeRestrictions(Topology& rTopology);
138
139     /** Get VehicleProperty restrictions
140     * Helper for 'getEdgeRestrictions()'
141     * @param      rResult        Store the result of query in here.
142     * @throw      MapProviderException
143     */
144     void      getVehiclePropertyEdgeRestrictions(pqxx::result& rResult);
145
146     /** Add the result of the query for vehicle properties to Edge's restrictions.
147     * Helper for 'getEdgeRestrictions()'
148     * @param      rResult        The results of the query
149     * @param      rTopology      Update affected edges in the topology.
150     * @throw      MapProviderException
151     */
152     void      addVehiclePropertyRestrictionsToEdge(
153         const pqxx::result&      rResult,
154         Topology&                  rTopology);
155
156     /** Get Access restrictions to edge.
157     * Helper for 'getEdgeRestrictions()'
158     * @param      rResult        Store the result of query in here.
159     * @throw      MapProviderException
160     */
161     void      getAccessRestrictions(pqxx::result& rResult);
162
163     /** Add the result of the query for Access to restrictions.
164     * Helper for 'getEdgeRestrictions()'
165     * @param      rResult        The results of the query
166     * @param      rTopology      Update affected edges in the topology.
167     * @throw      MapProviderException
168     */
169     void      addAccessRestrictionsToEdge(
170         const pqxx::result&      rResult,
```



```
171         Topology&                rTopology);
172
173     /** Get Turning restrictions for traveling from edge.
174     * Helper for 'getEdgeRestrictions()'.
175     * Turning restrictions are relations and not easily handled with
176     * osm2pgsql. Therefore we must use 'slim' mode when converting OSM to
177     * PostGis, and use the table 'planet_osm_rels' and column 'tags' to look
178     * for a 'restriction'. If we find one we have to parse the 'members'
179     * column ourselves.
180     * @param   rResult      Store the result of query in here.
181     * @throw   MapProviderException
182     */
183     void    getTurningRestrictions(pqxx::result& rResult);
184
185     /** Add the result of the query for Turning restrictions.
186     * Helper for 'getEdgeRestrictions()'
187     * @param   rResult      The results of the query
188     * @param   rTopology    Update affected edges in the topology.
189     * @throw   MapProviderException
190     */
191     void    addTurningRestrictionsToEdge(
192             const pqxx::result&    rResult,
193             Topology&                rTopology);
194
195     /** Get restrictions defined at points but applicable to edges,
196     * such as barriers and railway crossings.
197     * @param   rResult      Store the result of query in here.
198     * @throw   MapProviderException
199     */
200     void    getEdgePointRestrictions(pqxx::result& rResult);
201
202     /** Add the result of the query for Point restrictions on Edges .
203     * Helper for 'getEdgeRestrictions()'
204     * @param   rResult      The results of the query
205     * @param   rTopology    Update affected edges in the topology.
206     * @throw   MapProviderException
207     */
208     void    addPointRestrictionsToEdge(
209             const pqxx::result&    rResult,
210             Topology&                rTopology);
211
212     // Costs -----
213     /** Add costs to the edge.
214     * @param   The Topology with Edges to add cost to.
215     */
216     void    addEdgeCosts(Topology& rTopology);
217
218     /** Get costs for the travel time along an edge.
219     * The length is constant in the topology but we need to find out if
220     * there is a max speed restriction or if there is a bad surface.
221     * If no such restrictions are in the database then the default speed
222     * for the road category is used.
223     * @param   rResult      Store the result of the query here.
224     * @throw   MapProviderException
225     */
226     void    getTravelTimeCosts(pqxx::result& rResult);
227
```

```
228     /** Add costs for travel time along the edge.
229     * First set the speed of those with explicit restrictions in database,
230     * then set the default speed for those without explicit speeds.
231     * @param   rResult      The results of the query.
232     * @param   rTopology    The topology with edges to set cost for.
233     * @throw   MapProviderException
234     */
235     void    addTravelTimeCosts(const pqxx::result& rResult, Topology& rTopology);
236
237     /** Get other costs for the edge other than speed and barriers, those
238     * include slowdown at stop and yield signs, zebra crossings, railway
239     * crossings, bus stops, speed bumps, traffic lights...
240     * @param   rResult      Store the result of the query here.
241     */
242     void    getOtherEdgeCosts(pqxx::result& rResult);
243
244     /** Add costs for speed bumps and such to affected edges.
245     * @param   rResult      The results of the query.
246     * @param   rTopology    The topology with edges to set cost for.
247     * @throw   MapProviderException
248     */
249     void    addOtherCosts(const pqxx::result& rResult, Topology& rTopology);
250
251     // LineGraph persistence -----
252     /** Set up the schema and tables needed to persist the line graph.
253     */
254     void    setUpSchemaAndTables();
255
256     /** Create a new schema in the database
257     * @throw   MapProviderException
258     */
259     void    createLineGraphSchema();
260
261     /** Create the needed tables in the database
262     * @throw   MapProviderException
263     */
264     void    createLineGraphTables();
265
266     /** Insert the data in the database.
267     * @param   rGraph       The graph with data.
268     * @throw   MapProviderException
269     */
270     void    insertData(const GraphBuilder& rGraph);
271
272     /** Prepare the LineGraph data for inserting into the database.
273     * @param   rTrans       The transaction to operate within.
274     * @param   rGraph       The graph data
275     * @throw   MapProviderException
276     */
277     void    prepareLineGraphData(
278         pqxx::transaction_base& rTrans,
279         const GraphBuilder&      rGraph);
280
281     // Generic helpers to clean up the code some -----
282     /** Check that the connection with the database is up, or throw exception.
283     * @throw   MapProviderException
284     */
```

```
285     void      testConnection();
286
287 // ATTRIBUTES
288     const Configuration&      mConfig;
289     const DatabaseConfig&      mDbConfig;
290     const TopologyConfig&      mTopoConfig;
291     pqxx::connection          mConnection;
292     std::string                mOsmEdgeTable;
293     std::string                mPointTableName;
294     std::string                mSchemaName;
295     std::string                mTopoEdgeTable;
296     std::string                mEdgeIdCol;
297     std::string                mSourceCol;
298     std::string                mTargetCol;
299     std::string                mEdgeGeomCol;
300     std::string                mTopoVertexTable;
301     std::string                mVertexIdCol;
302     std::string                mVertexGeomCol;
303     std::string                mLineGraphSchema;
304     std::string                mLineGraphNodeTable;
305     std::string                mLineGraphLineTable;
306
307 // CONSTANTS
308 };
309
310 // INLINE METHODS
311 //
312
313 // EXTERNAL REFERENCES
314 //
315
316 #endif /* MAPPROVIDER_POSTGIS_POSTGISPROVIDER_H_ */
```

D.11.3 PostGisProvider.cc

```
1  /*
2   * PostGisProvider.cc
3   *
4   * @author  Jonas Bergman
5   */
6
7  #include "PostGisProvider.h" // class implemented
8  #include "TopologyQueries.h"
9  #include "RestrictionQueries.h"
10 #include "CostQueries.h"
11
12 #include "../graph/Edge.h"
13 #include "../osm/OsmId.h"
14 #include "../graph/EdgeRestriction.h"
15 #include "../graph/EdgeCost.h"
16
17
18
19 ////////////////////////////////// PUBLIC //////////////////////////////////
20
21 //===== LIFECYCLE =====
22 PostGisProvider::PostGisProvider(const Configuration& rConfig)
```

```
23  try
24      : MapProvider(rConfig),
25        mConfig(rConfig),
26        mDbConfig(rConfig.getDatabaseConfig()),
27        mTopoConfig(rConfig.getTopologyConfig()),
28        mConnection(mDbConfig.getConnectionString())
29  {
30      try
31      {
32          testConnection();
33
34          std::string topoBaseName;
35          setTopoBaseName(topoBaseName);
36
37          if(topoBaseName == "")
38          {
39              throw MapProviderException("No topology specified.");
40          }
41
42          pqxx::nontransaction nt(mConnection);
43          mOsmEdgeTable      = nt.esc(mTopoConfig.roadsPrefix + "_" +
44                                     topoBaseName);
45          mPointTableName    = nt.esc("planet_osm_point");
46          mSchemaName        = nt.esc(mTopoConfig.topologySchemaPrefix + "_" +
47                                     topoBaseName);
48          mTopoEdgeTable     = nt.esc(mSchemaName + "." +
49                                     mTopoConfig.edgeTableName);
50          mEdgeIdCol         = nt.esc(mSchemaName + "." +
51                                     mTopoConfig.edgeIdColumnName);
52          mSourceCol         = nt.esc(mSchemaName + "." +
53                                     mTopoConfig.sourceColumnName);
54          mTargetCol         = nt.esc(mSchemaName + "." +
55                                     mTopoConfig.targetColumnName);
56          mEdgeGeomCol       = nt.esc(mSchemaName + "." +
57                                     mTopoConfig.edgeGeomColumnName);
58          mTopoVertexTable   = nt.esc(mSchemaName + "." +
59                                     mTopoConfig.vertexTableName);
60          mVertexIdCol       = nt.esc(mSchemaName + "." +
61                                     mTopoConfig.vertexIdColumnName);
62          mVertexGeomCol     = nt.esc(mSchemaName + "." +
63                                     mTopoConfig.vertexGeomColumnName);
64          mLineGraphSchema   = nt.esc("line_graph_generated");
65          mLineGraphNodeTable = nt.esc(mLineGraphSchema + ".node");
66          mLineGraphLineTable = nt.esc(mLineGraphSchema + ".line");
67          nt.abort();
68
69          if(mBuildTempTopology)
70          {
71              buildTopology(mTopoConfig.srid, mTopoConfig.tolerance);
72          }
73      }
74      catch(const std::exception& e)
75      {
76          throw MapProviderException(
77              std::string("PostGisProvider:ctor(in): ") + e.what());
78      }
79  }
```

```
80 // catch error in initializer list (opening connection)
81 catch(const std::exception& e)
82 {
83     throw MapProviderException(
84         std::string("PostGisProvider:ctor(out): ") + e.what());
85 }
86
87 PostGisProvider::~PostGisProvider()
88 {
89     try
90     {
91         if(mBuildTempTopology)
92         {
93             removeTopology();
94         }
95         if(mConnection.is_open())
96         {
97             mConnection.disconnect();
98         }
99     }
100     catch(const std::exception& e)
101     {
102         throw MapProviderException(
103             std::string("PostGisProvider:dtor: ") + e.what());
104     }
105 }
106
107 //===== OPERATORS =====
108
109 //===== OPERATIONS =====
110 void
111 PostGisProvider::getTopology(Topology& rTopology)
112 {
113     pqxx::result vertex_result;
114     getTopologyVertices(vertex_result);
115     addVertexResultToTopology(vertex_result, rTopology);
116
117     pqxx::result edge_result;
118     getTopologyEdges(edge_result);
119     addEdgeResultToTopology(edge_result, rTopology);
120 }
121
122 void
123 PostGisProvider::setRestrictionsAndCosts(Topology& rTopology)
124 {
125     addEdgeRestrictions(rTopology);
126     addEdgeCosts(rTopology);
127 }
128
129 void
130 PostGisProvider::persistLineGraph(const GraphBuilder& rGraph)
131 {
132     setUpSchemaAndTables();
133     insertData(rGraph);
134 }
135
136 //===== ACCESS =====
```

```
137 //===== INQUIRY =====
138 ////////////////////////////////// PROTECTED //////////////////////////////////
139 ////////////////////////////////// PRIVATE //////////////////////////////////
140 void
141 PostGisProvider::getTopologyVertices(pqxx::result& rVertexResult)
142 {
143     try
144     {
145         testConnection();
146
147         // NON-TRANSACTION START
148         pqxx::nontransaction transaction(mConnection);
149
150         TopologyQueries::getTopologyVertices(
151             transaction,
152             rVertexResult,
153             mTopoVertexTable);
154     }
155     catch(const std::exception& e)
156     {
157         throw MapProviderException(
158             std::string("PostGisProvider:getTopologyVertices: ") + e.what());
159     }
160 }
161
162 void
163 PostGisProvider::addVertexResultToTopology(
164     const pqxx::result& rResult,
165     Topology& rTopology)
166 {
167     TopologyQueries::addVertexResultToTopology(rResult, rTopology);
168 }
169
170
171 void
172 PostGisProvider::getTopologyEdges(pqxx::result& rEdgeResult)
173 {
174     try
175     {
176         testConnection();
177
178         // NON-TRANSACTION START
179         pqxx::nontransaction transaction(mConnection);
180
181         TopologyQueries::getTopologyEdges(
182             transaction,
183             rEdgeResult,
184             mTopoEdgeTable,
185             mSchemaName,
186             mOsmEdgeTable);
187     }
188     catch(const std::exception& e)
189     {
190         throw MapProviderException(
191             std::string("PostGisProvider:getTopoEdges: ") + e.what());
192     }
193 }
```

```
194
195 void
196 PostGisProvider::addEdgeResultToTopology(
197     const pqxx::result& rResult,
198     Topology&           rTopology)
199 {
200     TopologyQueries::addEdgeResultToTopology(rResult, rTopology);
201 }
202
203 void
204 PostGisProvider::buildTopology(int srid, double tolerance)
205 {
206     try
207     {
208         testConnection();
209
210         // TRANSACTION START
211         pqxx::work transaction(mConnection);
212
213         try
214         {
215             TopologyQueries::installPostgisTopology(transaction);
216             TopologyQueries::setSearchPath(transaction);
217             TopologyQueries::createTemporaryTable(transaction, mOsmEdgeTable);
218             TopologyQueries::createTemporarySchema(
219                 transaction, mSchemaName, srid);
220             TopologyQueries::addTopoGeometryColumn(
221                 transaction, mSchemaName, mOsmEdgeTable);
222             TopologyQueries::fillTopoGeometryColumn(
223                 transaction, mSchemaName, mOsmEdgeTable, tolerance);
224
225             // TRANSACTION END
226             transaction.commit();
227         }
228         catch (const std::exception& e)
229         {
230             transaction.abort();
231             throw e;
232         }
233     }
234     catch(const std::exception& e)
235     {
236         throw MapProviderException(
237             std::string("PostGisProvider:buildTopology: ") + e.what());
238     }
239 }
240
241
242 void
243 PostGisProvider::removeTopology()
244 {
245     try
246     {
247         testConnection();
248
249         // TRANSACTION START
250         pqxx::work transaction(mConnection);
```

```
251
252     try
253     {
254         TopologyQueries::dropTemporaryTable(transaction, mOsmEdgeTable);
255         TopologyQueries::dropTemporarySchema(transaction, mSchemaName);
256         TopologyQueries::deleteTemporaryLayerRecord(transaction, mOsmEdgeTable);
257         TopologyQueries::deleteTemporaryTopoRecord(transaction, mSchemaName);
258
259         // TRANSACTION END
260         transaction.commit();
261     }
262     catch (const std::exception& e)
263     {
264         transaction.abort();
265         throw e;
266     }
267 }
268 catch(const std::exception& e)
269 {
270     throw MapProviderException(std::string(
271         "PostGisProvider:removeTopology: ") + e.what());
272 }
273 }
274
275 void
276 PostGisProvider::setTopoBaseName(std::string& rTopoBaseName)
277 {
278     if(mTopoConfig.tempTopoName == TopologyConfig::TEMP_TOPO_NAMEBASE)
279     {
280         rTopoBaseName = TimeToStringMaker::getEpochMsTimeString();
281         mBuildTempTopology = true;
282     }
283     else
284     {
285         rTopoBaseName = mTopoConfig.topoName;
286     }
287 }
288
289 // Restrictions -----
290 void
291 PostGisProvider::addEdgeRestrictions(Topology& rTopology)
292 {
293     pqxx::result result;
294
295     getVehiclePropertyEdgeRestrictions(result);
296     addVehiclePropertyRestrictionsToEdge(result, rTopology);
297
298     result.clear();
299     getAccessRestrictions(result);
300     addAccessRestrictionsToEdge(result, rTopology);
301
302     result.clear();
303     getTurningRestrictions(result);
304     addTurningRestrictionsToEdge(result, rTopology);
305
306     result.clear();
307     getEdgePointRestrictions(result);
```



```
308     addPointRestrictionsToEdge(result, rTopology);
309 }
310
311 void
312 PostGisProvider::getVehiclePropertyEdgeRestrictions(pqxx::result& rResult)
313 {
314     try
315     {
316         testConnection();
317
318         // NON-TRANSACTION START
319         pqxx::nontransaction transaction(mConnection);
320
321         RestrictionQueries::getVehiclePropertyEdgeRestrictions(
322             transaction,
323             rResult,
324             mTopoEdgeTable,
325             mOsmEdgeTable,
326             mSchemaName
327         );
328     }
329     catch(const std::exception& e)
330     {
331         throw MapProviderException(
332             std::string("PostGisProvider:getVehiclePropertyEdgeRestrictions: ")
333                 + e.what());
334     }
335 }
336
337 void
338 PostGisProvider::addVehiclePropertyRestrictionsToEdge(
339     const pqxx::result& rResult,
340     Topology& rTopology)
341 {
342     RestrictionQueries::addVehiclePropertyRestrictionsToEdge(rResult, rTopology);
343 }
344
345 void
346 PostGisProvider::getAccessRestrictions(pqxx::result& rResult)
347 {
348     try
349     {
350         testConnection();
351
352         // NON-TRANSACTION START
353         pqxx::nontransaction transaction(mConnection);
354
355         RestrictionQueries::getAccessRestrictions(
356             transaction,
357             rResult,
358             mTopoEdgeTable,
359             mOsmEdgeTable,
360             mSchemaName);
361     }
362     catch(const std::exception& e)
363     {
364         throw MapProviderException(
```

```
365         std::string("PostGisProvider:getAccessRestrictions: ")
366         + e.what());
367     }
368 }
369
370 void
371 PostGisProvider::addAccessRestrictionsToEdge(
372     const pqxx::result& rResult,
373     Topology&          rTopology)
374 {
375     RestrictionQueries::addAccessRestrictionsToEdge(rResult, rTopology, mConfig);
376 }
377
378 void
379 PostGisProvider::getTurningRestrictions(pqxx::result& rResult)
380 {
381     try
382     {
383         testConnection();
384
385         // TRANSACTION START
386         pqxx::nontransaction transaction(mConnection);
387
388         try
389         {
390             RestrictionQueries::dropCreateTurningRestrictionsTable(transaction);
391             RestrictionQueries::identifyTurningRestrictions(
392                 transaction,
393                 mOsmEdgeTable,
394                 mTopoEdgeTable);
395             RestrictionQueries::getTurningRestrictions(transaction, rResult);
396         }
397         catch (const std::exception& e)
398         {
399             transaction.abort();
400             throw e;
401         }
402     }
403     catch(const std::exception& e)
404     {
405         throw MapProviderException(
406             std::string("PostGisProvider:getTurningRestrictions: ")
407             + e.what());
408     }
409 }
410
411 void
412 PostGisProvider::addTurningRestrictionsToEdge(
413     const pqxx::result& rResult,
414     Topology&          rTopology)
415 {
416     RestrictionQueries::addTurningRestrictionsToEdge(rResult, rTopology);
417 }
418
419 void
420 PostGisProvider::getEdgePointRestrictions(pqxx::result& rResult)
421 {
```

```
422     try
423     {
424         testConnection();
425
426         // NON-TRANSACTION START
427         pqxx::nontransaction transaction(mConnection);
428
429         RestrictionQueries::getEdgePointRestrictions(
430             transaction,
431             rResult,
432             mPointTableName,
433             mTopoEdgeTable,
434             mOsmEdgeTable,
435             mSchemaName);
436     }
437     catch(const std::exception& e)
438     {
439         throw MapProviderException(
440             std::string("PostGisProvider:getEdgePointRestrictions: ") + e.what());
441     }
442 }
443
444 void
445 PostGisProvider::addPointRestrictionsToEdge(
446     const pqxx::result&      rResult,
447     Topology&                rTopology)
448 {
449     RestrictionQueries::addPointRestrictionsToEdge(rResult, rTopology, mConfig);
450 }
451
452 // Costs -----
453 void
454 PostGisProvider::addEdgeCosts(Topology& rTopology)
455 {
456     pqxx::result result;
457
458     getTravelTimeCosts(result);
459     addTravelTimeCosts(result, rTopology);
460
461     // barrier costs are added while looking for restrictions
462
463     result.clear();
464     getOtherEdgeCosts(result);
465     addOtherCosts(result, rTopology);
466 }
467
468 void
469 PostGisProvider::getTravelTimeCosts(pqxx::result& rResult)
470 {
471     try
472     {
473         testConnection();
474
475         // NON-TRANSACTION START
476         pqxx::nontransaction transaction(mConnection);
477
478         CostQueries::getTravelTimeEdgeCosts(
```

```
479         transaction,
480         rResult,
481         mTopoEdgeTable,
482         mOsmEdgeTable,
483         mSchemaName
484     );
485 }
486 catch(const std::exception& e)
487 {
488     throw MapProviderException(
489         std::string("PostGisProvider:getTravelTimCost: ")
490             + e.what());
491 }
492 }
493
494 void
495 PostGisProvider::addTravelTimeCosts(
496     const pqxx::result& rResult,
497     Topology& rTopology)
498 {
499     CostQueries::addTravelTimeCosts(rResult, rTopology, mConfig);
500 }
501
502 void
503 PostGisProvider::getOtherEdgeCosts(pqxx::result& rResult)
504 {
505     try
506     {
507         testConnection();
508
509         // NON-TRANSACTION START
510         pqxx::nontransaction transaction(mConnection);
511
512         CostQueries::getOtherCosts(
513             transaction,
514             rResult,
515             mPointTableName,
516             mTopoEdgeTable,
517             mOsmEdgeTable,
518             mSchemaName);
519     }
520     catch(const std::exception& e)
521     {
522         throw MapProviderException(
523             std::string("PostGisProvider:getOtherEdgeCosts: ") + e.what());
524     }
525 }
526
527 void
528 PostGisProvider::addOtherCosts(
529     const pqxx::result& rResult,
530     Topology& rTopology)
531 {
532     CostQueries::addOtherCosts(rResult, rTopology, mConfig);
533 }
534
535 // LineGraph persistence -----
```

```
536 void
537 PostGisProvider::setUpSchemaAndTables()
538 {
539     createLineGraphSchema();
540     createLineGraphTables();
541 }
542
543 void
544 PostGisProvider::createLineGraphSchema()
545 {
546     try
547     {
548         testConnection();
549
550         // NON-TRANSACTION START
551         pqxx::nontransaction transaction(mConnection);
552
553         LineGraphSaveQueries::dropCreateSchema(transaction, mLineGraphSchema);
554     }
555     catch(const std::exception& e)
556     {
557         throw MapProviderException(
558             std::string("PostGisProvider:createLineGraphSchema: ") + e.what());
559     }
560 }
561
562 void
563 PostGisProvider::createLineGraphTables()
564 {
565     try
566     {
567         testConnection();
568
569         // NON-TRANSACTION START
570         pqxx::nontransaction transaction(mConnection);
571
572         LineGraphSaveQueries::dropCreateLineTable(transaction, mLineGraphLineTable);
573         LineGraphSaveQueries::dropCreateNodeTable(transaction, mLineGraphNodeTable);
574     }
575     catch(const std::exception& e)
576     {
577         throw MapProviderException(
578             std::string("PostGisProvider:createLineGraphTables: ") + e.what());
579     }
580 }
581
582 void
583 PostGisProvider::insertData(const GraphBuilder& rGraph)
584 {
585     try
586     {
587         testConnection();
588
589         pqxx::work transaction(mConnection);
590
591         try
592         {
```

```
593         prepareLineGraphData(transaction, rGraph);
594
595         // TRANSACTION END
596         transaction.commit();
597     }
598     catch (const std::exception& e)
599     {
600         transaction.abort();
601         throw e;
602     }
603 }
604 catch(const std::exception& e)
605 {
606     throw MapProviderException(
607         std::string("PostGisProvider:insertData: ") + e.what());
608 }
609 }
610
611 void
612 PostGisProvider::prepareLineGraphData(
613     pqxx::transaction_base& rTrans,
614     const GraphBuilder&      rGraph)
615 {
616     const LineGraphType& rLineGraph = rGraph.getBoostLineGraph();
617     const Topology&      rTopology  = rGraph.getTopology();
618
619     for(auto line_it = boost::edges(rLineGraph);
620         line_it.first != line_it.second;
621         ++line_it.first)
622     {
623         const LineType& line = *(line_it.first);
624
625         NodeIdType source_node_id = rLineGraph[line].lgSourceNodeId;
626         NodeIdType target_node_id = rLineGraph[line].lgTargetNodeId;
627
628         Cost cost = rLineGraph[line].cost;
629
630         const NodeType& source_node = rGraph.getLineGraphNode(source_node_id);
631         const NodeType& target_node = rGraph.getLineGraphNode(target_node_id);
632
633         EdgeIdType source_edge_id = rLineGraph[source_node].topoEdgeId;
634         EdgeIdType target_edge_id = rLineGraph[target_node].topoEdgeId;
635
636
637         const Edge& sourceEdge = rTopology.getEdge(source_edge_id);
638         const Edge& targetEdge = rTopology.getEdge(target_edge_id);
639
640         const Point& sourcePoint = sourceEdge.geomData().centerPoint;
641         const Point& targetPoint = targetEdge.geomData().centerPoint;
642
643         std::string sourceWKT = "POINT(" + std::to_string(sourcePoint.x) + " "
644                                 + std::to_string(sourcePoint.y) + ")";
645         std::string targetWKT = "POINT(" + std::to_string(targetPoint.x) + " "
646                                 + std::to_string(targetPoint.y) + ")";
647         std::string lineWKT = "LINESTRING(" + std::to_string(sourcePoint.x) + " " +
648                                std::to_string(sourcePoint.y) + ", " +
649                                std::to_string(targetPoint.x) + " " +
```

```
650         std::to_string(targetPoint.y) + ")";
651
652     LineGraphSaveQueries::insertNode(
653         rTrans,
654         mLineGraphNodeTable,
655         source_edge_id,
656         sourceWKT);
657
658     LineGraphSaveQueries::insertNode(
659         rTrans,
660         mLineGraphNodeTable,
661         target_edge_id,
662         targetWKT);
663
664     LineGraphSaveQueries::insertLine(
665         rTrans,
666         mLineGraphLineTable,
667         cost,
668         lineWKT);
669 }
670 }
671
672 void
673 PostGisProvider::testConnection()
674 {
675     if(!mConnection.is_open())
676     {
677         throw MapProviderException(
678             std::string("Could not open ") + mDbConfig.database);
679     }
680 }
```

D.11.4 CostQueries.h

```
1  /** Queries for PostGisProvider to find costs.
2   *
3   * #include "CostQueries.h"
4   *
5   * @author Jonas Bergman
6   */
7  #ifndef MAPPROVIDER_POSTGIS_COSTQUERIES_H_
8  #define MAPPROVIDER_POSTGIS_COSTQUERIES_H_
9
10 // SYSTEM INCLUDES
11 //
12 #include <string>
13 #include <sstream>
14 #include <vector>
15
16 // PROJECT INCLUDES
17 //
18 #include <boost/algorithm/string.hpp>
19 #include <pqxx/pqxx>
20
21 // LOCAL INCLUDES
22 //
23 #include "../osm/OsmHighway.h"
```

```
24 #include "../graph/Edge.h"
25 #include "../graph/EdgeRestriction.h"
26 #include "../graph/Topology.h"
27 #include "../graph/Vertex.h"
28 #include "../MapProviderException.h"
29
30 /** Class for holding static queries about costs,
31  * needed by the PostGisProvider.
32  */
33 class CostQueries
34 {
35 public:
36 // TYPES
37
38     struct TravelTimeCostResult
39     {
40         enum Columns
41         {
42             EDGE_ID,
43             ELEMENT_ID,
44             MAXSPEED,
45             SURFACE
46         };
47     };
48
49     struct OtherCostResult
50     {
51         enum Columns
52         {
53             OSM_ID,
54             HIGHWAY,
55             RAILWAY,
56             PUBLIC_TRANSPORT,
57             TRAFFIC_CALMING,
58             EDGE_ID
59         };
60     };
61
62 // LIFECYCLE
63     CostQueries() = delete;
64     CostQueries(const CostQueries& from) = delete;
65     ~CostQueries() = default;
66
67 // OPERATORS
68 // OPERATIONS
69     /** Query for costs for travel time, meaning we need to find the speed.
70      * @param rTrans Transaction to perform query in.
71      * @param rResult Store the result of query here.
72      * @param rTopoEdgeTable Name of table with topology edges.
73      * @param rOsmEdgeTable Name of table with OSM edges.
74      * @param rSchemaName Name of the topology schema.
75      * @throw pqxx::pqxx_exception
76      */
77     static void getTravelTimeEdgeCosts(
78         pqxx::transaction_base& rTrans,
79         pqxx::result& rResult,
80         const std::string& rTopoEdgeTable,
```



```
81         const std::string&      rOsmEdgeTable,
82         const std::string&      rSchemaName);
83
84     /** Add costs for travel time along the edge.
85     * First set the speed of those with explicit restrictions in database,
86     * then set the default speed for those without explicit speeds.
87     * @param rResult      The results of the query.
88     * @param rTopology    The topology with edges to set cost for.
89     * @param rConfig      Configuration
90     * @throw MapProviderException
91     */
92     static void      addTravelTimeCosts(
93         const pqxx::result&      rResult,
94         Topology&                rTopology,
95         const Configuration&      rConfig);
96
97     /** Add cost relating to the maxspeed of the edge.
98     * The cost is the number of seconds to travel the edge.
99     * @param rEdge        The edge to add cost to
100    * @param speed         The speed for the edge found in the database.
101    * @param surfaceString The surface as string or empty if not specified.
102    * @param rConfig       Configuration
103    * @throw MapProviderException
104    */
105    static void      addTravelTimeCostToEdge(
106        Edge&         rEdge,
107        Speed         speed,
108        std::string&   surfaceString,
109        const Configuration& rConfig);
110
111    /** If the speed in the db was not set we must fetch the default
112    * for this road category from the configuration.
113    * @param rEdge The edge to find the default speed for
114    * @param rConfig Configuration
115    * @return The default speed for this type of highway.
116    */
117    static Speed      getDefaultSpeedForEdge(
118        const Edge&      rEdge,
119        const Configuration& rConfig);
120
121    /** Query for costs under the highway and railway tags:
122    * Highway:
123    * - bus_stop
124    * - crossing
125    * - give_way
126    * - mini_roundabout
127    * - stop
128    * - traffic_signals
129    * Railway:
130    * - level_crossing
131    * Traffic calming
132    *
133    * @param rTrans      Transaction to perform query in
134    * @param rResult      Store the result of the query here
135    * @param rOsmPointTable Name of table with OSM points (nodes)
136    * @param rTopoEdgeTable Name of table with topology edges.
137    * @param rOsmEdgeTable Name of table with OSM edges.
```

```
138     * @param   rSchemaName   The name of the schema with topology info.
139     */
140     static void   getOtherCosts(
141         pqxx::transaction_base&    rTrans,
142         pqxx::result&              rResult,
143         const std::string&         rOsmPointTable,
144         const std::string&         rTopoEdgeTable,
145         const std::string&         rOsmEdgeTable,
146         const std::string&         rSchemaName);
147
148     /** Add costs for speed bumps and such to affected edges.
149     * @param   rResult       The results of the query.
150     * @param   rTopology     The topology with edges to set cost for.
151     * @param   rConfig       The Configuration
152     * @throw   MapProviderException
153     */
154     static void   addOtherCosts(
155         const pqxx::result&         rResult,
156         Topology&                  rTopology,
157         const Configuration&        rConfig);
158
159     /** Add a cost of an other type to the edge.
160     * Look up the value in the configuration.
161     * @param   rEdge   The Edge to add a cost to.
162     * @param   key     The type of cost as a string
163     * @param   rConfig The Configuration
164     */
165     static void   addOtherCostToEdge(
166         Edge&      rEdge,
167         const std::string& key,
168         const Configuration& rConfig);
169
170     /** While looking for restrictions and we come across barriers,
171     * add the costs for barriers if they incur costs.
172     * @param   edge   The edge with a barrier.
173     * @param   type   The type of barrier.
174     * @param   rConfig The Configuration to use for the cost.
175     */
176     static void   addBarrierCostToEdge(
177         Edge&      rEdge,
178         OsmBarrier::BarrierType type,
179         const Configuration& rConfig);
180
181     // ACCESS
182     // INQUIRY
183
184     protected:
185     private:
186         /** SELECT FROM JOIN */
187         static std::string startOfQuery(const std::string& rTopoEdgeTable);
188
189         /** Which columns to pick */
190         static std::string queryColumns(const std::vector<std::string>& rCols);
191
192         /** FROM JOIN ON WHERE */
193         static std::string midOfQuery(
194             const std::string& rSchemaName,
```

```
195         const std::string& rOsmEdgeTable);
196
197     /** Make sure only to pick rows with content in some column. */
198     static std::string notNullColumns(const std::vector<std::string>& rCols);
199
200     /** AS ON ORDER BY */
201     static std::string endOfQuery();
202 };
203
204 #endif /* MAPPROVIDER_POSTGIS_COSTQUERIES_H_ */
```

D.11.5 CostQueries.cc

```
1  /*
2   * CostQueries.cc
3   *
4   * @author Jonas Bergman
5   */
6
7  #include "CostQueries.h" // class implemented
8
9  ////////////////////////////////// PUBLIC //////////////////////////////////
10
11  //===== LIFECYCLE =====
12  //===== OPERATORS =====
13  //===== OPERATIONS =====
14  //static
15  void
16  CostQueries::getTravelTimeEdgeCosts(
17      pqxx::transaction_base& rTrans,
18      pqxx::result&           rResult,
19      const std::string&      rTopoEdgeTable,
20      const std::string&      rOsmEdgeTable,
21      const std::string&      rSchemaName)
22  {
23      std::vector<std::string> columns {
24          "maxspeed",
25          "surface"
26      };
27
28      rResult = rTrans.exec(
29          startOfQuery(rTopoEdgeTable) +
30          queryColumns(columns) +
31          midOfQuery(rSchemaName, rOsmEdgeTable) +
32          //      notNullColumns(columns) +
33          endOfQuery()
34      );
35  }
36
37  // static
38  void
39  CostQueries::addTravelTimeCosts(
40      const pqxx::result&      rResult,
41      Topology&                rTopology,
42      const Configuration&     rConfig)
43  {
44      try
```

```
45     {
46         for(const pqxx::tuple& row : rResult)
47         {
48             // throw exception if no edgeId
49             EdgeIdType edgeId =
50                 row[TravelTimeCostResult::EDGE_ID].as<EdgeIdType>();
51
52             Edge& edge = rTopology.getEdge(edgeId);
53
54             Speed speed =
55                 row[TravelTimeCostResult::MAXSPEED].as<Speed>(
56                     EdgeRestriction::VehicleProperties::DEFAULT_SPEED_MAX);
57             std::string surface_string =
58                 row[TravelTimeCostResult::SURFACE].as<std::string>("");
59
60             addTravelTimeCostToEdge(edge, speed, surface_string, rConfig);
61         }
62     }
63     catch (std::exception& e)
64     {
65         throw MapProviderException(
66             std::string("PostGisProvider:addTravelTimeCost: ") + e.what());
67     }
68 }
69
70 //static
71 void
72 CostQueries::addTravelTimeCostToEdge(
73     Edge&                rEdge,
74     Speed                speed,
75     std::string&         surfaceString,
76     const Configuration& rConfig)
77 {
78     bool hasMaxSpeed =
79         (speed != EdgeRestriction::VehicleProperties::DEFAULT_SPEED_MAX);
80     bool hasSurface = surfaceString.length() > 0;
81     if(!(hasMaxSpeed || hasSurface))
82     {
83         speed = getDefaultSpeedForEdge(rEdge, rConfig);
84     }
85     // look if surface restricts speed
86     else if(hasSurface)
87     {
88         try
89         {
90             OsmHighway::SurfaceType surface =
91                 OsmHighway::parseSurfaceString(surfaceString);
92             Speed surfaceSpeed =
93                 rConfig.getCostConfig().surfaceMaxSpeed.getSurfaceMaxSpeed(surface);
94             if(surfaceSpeed < speed)
95             {
96                 speed = surfaceSpeed;
97             }
98         }
99         catch (OsmException& e)
100         {
101             throw MapProviderException(
```

```
102         std::string("CostQueries:addTravelTime... ") +
103         "could not parse surface " + surfaceString);
104     }
105 }
106 double speed_mps = speed / 3.6;
107 double travel_time = rEdge.geomData().length/ speed_mps;
108 rEdge.edgeCost().addCost(EdgeCost::TRAVEL_TIME, travel_time);
109 rEdge.setSpeed(speed);
110 }
111
112 // static
113 Speed
114 CostQueries::getDefaultSpeedForEdge(
115     const Edge&          rEdge,
116     const Configuration& rConfig)
117 {
118     OsmHighway::HighwayType type = rEdge.roadData().roadType;
119     const CostConfig& costConfig = rConfig.getCostConfig();
120     Speed speed=
121         costConfig.defaultSpeed.getDefaultSpeed(type, CostConfig::DefaultSpeed::LOW);
122     return speed;
123 }
124
125 // static
126 void
127 CostQueries::getOtherCosts(
128     pqxx::transaction_base& rTrans,
129     pqxx::result&           rResult,
130     const std::string&      rOsmPointTable,
131     const std::string&      rTopoEdgeTable,
132     const std::string&      rOsmEdgeTable,
133     const std::string&      rSchemaName)
134 {
135     rResult = rTrans.exec(
136         "SELECT p.osm_id, "
137         "       p.highway, "
138         "       p.railway, "
139         "       p.public_transport, "
140         "       p.traffic_calming, "
141         "       t.edge_id "
142         "FROM " + rOsmPointTable + " p, "
143         "      " + rTopoEdgeTable + " t, "
144         "      " + rOsmEdgeTable + " o, "
145         "      " + rSchemaName + ".relation r "
146         "WHERE r.topogeo_id = (topo_geom).id "
147         "AND   r.element_id = t.edge_id "
148         "AND   (p.highway = 'bus_stop' OR "
149         "       p.highway = 'crossing' OR "
150         "       p.highway = 'give_way' OR"
151         "       p.highway = 'mini_roundabout' OR"
152         "       p.highway = 'stop' OR"
153         "       p.highway = 'traffic_signals' OR"
154         "       p.railway = 'level_crossing' OR"
155         "       p.public_transport = 'stop_position' OR"
156         "       p.traffic_calming = 'yes' OR"
157         "       p.traffic_calming = 'bump' OR"
158         "       p.traffic_calming = 'hump' OR"
```

```
159         "        p.traffic_calming = 'table' OR"
160         "        p.traffic_calming = 'cushion' OR"
161         "        p.traffic_calming = 'rumble_strip' OR"
162         "        p.traffic_calming = 'chicane' OR"
163         "        p.traffic_calming = 'choker' OR"
164         "        p.traffic_calming = 'island' "
165         ") "
166         "AND    ST_Intersects(p.way, t.geom) "
167         "AND    o.highway IN " + OsmHighway::typesAsCommaSeparatedString()
168     );
169 }
170
171 // static
172 void
173 CostQueries::addOtherCosts(
174     const pqxx::result&      rResult,
175     Topology&                rTopology,
176     const Configuration&     rConfig)
177 {
178     try
179     {
180         for(const pqxx::tuple& row : rResult)
181         {
182             // throw exception if no edgeId
183             EdgeIdType edgeId =
184                 row[OtherCostResult::EDGE_ID].as<EdgeIdType>();
185
186             Edge& edge = rTopology.getEdge(edgeId);
187
188             std::string type_string = "highway=" +
189                 row[OtherCostResult::HIGHWAY].as<std::string>("");
190             addOtherCostToEdge(edge, type_string, rConfig);
191
192             type_string = "railway=" +
193                 row[OtherCostResult::RAILWAY].as<std::string>("");
194             addOtherCostToEdge(edge, type_string, rConfig);
195
196             type_string = "public_transport=" +
197                 row[OtherCostResult::PUBLIC_TRANSPORT].as<std::string>("");
198             addOtherCostToEdge(edge, type_string, rConfig);
199
200             type_string = "traffic_calming=" +
201                 row[OtherCostResult::TRAFFIC_CALMING].as<std::string>("");
202             addOtherCostToEdge(edge, type_string, rConfig);
203         }
204     }
205     catch (std::exception& e)
206     {
207         throw MapProviderException(
208             std::string("CostQueries::addOtherCosts... ") + e.what());
209     }
210 }
211
212 // static
213 void
214 CostQueries::addOtherCostToEdge(
215     Edge&                rEdge,
```

```
216     const std::string&      key,  
217     const Configuration&    rConfig)  
218 {  
219     size_t eq_char = key.find('=');  
220     if((eq_char == std::string::npos) || (eq_char == key.length() - 1))  
221     {  
222         return;  
223     }  
224  
225     Cost cost = rConfig.getCostConfig().otherEdgeCosts.getOtherCost(key);  
226     rEdge.edgeCost().addCost(EdgeCost::OTHER, cost);  
227 }  
228  
229 // static  
230 void  
231 CostQueries::addBarrierCostToEdge(  
232     Edge&                rEdge,  
233     OsmBarrier::BarrierType type,  
234     const Configuration& rConfig)  
235 {  
236     if(rConfig.getBarrierCostsRule().costsToPass(type))  
237     {  
238         Cost cost = rConfig.getBarrierCostsRule().getCost(type);  
239         rEdge.edgeCost().addCost(EdgeCost::BARRIER, cost);  
240     }  
241 }  
242  
243 //===== ACCESS =====  
244 //===== INQUIRY =====  
245 /////////////// PROTECTED ///////////  
246 /////////////// PRIVATE  ///////////  
247 //static  
248 std::string  
249 CostQueries::startOfQuery(const std::string& rTopoEdgeTable)  
250 {  
251     return (  
252         "SELECT      edge_id, "  
253         "-- osm data about original edge  
254         "          osm.* "  
255         "FROM        " + rTopoEdgeTable +  
256         " JOIN ( "  
257         "   SELECT element_id "  
258     );  
259 }  
260  
261 //static  
262 std::string  
263 CostQueries::queryColumns(const std::vector<std::string>& rCols)  
264 {  
265     std::ostringstream oss;  
266     for(const std::string& col : rCols)  
267     {  
268         oss << ", " << col;  
269     }  
270     return oss.str();  
271 }  
272
```

```
273 //static
274 std::string
275 CostQueries::midOfQuery(
276     const std::string& rSchemaName,
277     const std::string& rOsmEdgeTable)
278 {
279     return (
280         " FROM " + rSchemaName + ".relation "
281         " JOIN " + rOsmEdgeTable +
282         " ON topogeo_id = (topo_geom).id "
283         " WHERE highway in " + OsmHighway::typesAsCommaSeparatedString()
284     );
285 }
286
287 //static
288 std::string
289 CostQueries::notNullColumns(const std::vector<std::string>& rCols)
290 {
291     std::ostringstream oss;
292     oss << " AND ";
293     size_t i = 0;
294     for(const std::string& col : rCols)
295     {
296         oss << col << " IS NOT NULL ";
297         if(i < (rCols.size() - 1))
298         {
299             oss << " OR ";
300         }
301         ++i;
302     }
303     oss << ") ";
304     return oss.str();
305 }
306
307 //static
308 std::string
309 CostQueries::endOfQuery()
310 {
311     return (
312         ") AS osm "
313         "ON edge_id = element_id "
314         "ORDER BY edge_id ASC;"
315     );
316 }
```

D.11.6 LineGraphSaveQueries.h

```
1 /** Queries for saving the LineGraph to database
2  *
3  * #include "LineGraphSaveQueries.h"
4  *
5  * @author Jonas Bergman
6  */
7
8 #ifndef MAPPROVIDER_POSTGIS_LINEGRAPHSERVEQUERIES_H_
9 #define MAPPROVIDER_POSTGIS_LINEGRAPHSERVEQUERIES_H_
10
```



```
11 // SYSTEM INCLUDES
12 //
13 #include <string>
14 #include <sstream>
15 #include <vector>
16
17 // PROJECT INCLUDES
18 //
19 #include <boost/algorithm/string.hpp>
20 #include <pqxx/pqxx>
21
22 // LOCAL INCLUDES
23 //
24 #include "../..graph/GraphBuilder.h"
25 #include "../..graph/Topology.h"
26
27 /** Class for holding static queries for saving the line graph to database
28  */
29 class LineGraphSaveQueries
30 {
31 public:
32 // TYPES
33
34 // LIFECYCLE
35     LineGraphSaveQueries() = delete;
36     LineGraphSaveQueries(const LineGraphSaveQueries& from) = delete;
37     ~LineGraphSaveQueries() = default;
38
39 // OPERATORS
40 // OPERATIONS
41
42     /** Create a new schema, dropping any existing with the same name first.
43      * @param rTrans Transaction to perform the query in.
44      * @param rSchemaName Name of the schema to create.
45      * @throw pqxx::pqxx_exception
46      */
47     static void dropCreateSchema(
48         pqxx::transaction_base& rTrans,
49         const std::string& rSchemaName);
50
51     /** Create a new table for lines, dropping any existing with the same name.
52      * @param rTrans Transaction to perform the query in.
53      * @param rTableName Name of the table to create.
54      * @throw pqxx::pqxx_exception
55      */
56     static void dropCreateLineTable(
57         pqxx::transaction_base& rTrans,
58         const std::string& rTableName);
59
60     /** Create a new table for nodes, dropping any existing with the same name.
61      * @param rTrans Transaction to perform the query in.
62      * @param rTableName Name of the table to create.
63      * @throw pqxx::pqxx_exception
64      */
65     static void dropCreateNodeTable(
66         pqxx::transaction_base& rTrans,
67         const std::string& rTableName);
```

```
68
69  /** Insert a node into the database
70   * @param rTrans Transaction to perform the query in.
71   * @param id The id of the node's corresponding edge in the topology.
72   * @param rGeomString WKT (well-known text) representation of the node
73   * @throw pqxx::pqxx_exception
74   */
75  static void insertNode(
76      pqxx::transaction_base& rTrans,
77      const std::string& rTableName,
78      EdgeIdType id,
79      const std::string& rGeomString);
80
81  /** Insert a line into the database
82   * @param rTrans Transaction to perform the query in.
83   * @param cost The cost of traveling the edge
84   * @param rGeomString WKT (well-known text) representation of the line
85   * @throw pqxx::pqxx_exception
86   */
87  static void insertLine(
88      pqxx::transaction_base& rTrans,
89      const std::string& rTableName,
90      Cost cost,
91      const std::string& rGeomString);
92
93  // ACCESS
94  // INQUIRY
95
96  protected:
97  private:
98  };
99
100 #endif /* MAPPROVIDER_POSTGIS_LINEGRAPHSAVEQUERIES_H_ */
```

D.11.7 LineGraphSaveQueries.cc

```
1  /*
2   * LineGraphSaveQueries.cc
3   *
4   * @author Jonas Bergman
5   */
6
7  #include "LineGraphSaveQueries.h"
8
9  ////////////////////////////////// PUBLIC //////////////////////////////////
10
11  //===== LIFECYCLE =====
12  //===== OPERATORS =====
13  //===== OPERATIONS =====
14  //static
15  void
16  LineGraphSaveQueries::dropCreateSchema(
17      pqxx::transaction_base& rTrans,
18      const std::string& rSchemaName)
19  {
20      rTrans.exec(
21          "DROP SCHEMA IF EXISTS " + rSchemaName + " CASCADE; "
```

```
22         "CREATE SCHEMA " + rSchemaName
23     );
24 }
25
26 //static
27 void
28 LineGraphSaveQueries::dropCreateLineTable(
29     pqxx::transaction_base& rTrans,
30     const std::string&      rTableName)
31 {
32     rTrans.exec(
33         "DROP TABLE IF EXISTS " + rTableName + " CASCADE; "
34         "CREATE TABLE " + rTableName + " ( "
35         "    cost      double precision, "
36         "    geom      geometry(LineString, 900913) "
37         "); "
38     );
39 }
40
41 //static
42 void
43 LineGraphSaveQueries::dropCreateNodeTable(
44     pqxx::transaction_base& rTrans,
45     const std::string&      rTableName)
46 {
47     rTrans.exec(
48         "DROP TABLE IF EXISTS " + rTableName + " CASCADE; "
49         "CREATE TABLE " + rTableName + " ( "
50         "    topo_id  bigint unique, "
51         "    geom      geometry(Point, 900913) "
52         "); "
53     );
54 }
55
56 //static
57 void
58 LineGraphSaveQueries::insertNode(
59     pqxx::transaction_base& rTrans,
60     const std::string&      rTableName,
61     EdgeIdType              id,
62     const std::string&      rGeomString)
63 {
64
65     rTrans.exec(
66         "INSERT INTO " + rTableName + " (topo_id, geom) "
67         "SELECT " + std::to_string(id) +
68         ", ST_GeomFromText(' " + rGeomString + "', 900913) "
69         "WHERE NOT EXISTS ( "
70         "    SELECT topo_id FROM " + rTableName +
71         "    WHERE topo_id = " + std::to_string(id) + " );"
72     );
73 }
74
75 //static
76 void
77 LineGraphSaveQueries::insertLine(
78     pqxx::transaction_base& rTrans,
```

```

79     const std::string&      rTableName,
80     Cost                    cost,
81     const std::string&      rGeomString)
82 {
83     rTrans.exec(
84         "INSERT INTO " + rTableName + " (cost, geom) "
85         "VALUES (" + std::to_string(cost) +
86         ", ST_GeomFromText('" + rGeomString + "', 900913)); "
87     );
88 }
89 //===== ACCESS =====
90 //===== INQUIRY =====
91 ////////////////////////////////// PROTECTED //////////////////////////////////
92 ////////////////////////////////// PRIVATE //////////////////////////////////

```

D.11.8 RestrictionQueries.h

```

1  /** Queries for PostGisProvider to find restrictions.
2   *
3   * #include "RestrictionQueries.h"
4   *
5   * @author Jonas Bergman
6   */
7
8  #ifndef MAPPROVIDER_POSTGIS_RESTRICTIONQUERIES_H_
9  #define MAPPROVIDER_POSTGIS_RESTRICTIONQUERIES_H_
10
11 // SYSTEM INCLUDES
12 //
13 #include <string>
14 #include <sstream>
15 #include <vector>
16
17 // PROJECT INCLUDES
18 //
19 #include <boost/algorithm/string.hpp>
20 #include <pqxx/pqxx>
21
22 // LOCAL INCLUDES
23 //
24 #include "CostQueries.h"
25 #include "../osm/OsmHighway.h"
26 #include "../osm/OsmTurningRestriction.h"
27 #include "../graph/Edge.h"
28 #include "../graph/EdgeRestriction.h"
29 #include "../graph/Topology.h"
30 #include "../graph/Vertex.h"
31 #include "../MapProviderException.h"
32
33 /** Class for holding static queries about restrictions,
34  * needed by the PostGisProvider.
35  */
36 class RestrictionQueries
37 {
38 public:
39     // TYPES
40

```

```
41  /** Columns used in query for Vehicle Properties restrictions. */
42  struct VehiclePropertiesRestrictions
43  {
44      enum Columns
45      {
46          EDGE_ID,
47          ELEMENT_ID,
48          MAXHEIGHT,
49          MAXLENGTH,
50          MAXWEIGHT,
51          MAXWIDTH,
52          MAXSPEED,
53          MINSPEED,
54      };
55  };
56
57  /** Columns used in query for Access restrictions. */
58  struct AccessRestrictions
59  {
60      enum Columns
61      {
62          EDGE_ID,
63          ELEMENT_ID,
64          ACCESS,
65          BARRIER,
66          DISUSED,
67          NOEXIT,
68          MOTORCAR,
69          GOODS,
70          HGV,
71          PSV,
72          LHV,
73          MOTOR_VEHICLE,
74          VEHICLE,
75      };
76  };
77
78  /** Columns used in query for Turning restrictions. */
79  struct TurningRestrictions
80  {
81      enum Columns
82      {
83          FROM_OSM_ID,
84          TO_OSM_ID,
85          VIA_OSM,
86          EDGE_IDS,
87          RESTRICTION_TYPE
88      };
89
90  /** Results from queries are handled by these functions. */
91  struct Results
92  {
93      /** Parse a row in the results from turning restrictions.
94       * @param rRow      The row with results.
95       * @param rTopology The topology that needs to be queried.
96       * @return A turning restriction object.
97       * @throw pqxx::pqxx_exception
```

```

98         * @throw    TopologyException
99         * @throw    MapProviderException
100        */
101        static OsmTurningRestriction* parseTurningRestrictionResultRow(
102            const pqxx::tuple&    rRow,
103            Topology&              rTopology);
104
105
106        /** Try to parse the column 'edge_ids' from the 'turning_restrictions'.
107         * Split the string of edge ids and convert them to a vector of EdgeIds.
108         * @param    rEdgeIds    A string like "{123, 456}". Gets trimmed of {}.
109         * @return    A vector of the EdgeIds separately.
110         * @throw    std::invalid_argument
111         * @throw    std::out_of_range
112        */
113        static std::vector<EdgeIdType> parseEdgeIdsString(
114            std::string& rEdgeIds);
115
116        /** Find the Edge that matches the OsmId in turning restriction.
117         * @param    osmId        The original edge osm id.
118         * @param    rEdgeIds     The candidate edges that are near restriction.
119         * @param    rTopology    The Topology to ask for edges.
120        */
121        static Edge& findEdgeMatchingOsmId(
122            OsmIdType                osmId,
123            const std::vector<EdgeIdType>& rEdgeIds,
124            Topology&                  rTopology);
125    };
126};
127
128/** Columns used in query for EdgePoint restrictions. */
129struct EdgePointRestrictions
130{
131    enum Columns
132    {
133        POINT_OSM_ID,
134        BARRIER,
135        ACCESS,
136        GOODS,
137        HGV,
138        LHV,
139        MOTORCAR,
140        MOTOR_VEHICLE,
141        PSV,
142        VEHICLE,
143        EDGE_ID,
144    };
145};
146
147
148// LIFECYCLE
149RestrictionQueries() = delete;
150RestrictionQueries(const RestrictionQueries& from) = delete;
151~RestrictionQueries() = default;
152
153// OPERATORS
154// OPERATIONS
```

```
155     /** Query for restrictions based on Vehicle Properties.
156     * @param rTrans Transaction to perform query in.
157     * @param rResult Store the result of query here.
158     * @param rTopoEdgeTable Name of table with topology edges.
159     * @param rOsmEdgeTable Name of table with OSM edges.
160     * @param rSchemaName Name of the topology schema.
161     * @throw pqxx::pqxx_exception
162     */
163     static void getVehiclePropertyEdgeRestrictions(
164         pqxx::transaction_base& rTrans,
165         pqxx::result& rResult,
166         const std::string& rTopoEdgeTable,
167         const std::string& rOsmEdgeTable,
168         const std::string& rSchemaName);
169
170     /** Add the result of the query for vehicle properties to Edge's restrictions.
171     * @param rResult The results of the query
172     * @param rTopology Update affected edges in the topology.
173     * @throw MapProviderException
174     */
175     static void addVehiclePropertyRestrictionsToEdge(
176         const pqxx::result& rResult,
177         Topology& rTopology);
178
179     /** Query for general access restrictions.
180     * @param rTrans Transaction to perform query in.
181     * @param rResult Store the result of query here.
182     * @param rTopoEdgeTable Name of table with topology edges.
183     * @param rOsmEdgeTable Name of table with OSM edges.
184     * @param rSchemaName Name of the topology schema.
185     * @throw pqxx::pqxx_exception
186     */
187     static void getAccessRestrictions(
188         pqxx::transaction_base& rTrans,
189         pqxx::result& rResult,
190         const std::string& rTopoEdgeTable,
191         const std::string& rOsmEdgeTable,
192         const std::string& rSchemaName);
193
194     /** Add the result of the query for Access to restrictions.
195     * @param rResult The results of the query
196     * @param rTopology Update affected edges in the topology.
197     * @param rConfig Configuration
198     * @throw MapProviderException
199     */
200     static void addAccessRestrictionsToEdge(
201         const pqxx::result& rResult,
202         Topology& rTopology,
203         const Configuration& rConfig);
204
205     /** Drop and create the table 'turning_restrictions'.
206     * @param rTrans Transaction to perform query in.
207     * @throw pqxx::pqxx_exception
208     */
209     static void dropCreateTurningRestrictionsTable(
210         pqxx::transaction_base& rTrans);
211
```

```
212     /** Populate the table 'turning_restrictions'.
213     * @param rTrans      The transaction to execute within.
214     * @param rOsmEdgeTable The name of the table with original osm edges.
215     * @param rTopoEdgeTable The name of the table with topology edges.
216     * @throw pqxx::pqxx_exception
217     */
218     static void      identifyTurningRestrictions(
219         pqxx::transaction_base& rTrans,
220         const std::string&      rOsmEdgeTable,
221         const std::string&      rTopoEdgeTable);
222
223     /** Get the restrictions from the 'turning_restrictions' table.
224     * @param rTrans      Transaction to perform query in.
225     * @param rResult      Store the result of query here.
226     * @throw pqxx::pqxx_exception
227     */
228     static void      getTurningRestrictions(
229         pqxx::transaction_base& rTrans,
230         pqxx::result&          rResult);
231
232     /** Add the result of the query for Turning restrictions.
233     * @param rResult      The results of the query
234     * @param rTopology      Update affected edges in the topology.
235     * @throw MapProviderException
236     */
237     static void      addTurningRestrictionsToEdge(
238         const pqxx::result&      rResult,
239         Topology&                rTopology);
240
241     /** Get the restrictions from the 'planet_osm_point' that relates to edges.
242     * @param rTrans      Transaction to perform query in.
243     * @param rResult      Store the result of query here.
244     * @param rOsmPointTabl The name of the table with original osm points.
245     * @param rTopoEdgeTable The name of the table with topology edges.
246     * @param rOsmEdgeTable The name of the table with OSM edges.
247     * @param rSchemaName The name of the schema with topology info.
248     * @throw pqxx::pqxx_exception
249     */
250     static void      getEdgePointRestrictions(
251         pqxx::transaction_base& rTrans,
252         pqxx::result&          rResult,
253         const std::string&      rOsmPointTable,
254         const std::string&      rTopoEdgeTable,
255         const std::string&      rOsmEdgeTable,
256         const std::string&      rSchemaName);
257
258     /** Add the result of the query for Point restrictions on Edges .
259     * @param rResult      The results of the query
260     * @param rTopology      Update affected edges in the topology.
261     * @param rConfig      Configuration
262     * @throw MapProviderException
263     */
264     static void      addPointRestrictionsToEdge(
265         const pqxx::result&      rResult,
266         Topology&                rTopology,
267         const Configuration&      rConfig);
268     // ACCESS
```



```
269 // INQUIRY
270
271 protected:
272 private:
273     /** SELECT FROM JOIN */
274     static std::string startOfQuery(const std::string& rTopoEdgeTable);
275
276     /** Which columns to pick */
277     static std::string queryColumns(const std::vector<std::string>& rCols);
278
279     /** FROM JOIN ON WHERE */
280     static std::string midOfQuery(
281         const std::string& rSchemaName,
282         const std::string& rOsmEdgeTable);
283
284     /** Make sure only to pick rows with content in some column. */
285     static std::string notNullColumns(const std::vector<std::string>& rCols);
286
287     /** AS ON ORDER BY */
288     static std::string endOfQuery();
289 };
290
291 #endif /* MAPPROVIDER_POSTGIS_RESTRICTIONQUERIES_H_ */
```

D.11.9 RestrictionQueries.cc

```
1  /*
2   * RestrictionQueries.cc
3   *
4   * @author Jonas Bergman
5   */
6
7  #include "RestrictionQueries.h" // class implemented
8
9  // Result -----
10 //static
11 OsmTurningRestriction*
12 RestrictionQueries::TurningRestrictions::
13     Results::parseTurningRestrictionResultRow(
14         const pqxx::tuple& rRow,
15         Topology& rTopology)
16 {
17     OsmIdType fromOsmId =
18         rRow[RestrictionQueries::TurningRestrictions::FROM_OSM_ID].as<OsmIdType>();
19     OsmIdType toOsmId =
20         rRow[RestrictionQueries::TurningRestrictions::TO_OSM_ID].as<OsmIdType>();
21     std::string typeString =
22         rRow[RestrictionQueries::TurningRestrictions::RESTRICTION_TYPE].as<std::string>();
23     OsmTurningRestriction::TurningRestrictionType type =
24         OsmTurningRestriction::parseString(typeString);
25     std::string edgeIdsString =
26         rRow[RestrictionQueries::TurningRestrictions::EDGE_IDS].as<std::string>();
27     std::string viaOsmIdsString =
28         rRow[RestrictionQueries::TurningRestrictions::VIA_OSM].as<std::string>("");
29
30     std::vector<EdgeIdType> edgeIds = parseEdgeIdsString(edgeIdsString);
31 }
```

```
32     Edge& fromEdge = findEdgeMatchingOsmId(fromOsmId, edgeIds, rTopology);
33     Edge& toEdge    = findEdgeMatchingOsmId(toOsmId, edgeIds, rTopology);
34
35     OsmTurningRestriction* p_restriction {nullptr};
36
37     // VIA WAY
38     if(fromEdge.targetId() != toEdge.sourceId())
39     {
40         p_restriction = new OsmTurningRestriction(
41             type,
42             fromEdge.id(),
43             viaOsmIdsString,
44             toEdge.id());
45     }
46     // VIA NODE
47     else
48     {
49         VertexIdType vertexId = fromEdge.targetId();
50         p_restriction = new OsmTurningRestriction(
51             type,
52             fromEdge.id(),
53             vertexId,
54             toEdge.id());
55     }
56     return p_restriction;
57 }
58
59 //static
60 std::vector<EdgeIdType>
61 RestrictionQueries::TurningRestrictions::Results::parseEdgeIdsString(
62     std::string& rEdgeIds)
63 {
64     boost::trim_if(rEdgeIds, boost::is_any_of("{}"));
65     std::vector<std::string> idStrings;
66     boost::split(idStrings, rEdgeIds, boost::is_any_of(", "));
67
68     std::vector<EdgeIdType> edgeIds;
69     for(const std::string& idStr : idStrings)
70     {
71         edgeIds.push_back(Edge::parse(idStr));
72     }
73     return edgeIds;
74 }
75
76 //static
77 Edge&
78 RestrictionQueries::TurningRestrictions::Results::findEdgeMatchingOsmId(
79     OsmIdType          osmId,
80     const std::vector<EdgeIdType>& rEdgeIds,
81     Topology&          rTopology)
82 {
83     for(EdgeIdType id : rEdgeIds)
84     {
85         Edge& edge = rTopology.getEdge(id);
86         if(edge.osmId() == osmId)
87         {
88             return edge;
```

```
89     }
90 }
91 throw MapProviderException(
92     "PostGisRestrictionQueries::Result::findEdgeMatchingOsmId: "
93     "No edges matching osm_id: " + std::to_string(osmId));
94 }
95
96 ////////////////////////////////// PUBLIC //////////////////////////////////
97
98 //===== LIFECYCLE =====
99 //===== OPERATORS =====
100 //===== OPERATIONS =====
101 //static
102 void
103 RestrictionQueries::getVehiclePropertyEdgeRestrictions(
104     pqxx::transaction_base& rTrans,
105     pqxx::result&           rResult,
106     const std::string&      rTopoEdgeTable,
107     const std::string&      rOsmEdgeTable,
108     const std::string&      rSchemaName)
109 {
110     std::vector<std::string> columns {
111         "maxheight",
112         "maxlength",
113         "maxweight",
114         "maxwidth",
115         "maxspeed",
116         "minspeed"
117     };
118
119     rResult = rTrans.exec(
120         startOfQuery(rTopoEdgeTable) +
121         queryColumns(columns) +
122         midOfQuery(rSchemaName, rOsmEdgeTable) +
123         notNullColumns(columns) +
124         endOfQuery()
125     );
126 }
127
128 // static
129 void
130 RestrictionQueries::addVehiclePropertyRestrictionsToEdge(
131     const pqxx::result& rResult,
132     Topology&           rTopology)
133 {
134     try
135     {
136         for(const pqxx::tuple& row : rResult)
137         {
138             // throw exception if no edgeId
139             EdgeIdType edgeId =
140                 row[VehiclePropertiesRestrictions::EDGE_ID].as<EdgeIdType>();
141
142             Edge& edge = rTopology.getEdge(edgeId);
143             EdgeRestriction& r_restrictions = edge.restrictions();
144
145             EdgeRestriction::VehicleProperties* p_vp =
```

```
146         new EdgeRestriction::VehicleProperties();
147
148     p_vp->maxHeight =
149         row[VehiclePropertiesRestrictions::MAXHEIGHT].as<double>
150         (EdgeRestriction::VehicleProperties::DEFAULT_DIMENSION_MAX);
151     p_vp->maxLength =
152         row[VehiclePropertiesRestrictions::MAXLENGTH].as<double>
153         (EdgeRestriction::VehicleProperties::DEFAULT_DIMENSION_MAX);
154     p_vp->maxWeight =
155         row[VehiclePropertiesRestrictions::MAXWEIGHT].as<double>
156         (EdgeRestriction::VehicleProperties::DEFAULT_DIMENSION_MAX);
157     p_vp->maxWidth =
158         row[VehiclePropertiesRestrictions::MAXWIDTH].as<double>
159         (EdgeRestriction::VehicleProperties::DEFAULT_DIMENSION_MAX);
160     p_vp->maxSpeed =
161         row[VehiclePropertiesRestrictions::MAXSPEED].as<unsigned>
162         (EdgeRestriction::VehicleProperties::DEFAULT_SPEED_MAX);
163     p_vp->minSpeed =
164         row[VehiclePropertiesRestrictions::MINSPEED].as<unsigned>
165         (EdgeRestriction::VehicleProperties::DEFAULT_SPEED_MIN);
166
167     r_restrictions.setVehiclePropertyRestriction(p_vp);
168 }
169 }
170 catch (std::exception& e)
171 {
172     throw MapProviderException(
173         std::string("RestrictionQueries:addVehicleProp..ToEdge... ")
174         + e.what());
175 }
176 }
177
178 //static
179 void
180 RestrictionQueries::getAccessRestrictions(
181     pqxx::transaction_base& rTrans,
182     pqxx::result&           rResult,
183     const std::string&      rTopoEdgeTable,
184     const std::string&      rOsmEdgeTable,
185     const std::string&      rSchemaName)
186 {
187     std::vector<std::string> columns {
188         "access",
189         "barrier",
190         "disused",
191         "noexit",
192         "motorcar",
193         "goods",
194         "hgv",
195         "psv",
196         "lhv",
197         "motor_vehicle",
198         "vehicle"
199     };
200
201     rResult = rTrans.exec(
202         startOfQuery(rTopoEdgeTable) +
```

```
203         queryColumns(columns) +
204         midOfQuery(rSchemaName, rOsmEdgeTable) +
205         notNullColumns(columns) +
206         endOfQuery()
207     );
208 }
209
210 // static
211 void
212 RestrictionQueries::addAccessRestrictionsToEdge(
213     const pqxx::result&      rResult,
214     Topology&                rTopology,
215     const Configuration&     rConfig)
216 {
217     try
218     {
219         for(const pqxx::tuple& row : rResult)
220         {
221             // throw exception if no edgeId
222             EdgeIdType edgeId =
223                 row[AccessRestrictions::EDGE_ID].as<EdgeIdType>();
224
225             Edge& edge = rTopology.getEdge(edgeId);
226             EdgeRestriction& r_restrictions = edge.restrictions();
227
228             std::string colString;
229             colString = row[AccessRestrictions::ACCESS].as<std::string>("");
230             if(colString != "")
231             {
232                 OsmAccess::AccessType type = OsmAccess::parseString(colString);
233                 r_restrictions.setGeneralAccessRestriction(type);
234             }
235
236             colString = row[AccessRestrictions::MOTORCAR].as<std::string>("");
237             if(colString != "")
238             {
239                 OsmAccess::AccessType type = OsmAccess::parseString(colString);
240                 r_restrictions.addVehicleTypeAccessRestriction(
241                     OsmVehicle::MOTORCAR,
242                     type
243                 );
244             }
245
246             colString = row[AccessRestrictions::GOODS].as<std::string>("");
247             if(colString != "")
248             {
249                 OsmAccess::AccessType type = OsmAccess::parseString(colString);
250                 r_restrictions.addVehicleTypeAccessRestriction(
251                     OsmVehicle::GOODS,
252                     type
253                 );
254             }
255
256             colString = row[AccessRestrictions::HGV].as<std::string>("");
257             if(colString != "")
258             {
259                 OsmAccess::AccessType type = OsmAccess::parseString(colString);
```

```
260         r_restrictions.addVehicleTypeAccessRestriction(  
261             OsmVehicle::HGV,  
262             type  
263         );  
264     }  
265  
266     colString = row[AccessRestrictions::PSV].as<std::string>("");  
267     if(colString != "")  
268     {  
269         OsmAccess::AccessType type = OsmAccess::parseString(colString);  
270         r_restrictions.addVehicleTypeAccessRestriction(  
271             OsmVehicle::PSV,  
272             type  
273         );  
274     }  
275  
276     colString = row[AccessRestrictions::LHV].as<std::string>("");  
277     if(colString != "")  
278     {  
279         OsmAccess::AccessType type = OsmAccess::parseString(colString);  
280         r_restrictions.addVehicleTypeAccessRestriction(  
281             OsmVehicle::LHV,  
282             type  
283         );  
284     }  
285  
286     colString = row[AccessRestrictions::MOTOR_VEHICLE].as<std::string>("");  
287     if(colString != "")  
288     {  
289         OsmAccess::AccessType type = OsmAccess::parseString(colString);  
290         r_restrictions.addVehicleTypeAccessRestriction(  
291             OsmVehicle::MOTOR_VEHICLE,  
292             type  
293         );  
294     }  
295  
296     colString = row[AccessRestrictions::VEHICLE].as<std::string>("");  
297     if(colString != "")  
298     {  
299         OsmAccess::AccessType type = OsmAccess::parseString(colString);  
300         r_restrictions.addVehicleTypeAccessRestriction(  
301             OsmVehicle::VEHICLE,  
302             type  
303         );  
304     }  
305  
306     colString = row[AccessRestrictions::BARRIER].as<std::string>("");  
307     if(colString != "")  
308     {  
309         OsmBarrier::BarrierType type = OsmBarrier::parseString(colString);  
310         r_restrictions.setBarrierRestriction(type);  
311         CostQueries::addBarrierCostToEdge(edge, type, rConfig);  
312     }  
313  
314     colString = row[AccessRestrictions::DISUSED].as<std::string>("");  
315     if(colString == "yes")  
316     {
```

```
317         r_restrictions.setDisusedRestriction();
318     }
319
320     colString = row[AccessRestrictions::NOEXIT].as<std::string>("");
321     if(colString == "yes")
322     {
323         r_restrictions.setNoExitRestriction();
324     }
325 }
326 }
327 catch (std::exception& e)
328 {
329     throw MapProviderException(
330         std::string("RestrictionQueries:addAccessResultToEdge..: ") + e.what());
331 }
332 }
333
334 //static
335 void
336 RestrictionQueries::dropCreateTurningRestrictionsTable(
337     pqxx::transaction_base& rTrans)
338 {
339     rTrans.exec(
340         "DROP TABLE IF EXISTS turning_restrictions; "
341         "CREATE TABLE turning_restrictions( "
342         "    from_osm_id      bigint, "
343         "    to_osm_id       bigint, "
344         "    via_osm         varchar, "
345         "    edge_ids        integer[], "
346         "    restriction_type varchar)"
347     );
348 }
349
350 //static
351 void
352 RestrictionQueries::identifyTurningRestrictions(
353     pqxx::transaction_base& rTrans,
354     const std::string&      rOsmEdgeTable,
355     const std::string&      rTopoEdgeTable)
356 {
357     rTrans.exec(
358         "SELECT * FROM find_osm_turning_restrictions('"
359         + rOsmEdgeTable + "', '" + rTopoEdgeTable + "')"
360     );
361 }
362
363 //static
364 void
365 RestrictionQueries::getTurningRestrictions(
366     pqxx::transaction_base& rTrans,
367     pqxx::result&           rResult)
368 {
369     rResult = rTrans.exec(
370         "SELECT * FROM turning_restrictions"
371     );
372 }
373
```

```
374 // static
375 void
376 RestrictionQueries::addTurningRestrictionsToEdge(
377     const pqxx::result&      rResult,
378     Topology&                rTopology)
379 {
380     try
381     {
382         for(const pqxx::tuple& row : rResult)
383         {
384             OsmTurningRestriction* p_turn =
385                 TurningRestrictions::Results::
386                     parseTurningRestrictionResultRow(row, rTopology);
387
388             // mark edge as having a restriction
389             Edge& edge = rTopology.getEdge(p_turn->fromEdgeId());
390             EdgeRestriction& r_restrictions = edge.restrictions();
391             r_restrictions.addTurningRestriction(p_turn);
392
393             // explicit mark "VIA WAY"
394             if(p_turn->viaType() == OsmTurningRestriction::VIA_WAY)
395             {
396                 r_restrictions.setViaWayRestriction();
397             }
398         }
399     }
400     catch (std::exception& e)
401     {
402         throw MapProviderException(
403             std::string("RestrictionQueries:addTurningResultToEdge... ") + e.what());
404     }
405 }
406
407 //static
408 void
409 RestrictionQueries::getEdgePointRestrictions(
410     pqxx::transaction_base& rTrans,
411     pqxx::result&           rResult,
412     const std::string&      rOsmPointTable,
413     const std::string&      rTopoEdgeTable,
414     const std::string&      rOsmEdgeTable,
415     const std::string&      rSchemaName)
416 {
417     rResult = rTrans.exec(
418         "SELECT p.osm_id, "
419         "        p.barrier, "
420         "        p.access, "
421         "        p.goods, "
422         "        p.hgv, "
423         "        p.lhv, "
424         "        p.motorcar, "
425         "        p.motor_vehicle, "
426         "        p.psv, "
427         "        p.vehicle, "
428         "        t.edge_id "
429         "FROM " + rOsmPointTable + " p, "
430         "      " + rTopoEdgeTable + " t, "
```



```
431         "      " + rOsmEdgeTable + " o, "
432         "      " + rSchemaName + ".relation r "
433         "WHERE  r.topogeo_id = (topo_geom).id "
434         "AND    r.element_id = t.edge_id "
435         "AND    p.barrier IS NOT NULL "
436         "AND    ST_Intersects(p.way, t.geom) "
437         "AND    o.highway IN " + OsmHighway::typesAsCommaSeparatedString()
438     );
439 }
440 // static
441 void
442 RestrictionQueries::addPointRestrictionsToEdge(
443     const pqxx::result&      rResult,
444     Topology&                rTopology,
445     const Configuration&     rConfig)
446 {
447     try
448     {
449         for(const pqxx::tuple& row : rResult)
450         {
451             // throw exception if no edgeId
452             EdgeIdType edgeId =
453                 row[EdgePointRestrictions::EDGE_ID].as<EdgeIdType>();
454
455             Edge& edge = rTopology.getEdge(edgeId);
456             EdgeRestriction& r_restrictions = edge.restrictions();
457
458             std::string barrierTypeString =
459                 row[EdgePointRestrictions::BARRIER].as<std::string>();
460             OsmBarrier::BarrierType barrierType =
461                 OsmBarrier::parseString(barrierTypeString);
462             r_restrictions.setBarrierRestriction(barrierType);
463             CostQueries::addBarrierCostToEdge(edge, barrierType, rConfig);
464
465             std::string colString;
466             colString = row[EdgePointRestrictions::ACCESS].as<std::string>("");
467             if(colString != "")
468             {
469                 OsmAccess::AccessType type = OsmAccess::parseString(colString);
470                 r_restrictions.setGeneralAccessRestriction(type);
471             }
472
473             colString = row[EdgePointRestrictions::GOODS].as<std::string>("");
474             if(colString != "")
475             {
476                 OsmAccess::AccessType type = OsmAccess::parseString(colString);
477                 r_restrictions.addVehicleTypeAccessRestriction(
478                     OsmVehicle::GOODS,
479                     type);
480             }
481
482             colString = row[EdgePointRestrictions::HGV].as<std::string>("");
483             if(colString != "")
484             {
485                 OsmAccess::AccessType type = OsmAccess::parseString(colString);
486                 r_restrictions.addVehicleTypeAccessRestriction(
487                     OsmVehicle::HGV,
```

```
488         type);
489     }
490
491     colString = row[EdgePointRestrictions::LHV].as<std::string>("");
492     if(colString != "")
493     {
494         OsmAccess::AccessType type = OsmAccess::parseString(colString);
495         r_restrictions.addVehicleTypeAccessRestriction(
496             OsmVehicle::LHV,
497             type);
498     }
499
500     colString = row[EdgePointRestrictions::MOTORCAR].as<std::string>("");
501     if(colString != "")
502     {
503         OsmAccess::AccessType type = OsmAccess::parseString(colString);
504         r_restrictions.addVehicleTypeAccessRestriction(
505             OsmVehicle::MOTORCAR,
506             type);
507     }
508
509     colString = row[EdgePointRestrictions::MOTOR_VEHICLE].as<std::string>("");
510     if(colString != "")
511     {
512         OsmAccess::AccessType type = OsmAccess::parseString(colString);
513         r_restrictions.addVehicleTypeAccessRestriction(
514             OsmVehicle::MOTOR_VEHICLE,
515             type);
516     }
517
518     colString = row[EdgePointRestrictions::PSV].as<std::string>("");
519     if(colString != "")
520     {
521         OsmAccess::AccessType type = OsmAccess::parseString(colString);
522         r_restrictions.addVehicleTypeAccessRestriction(
523             OsmVehicle::PSV,
524             type);
525     }
526
527     colString = row[EdgePointRestrictions::VEHICLE].as<std::string>("");
528     if(colString != "")
529     {
530         OsmAccess::AccessType type = OsmAccess::parseString(colString);
531         r_restrictions.addVehicleTypeAccessRestriction(
532             OsmVehicle::VEHICLE,
533             type);
534     }
535 }
536 }
537 catch (std::exception& e)
538 {
539     throw MapProviderException(
540         std::string("RestrictionQueries:addPointResultToEdge... ") + e.what());
541 }
542 }
543 //===== ACCESS =====
544 //===== INQUIRY =====
```

```
545 ////////////////////////////////////////////////// PROTECTED //////////////////////////////////////
546 ////////////////////////////////////////////////// PRIVATE  //////////////////////////////////////
547 //static
548 std::string
549 RestrictionQueries::startOfQuery(const std::string& rTopoEdgeTable)
550 {
551     return (
552         "SELECT      edge_id, "
553         "-- osm data about original edge
554         "      osm.* "
555         "FROM        " + rTopoEdgeTable +
556         " JOIN ( "
557         "    SELECT element_id "
558     );
559 }
560
561 //static
562 std::string
563 RestrictionQueries::queryColumns(const std::vector<std::string>& rCols)
564 {
565     std::ostringstream oss;
566     for(const std::string& col : rCols)
567     {
568         oss << ", " << col;
569     }
570     return oss.str();
571 }
572
573 //static
574 std::string
575 RestrictionQueries::midOfQuery(
576     const std::string& rSchemaName,
577     const std::string& rOsmEdgeTable)
578 {
579     return (
580         " FROM    " + rSchemaName + ".relation "
581         " JOIN    " + rOsmEdgeTable +
582         " ON      topogeo_id = (topo_geom).id "
583         " WHERE   highway in " + OsmHighway::typesAsCommaSeparatedString()
584     );
585 }
586
587 //static
588 std::string
589 RestrictionQueries::notNullColumns(const std::vector<std::string>& rCols)
590 {
591     std::ostringstream oss;
592     oss << " AND (";
593     size_t i = 0;
594     for(const std::string& col : rCols)
595     {
596         oss << col << " IS NOT NULL ";
597         if(i < (rCols.size() - 1))
598         {
599             oss << " OR ";
600         }
601         ++i;
```

```
602     }
603     oss << ") ";
604     return oss.str();
605 }
606
607 //static
608 std::string
609 RestrictionQueries::endOfQuery()
610 {
611     return (
612         ") AS osm "
613         "ON edge_id = element_id "
614         "ORDER BY edge_id ASC;"
615     );
616 }
```

D.11.10 TopologyQueries.h

```
1  /** A class for holding static queries about the topology
2   * for the PostGisProvider.
3   *
4   * #include "TopologyQueries.h"
5   *
6   * @author Jonas Bergman
7   */
8
9  #ifndef MAPPROVIDER_POSTGIS_TOPOLOGYQUERIES_H_
10 #define MAPPROVIDER_POSTGIS_TOPOLOGYQUERIES_H_
11
12 // SYSTEM INCLUDES
13 //
14 #include <string>
15
16 // PROJECT INCLUDES
17 //
18 #include <pqxx/pqxx>
19
20 // LOCAL INCLUDES
21 //
22 #include "../graph/Topology.h"
23 #include "../graph/TopologyException.h"
24 #include "../MapProviderException.h"
25
26 // FORWARD REFERENCES
27 //
28
29 /** This class holds static queries about the topology to be used by the
30 * PostGisProvider. It also holds types for handling the results.
31 */
32 class TopologyQueries
33 {
34 public:
35     // TYPES
36
37     /** Columns used in queries for Vertices. */
38     struct VertexResult
39     {
```

```
40     enum Columns
41     {
42         NODE_ID,
43         X,
44         Y
45     };
46 };
47
48 /** Columns used in queries for Edges. */
49 struct EdgeResult
50 {
51     enum Columns
52     {
53         EDGE_ID,
54         START_NODE,
55         END_NODE,
56         EDGE_LENGTH,
57         CENTER_X,
58         CENTER_Y,
59         SOURCE_BEARING,
60         TARGET_BEARING,
61         OSM_ID,
62         ELEMENT_ID,      // NOT USED: same as EDGE_ID_COL
63
64         // road data
65         HIGHWAY,
66         JUNCTION,
67         LANES,
68         ONEWAY,
69
70         // access
71         ACCESS,
72         MOTORCAR,
73         GOODS,
74         HGV,
75         PSV,
76         LHV,
77         MOTOR_VEHICLE,
78         VEHICLE,
79     };
80 };
81
82
83
84 // LIFECYCLE
85 /** Constructor. */
86 TopologyQueries() = delete;
87 /** Copy constructor. */
88 TopologyQueries(const TopologyQueries& from) = delete;
89
90 // OPERATORS
91 // OPERATIONS
92 /** Fetch the vertices for the topology.
93  * @param rTrans      Transaction to perform query in.
94  * @param rResult      Store the result of query here.
95  * @param rVertexTable Name of table to fetch topology vertices from.
96  */
```

```
97     static void      getTopologyVertices(  
98         pqxx::transaction_base& rTrans,  
99         pqxx::result&          rResult,  
100         const std::string&      rVertexTable);  
101  
102     /** Add vertices to topology.  
103     * @throws TopologyException  
104     */  
105     static void      addVertexResultToTopology(  
106         const pqxx::result&      rResult,  
107         Topology&              rTopology);  
108  
109     /** Fetch the edges for the topology.  
110     * @param rTrans      Transaction to perform query in.  
111     * @param rResult      Store the result of query here.  
112     * @param rTopoEdgeTable Name of table to fetch topology edges from.  
113     * @param rSchemaName  Name of topology schema.  
114     * @param rOsmEdgeTable Name of table with original OSM edge data.  
115     */  
116     static void      getTopologyEdges(  
117         pqxx::transaction_base& rTrans,  
118         pqxx::result&          rResult,  
119         const std::string&      rTopoEdgeTable,  
120         const std::string&      rSchemaName,  
121         const std::string&      rOsmEdgeTable);  
122  
123     /** Add edges to topology.  
124     * @param rEdgeResult  Result of db query for edges.  
125     * @param rTopology    Topology to fill with edges.  
126     * @throws TopologyException  
127     */  
128     static void      addEdgeResultToTopology(  
129         const pqxx::result&      rResult,  
130         Topology&              rTopology);  
131  
132     /** Helper to add basic data from db to Edge.  
133     * @param rRow          Row with data for an Edge.  
134     * @param rTopology    Topology to add edge to.  
135     * @return Reference to the newly added Edge.  
136     * @throws TopologyException  
137     */  
138     static Edge&      addBasicResultToEdge(  
139         const pqxx::tuple&      rRow,  
140         Topology&              rTopology);  
141  
142     /** Add geometric result from query to an Edge.  
143     * @param rEdge        Reference to Edge to set Geom data on.  
144     * @param rRow          Reference to Row with Geom data in it.  
145     */  
146     static void      addGeomDataResultToEdge(  
147         Edge&              rEdge,  
148         const pqxx::tuple&  rRow);  
149  
150     /** Add road related result from query to an Edge.  
151     * @param rEdge        Reference to Edge to set road data on.  
152     * @param rRow          Reference to Row with road data in it.  
153     */
```

```
154     static void      addRoadDataResultToEdge(  
155                     Edge&          rEdge,  
156                     const pqxx::tuple& rRow);  
157  
158     /** Extract highway type from database result and store in RoadData.  
159     * @param rRoadData The RoadData to store in.  
160     * @param rRow Reference to Row with road data in it.  
161     * @throw MapProviderException  
162     */  
163     static void      addHighwayTypeToEdgeRoadData(  
164                     Edge::RoadData& rRoadData,  
165                     const pqxx::tuple& rRow);  
166  
167     /** Make sure the 'postgis_topology' extension is installed.  
168     * @param rTrans Transaction to perform query in.  
169     */  
170     static void      installPostgisTopology(pqxx::transaction_base& rTrans);  
171  
172     /** Set schema search path for queries.  
173     * @param rTrans Transaction to perform query in.  
174     */  
175     static void      setSearchPath(pqxx::transaction_base& rTrans);  
176  
177     /** Create the temporary table for topologies.  
178     * @param rTrans Transaction to perform query in.  
179     * @param rTableName Name of the temporary topology table.  
180     */  
181     static void      createTemporaryTable(  
182                     pqxx::transaction_base& rTrans,  
183                     const std::string& rTableName);  
184  
185     /** Create a schema for the temporary postgis topology.  
186     * @param rTrans Transaction to perform query in.  
187     * @param rSchemaName Name of the temporary schema.  
188     * @param srid The projection to use.  
189     */  
190     static void      createTemporarySchema(  
191                     pqxx::transaction_base& rTrans,  
192                     const std::string& rSchemaName,  
193                     int srid);  
194  
195     /** Add a column for geometry in the table with Osm Edges.  
196     * @param rTrans Transaction to perform query in.  
197     * @param rSchemaName Name of the temporary schema.  
198     * @param rOsmEdgeTable Name of the table with OSM edges.  
199     */  
200     static void      addTopoGeometryColumn(  
201                     pqxx::transaction_base& rTrans,  
202                     const std::string& rSchemaName,  
203                     const std::string& rOsmEdgeTable);  
204  
205     /** Fill geometry in the table with Osm Edges, using a tolerance for  
206     * merging nodes near one another.  
207     * @param rTrans Transaction to perform query in.  
208     * @param rSchemaName Name of the temporary schema.  
209     * @param rOsmEdgeTable Name of the table with OSM edges.  
210     * @param tolerance Tolerance in unit of projection.
```

```
211     */
212     static void      fillTopoGeometryColumn(
213         pqxx::transaction_base& rTrans,
214         const std::string&      rSchemaName,
215         const std::string&      rOsmEdgeTable,
216         double                  tolerance);
217
218     /** Drop the temporary table for topologies.
219     * @param rTrans      Transaction to perform query in.
220     * @param rTableName  Name of the temporary topology table.
221     */
222     static void      dropTemporaryTable(
223         pqxx::transaction_base& rTrans,
224         const std::string&      rTableName);
225
226     /** Drop the temporary schema for topologies.
227     * @param rTrans      Transaction to perform query in.
228     * @param rSchemaName Name of the temporary topology schema.
229     */
230     static void      dropTemporarySchema(
231         pqxx::transaction_base& rTrans,
232         const std::string&      rTableName);
233
234     /** Clean up in records for postgis topologies.
235     * @param rTrans      Transaction to perform query in.
236     * @param rTableName  Name of the temporary topology table.
237     */
238     static void      deleteTemporaryLayerRecord(
239         pqxx::transaction_base& rTrans,
240         const std::string&      rTableName);
241
242     /** Clean up in records for postgis topologies.
243     * @param rTrans      Transaction to perform query in.
244     * @param rTableName  Name of the temporary topology table.
245     */
246     static void      deleteTemporaryTopoRecord(
247         pqxx::transaction_base& rTrans,
248         const std::string&      rSchemaName);
249
250     // ACCESS
251     // INQUIRY
252
253     protected:
254     private:
255     };
256
257     // INLINE METHODS
258     //
259
260     // EXTERNAL REFERENCES
261     //
262
263     #endif /* MAPPROVIDER_POSTGIS_TOPOLOGYQUERIES_H_ */
```


D.11.11 TopologyQueries.cc

```
1  /*
2   * TopologyQueries.cc
3   *
4   * @author Jonas Bergman
5   */
6
7  #include "TopologyQueries.h" // class implemented
8
9  #include "../osm/OsmHighway.h"
10
11
12  ////////////////////////////////// PUBLIC //////////////////////////////////
13
14  //===== LIFECYCLE =====
15  //===== OPERATORS =====
16  //===== OPERATIONS =====
17  //static
18  void
19  TopologyQueries::getTopologyVertices(
20      pqxx::transaction_base& rTrans,
21      pqxx::result&          rResult,
22      const std::string&      rVertexTable)
23  {
24      rResult = rTrans.exec(
25          "SELECT node_id, ST_X(geom) AS x, ST_Y(geom) AS y "
26          " FROM " + rVertexTable +
27          " ORDER BY node_id ASC;")
28  };
29  }
30
31  // static
32  void
33  TopologyQueries::addVertexResultToTopology(
34      const pqxx::result& rResult,
35      Topology&           rTopology)
36  {
37      for(size_t row = 0; row < rResult.size(); ++row)
38      {
39          VertexIdType id(rResult[row][VertexResult::NODE_ID].as<int>());
40          Point point(rResult[row][VertexResult::X].as<double>(),
41                     rResult[row][VertexResult::Y].as<double>());
42          rTopology.addVertex(id, point);
43      }
44  }
45
46  //static
47  void
48  TopologyQueries::getTopologyEdges(
49      pqxx::transaction_base& rTrans,
50      pqxx::result&          rResult,
51      const std::string&      rTopoEdgeTable,
52      const std::string&      rSchemaName,
53      const std::string&      rOsmEdgeTable)
54  {
55      std::string sql(
56          "SELECT edge_id, "
```

```

57         "            start_node, "
58         "            end_node, "
59         "-- geom data about edge
60         "            ST_Length(geom) AS edge_length, "
61         "            ST_X(ST_LineInterpolatePoint(geom, 0.5)) AS center_x, "
62         "            ST_Y(ST_LineInterpolatePoint(geom, 0.5)) AS center_y, "
63         "            (ST_Azimuth("
64         "                ST_PointN(geom,1), "
65         "                ST_PointN(geom,2))/(2*pi())*360)::int "
66         "            AS source_bearing, "
67         "            (ST_Azimuth("
68         "                ST_PointN(geom,ST_NPoints(geom)-1), "
69         "                ST_PointN(geom,ST_NPoints(geom)))/(2*pi())*360)::int "
70         "            AS target_bearing, "
71         "-- osm data about original edge
72         "            osm.* "
73         "FROM      " + rTopoEdgeTable +
74         " JOIN ( "
75         "     SELECT  osm_id, element_id "
76         "-- road data
77         "            , highway "
78         "            , junction "
79         "            , lanes "
80         "            , oneway "
81         " FROM      " + rSchemaName + ".relation "
82         " JOIN      " + rOsmEdgeTable +
83         " ON        topogeo_id = (topo_geom).id "
84         " WHERE     highway in " + OsmHighway::typesAsCommaSeparatedString() +
85         ") AS osm "
86         "ON edge_id = element_id "
87         "ORDER BY edge_id ASC;"
88     );
89     rResult = rTrans.exec(sql);
90 }
91
92 // static
93 void
94 TopologyQueries::addEdgeResultToTopology(
95     const pqxx::result& rResult,
96     Topology&           rTopology)
97 {
98     for(const pqxx::tuple& row : rResult)
99     {
100         Edge& edge = addBasicResultToEdge(row, rTopology);
101         addGeomDataResultToEdge(edge, row);
102         addRoadDataResultToEdge(edge, row);
103     }
104 }
105
106 // static
107 Edge&
108 TopologyQueries::addBasicResultToEdge(
109     const pqxx::tuple& rRow,
110     Topology&         rTopology)
111 {
112     EdgeIdType
113     edge_id(rRow[EdgeResult::EDGE_ID].as<EdgeIdType>(Edge::MAX_ID));

```

```
114     OsmIdType
115         osm_id(rRow[EdgeResult::OSM_ID].as<OsmIdType>(Osm::MAX_ID));
116     VertexIdType
117         source_id(rRow[EdgeResult::START_NODE].as<int>(Vertex::MAX_ID));
118     VertexIdType
119         target_id(rRow[EdgeResult::END_NODE].as<int>(Vertex::MAX_ID));
120
121     Edge& edge = rTopology.addEdge(edge_id, osm_id, source_id, target_id);
122
123     return edge;
124 }
125
126 // static
127 void
128 TopologyQueries::addGeomDataResultToEdge(Edge& rEdge, const pqxx::tuple& rRow)
129 {
130     Edge::GeomData gd(
131         rRow[EdgeResult::EDGE_LENGTH].as<double>(0),
132         Point(rRow[EdgeResult::CENTER_X].as<double>(0),
133             rRow[EdgeResult::CENTER_Y].as<double>(0)),
134         rRow[EdgeResult::SOURCE_BEARING].as<int>(0),
135         rRow[EdgeResult::TARGET_BEARING].as<int>(0));
136     rEdge.setGeomData(gd);
137 }
138
139 // static
140 void
141 TopologyQueries::addRoadDataResultToEdge(Edge& rEdge, const pqxx::tuple& rRow)
142 {
143     Edge::RoadData rd;
144     std::string
145         onewayStr(rRow[EdgeResult::ONEWAY].as<std::string>("no"));
146
147     if(rRow[EdgeResult::JUNCTION].as<std::string>("") ==
148         OsmHighway::JUNCTION_ROUNDABOUT)
149     {
150         onewayStr = "yes";
151     }
152     if(onewayStr == "yes")
153     {
154         rd.direction = Edge::DirectionType::FROM_TO;
155     }
156     else if(onewayStr == "-1")
157     {
158         rd.direction = Edge::DirectionType::TO_FROM;
159     }
160
161     rd.nrLanes = rRow[EdgeResult::LANES].as<size_t>(1);
162
163     addHighwayTypeToEdgeRoadData(rd, rRow);
164
165     rEdge.setRoadData(rd);
166 }
167
168 // static
169 void
170 TopologyQueries::addHighwayTypeToEdgeRoadData(Edge::RoadData& rRoadData,
```

```
171         const pqxx::tuple& rRow)
172     {
173         std::string roadTypeStr( rRow[EdgeResult::HIGHWAY].as<std::string>("road"));
174         try
175         {
176             rRoadData.roadType = OsmHighway::parseString(roadTypeStr);
177         }
178         catch (OsmException& oe)
179         {
180             throw MapProviderException(
181                 std::string("TopologyQueries:addHighwayTypeToEdgeRoadData:")
182                 + oe.what());
183         }
184     }
185
186     //static
187     void
188     TopologyQueries::installPostgisTopology(pqxx::transaction_base& rTrans)
189     {
190         rTrans.exec(
191             "CREATE EXTENSION IF NOT EXISTS postgis_topology"
192         );
193     }
194
195     //static
196     void
197     TopologyQueries::setSearchPath(pqxx::transaction_base& rTrans)
198     {
199         rTrans.exec(
200             "SET search_path = topology, public"
201         );
202     }
203
204     //static
205     void
206     TopologyQueries::createTemporaryTable(pqxx::transaction_base& rTrans,
207                                           const std::string& rTableName)
208     {
209         rTrans.exec(
210             "CREATE TABLE public." + rTableName + " " +
211             "AS SELECT * "
212             "FROM planet_osm_line "
213             "WHERE highway IS NOT NULL"
214         );
215     }
216
217     //static
218     void
219     TopologyQueries::createTemporarySchema(pqxx::transaction_base& rTrans,
220                                           const std::string& rSchemaName, int srid)
221     {
222         rTrans.exec(
223             "SELECT topology.CreateTopology(' " +
224             rSchemaName + " ', " +
225             rTrans.quote(srid) + " )"
226         );
227     }
```

```
228
229 //static
230 void
231 TopologyQueries::addTopoGeometryColumn(pqxx::transaction_base& rTrans,
232                                       const std::string& rSchemaName,
233                                       const std::string& rOsmEdgeTable)
234 {
235     rTrans.exec(
236         "SELECT topology.AddTopoGeometryColumn('\" +
237         rSchemaName + "\", \" +
238         \"'public', '\" +
239         rOsmEdgeTable + "\", \" +
240         \"'topo_geom', 'LINESTRING')\"
241     );
242 }
243
244 //static
245 void
246 TopologyQueries::fillTopoGeometryColumn(pqxx::transaction_base& rTrans,
247                                       const std::string& rSchemaName,
248                                       const std::string& rOsmEdgeTable,
249                                       double tolerance)
250 {
251     rTrans.exec(
252         "UPDATE public.\" +
253         rOsmEdgeTable + \" \" +
254         "SET topo_geom = topology.toTopoGeom(way, '\" +
255         rSchemaName +
256         \"', 1, \" +
257         rTrans.quote(tolerance) + \")\"
258     );
259 }
260
261 //static
262 void
263 TopologyQueries::dropTemporaryTable(pqxx::transaction_base& rTrans,
264                                     const std::string& rTableName)
265 {
266     rTrans.exec(
267         "DROP TABLE IF EXISTS public.\" + rTableName
268     );
269 }
270
271 //static
272 void
273 TopologyQueries::dropTemporarySchema(pqxx::transaction_base& rTrans,
274                                     const std::string& rSchemaName)
275 {
276     rTrans.exec(
277         "DROP SCHEMA IF EXISTS \" + rSchemaName + \" CASCADE\"
278     );
279 }
280
281 //static
282 void
283 TopologyQueries::deleteTemporaryLayerRecord(pqxx::transaction_base& rTrans,
284                                             const std::string& rTableName)
```

```

285 {
286     rTrans.exec(
287         "DELETE FROM topology.layer "
288         "WHERE table_name = " + rTrans.quote(rTableName)
289     );
290 }
291
292 //static
293 void
294 TopologyQueries::deleteTemporaryTopoRecord(pqxx::transaction_base& rTrans,
295                                             const std::string& rSchemaName)
296 {
297     rTrans.exec(
298         "DELETE FROM topology.topology "
299         "WHERE name = " + rTrans.quote(rSchemaName)
300     );
301 }
302 //===== ACCESS =====
303 //===== INQUIRY =====
304 ////////////////////////////////// PROTECTED //////////////////////////////////
305
306 ////////////////////////////////// PRIVATE //////////////////////////////////

```

D.11.12 PostGisProvider_test.cc

```

1  /*
2   * DatabaseHandler_test.cc
3   *
4   * @author Jonas Bergman
5   */
6
7  #include "../postgis/PostGisProvider.h"
8  #include "../postgis/RestrictionQueries.h"
9
10 #include <iostream>
11 #include <string>
12 #include <sstream>
13 #include <vector>
14
15 #include "../../catchtest/catch.hpp"
16 #include "../../config/ConfigurationReader.h"
17 #include "../../config/DatabaseConfig.h"
18 #include "../../util/TimeToStringMaker.h"
19 #include "../../graph/Edge.h"
20 #include "../../graph/Vertex.h"
21 #include "../../graph/GraphBuilder.h"
22
23 SCENARIO ("PostGis topology handling", "[postgis][topology]")
24 {
25     try
26     {
27         // =====
28         GIVEN ("a configuration file with NO topology name")
29         {
30             WHEN ("we try to read in topology")
31             {
32                 std::string config_file(

```

```
33         "catchtest/testsettings/missing-topo-testsettings.json");
34     ConfigurationReader config_reader(config_file);
35     Configuration config;
36     config_reader.fillConfiguration(config);
37
38     THEN ("we should get an exception")
39     {
40         REQUIRE_THROWS_AS (PostGisProvider pgp(config),
41                             MapProviderException&);
42     }
43 }
44 }
45 }
46 catch (ConfigurationException& e) {
47     INFO(e.what());
48     REQUIRE (false);    // force output of error and failure
49 }
50 }
51
52
53 SCENARIO ("PostGis queries", "[postgis][query]")
54 {
55     try
56     {
57
58         // =====
59         GIVEN ("a valid database configuration structure and "
60              "name to existing topology")
61         {
62             std::string config_file(
63                 "catchtest/testsettings/mikh0522-testsettings.json");
64             ConfigurationReader config_reader(config_file);
65             Configuration config;
66             config_reader.fillConfiguration(config);
67
68             PostGisProvider db_handler(config);
69
70             // .....
71             WHEN ("we try to fetch a topology")
72             {
73                 Topology topology;
74
75                 THEN ("we should not get an exception")
76                 {
77                     REQUIRE_NOTHROW (db_handler.getTopology(topology));
78                 }
79             }
80
81             // .....
82             WHEN ("we try to fetch topology ")
83             {
84                 Topology topology;
85                 db_handler.getTopology(topology);
86
87                 THEN ("we should receive a vertices and edges")
88                 {
89                     REQUIRE (topology.nrVertices() > 0);
```

```

90         REQUIRE (topology.nrEdges() > 0);
91     }
92 }
93
94 // .....
95 WHEN ("we try to build a graph ")
96 {
97     Topology topology;
98     db_handler.getTopology(topology);
99     Configuration config;
100     GraphBuilder graph(topology, config);
101     std::ostringstream oss;
102
103     THEN ("we should be able to print some information")
104     {
105         graph.printGraphInformation(oss);
106         INFO(oss.str());
107         REQUIRE (true);
108     }
109 }
110
111 // .....
112 WHEN ("fetching an edge from topology")
113 {
114     Topology topology;
115     db_handler.getTopology(topology);
116     const Edge& edge = topology.getEdge(1);
117
118     THEN ("we should be able to print it out")
119     {
120         INFO (edge);
121         REQUIRE (true);
122
123         /* Information matches this query:
124 $ psql -U jonas -d mikh_0522 -c
125 "SELECT edge_id, osm_id, start_node, end_node, lanes, highway
126 FROM   topo_test.edge_data
127 JOIN (
128 SELECT osm_id, element_id, highway, lanes
129 FROM topo_test.relation
130 JOIN highways_test
131 ON topogeo_id = (topo_geom).id )
132 AS osm
133 ON edge_id = element_id
134 WHERE edge_id = 1;"
135
136 edge_id | osm_id | start_node | end_node | lanes | highway
137 -----+-----+-----+-----+-----+-----
138      1 | 124227193 |      1 |      54 |      | residential
139 (1 row)
140
141 */
142     }
143 }
144
145 }
146

```



```
147     catch (ConfigurationException& e)
148     {
149         INFO(e.what());
150         REQUIRE (false);    // force output of error and failure
151     }
152     catch (MapProviderException& dbe)
153     {
154         INFO(dbe.what());
155         REQUIRE (false);    // force output of error and failure
156     }
157 }
158 }
159
160 SCENARIO ("Set costs on Edges", "[postgis][cost]")
161 {
162     try
163     {
164         // =====
165         GIVEN ("a valid database configuration structure and "
166              "name to existing topology")
167         {
168             std::string config_file(
169                 "catchtest/testsettings/mikh_restr_0617-testsettings.json");
170             ConfigurationReader config_reader(config_file);
171             Configuration config;
172             config_reader.fillConfiguration(config);
173
174             PostGisProvider pgp(config);
175
176             Topology topology;
177             pgp.getTopology(topology);
178
179             // .....
180             WHEN ("we try to set restrictions and costs on topology")
181             {
182                 pgp.setRestrictionsAndCosts(topology);
183
184                 THEN ("we should be able to read travel time cost on edges")
185                 {
186                     EdgeIdType id = 1;
187                     const Edge& edge = topology.getEdge(id);
188                     INFO ("edge " << id
189                          << ", length: " << edge.geomData().length
190                          << ", travel time: "
191                          << edge.edgeCost().getCost(EdgeCost::TRAVEL_TIME)
192                          << ", total cost: " << edge.cost());
193                     INFO ("edge " << edge);
194                     REQUIRE (edge.cost() > 0);
195                 }
196
197                 THEN ("we should be able to find cost for barriers")
198                 {
199                     EdgeIdType id = 869;
200                     const Edge& edge = topology.getEdge(id);
201                     INFO ("edge " << id
202                          << ", length: " << edge.geomData().length
203                          << ", travel time: "
```

```
204         << edge.edgeCost().getCost(EdgeCost::TRAVEL_TIME)
205         << ", barrier cost: "
206         << edge.edgeCost().getCost(EdgeCost::BARRIER)
207         << ", total cost: " << edge.cost();
208     REQUIRE (edge.cost() > 0);
209 }
210
211 THEN ("we should be able to find cost for other hindrances")
212 {
213     EdgeIdType id = 869;
214     const Edge& edge = topology.getEdge(id);
215     INFO ("edge " << id
216         << ", length: " << edge.geomData().length
217         << ", travel time: "
218         << edge.edgeCost().getCost(EdgeCost::TRAVEL_TIME)
219         << ", barrier cost: "
220         << edge.edgeCost().getCost(EdgeCost::BARRIER)
221         << ", other cost: "
222         << edge.edgeCost().getCost(EdgeCost::OTHER)
223         << ", total cost: " << edge.cost());
224     REQUIRE (edge.cost() > 0);
225 }
226 }
227 }
228 }
229 catch (ConfigurationException& e)
230 {
231     INFO(e.what());
232     REQUIRE (false);    // force output of error and failure
233 }
234 catch (MapProviderException& dbe)
235 {
236     INFO(dbe.what());
237     REQUIRE (false);    // force output of error and failure
238 }
239
240 }
```

D.12 osm

D.12.1 README.md

OSM
===

OpenStreetMap related classes and constants are placed in this package.

Relations

There is no really easy way to get to relations if data has been imported with
→ osm2pgsql. Best chance is to import in "slim mode" (with flag `-s``) and look
→ through table ``planet_osm_rel`` and search the column ``tags`` for
→ ``restriction``. Then parse the ``members`` column for members of the relation
→ and their roles.

The TurnRestriction class could be smarter with handling turn either via `nodes`
↪ or `ways` but it is not implemented yet.

D.12.2 OsmAccess.h

```
1  /** Access to `Access` data from the OSM file.
2   *
3   * #include "OsmAccess.h"
4   *
5   * @author Jonas Bergman
6   */
7
8  #ifndef OSM_OSMACCESS_H_
9  #define OSM_OSMACCESS_H_
10
11 // SYSTEM INCLUDES
12 //
13 #include <algorithm>
14 #include <initializer_list>
15 #include <string>
16 #include <vector>
17
18 // PROJECT INCLUDES
19 //
20
21 // LOCAL INCLUDES
22 //
23 #include "OsmException.h"
24
25 // FORWARD REFERENCES
26 //
27
28 /**
29  * Class to represent OSM key `access`.
30  */
31 class OsmAccess
32 {
33 public:
34 // TYPES
35     enum AccessType
36     {
37         YES,
38         PRIVATE,
39         NO,
40         PERMISSIVE,
41         AGRICULTURAL,
42         USE_SIDEPATH,
43         DELIVERY,
44         DESIGNATED,
45         DISMOUNT,
46         DISCOURAGED,
47         FORESTRY,
48         DESTINATION,
49         CUSTOMERS,
50
51         NR_ACCESS_TYPES
52     };
```

```
53
54
55     /** Allow access to the types in the 'allowAccessTypes', deny all other.
56     */
57     struct AccessRule
58     {
59         AccessRule() = default;
60         AccessRule(const AccessRule& from) = default;
61         AccessRule(std::initializer_list<AccessType> allowedTypes);
62
63         bool    hasAccess(AccessType type) const;
64
65         std::vector<AccessType> allowAccessToTypes;
66     };
67
68     // LIFECYCLE
69     OsmAccess() = delete;
70     OsmAccess(AccessType type);
71     OsmAccess(const OsmAccess& from) = default;
72     ~OsmAccess() = default;
73
74     // OPERATORS
75     // OPERATIONS
76     /** Attempt to parse a string to a AccessType
77     * @param rTypeString String which could contain a Access type
78     * @return A valid AccessType
79     * @throw OsmException if invalid string.
80     */
81     static AccessType parseString(const std::string& rTypeString);
82
83     /** Convert a Access Type to a string representation.
84     * @param accessType The type to convert.
85     * @return string representation of the type.
86     * @throw OsmException if unknown vehicle type (out of bounds).
87     */
88     static std::string toString(AccessType accessType);
89
90     /** Convert this AccessType to a string.
91     * @return string representation of this VehicleType.
92     */
93     std::string toString() const;
94
95     /** See if this Access type permits access according to rule;
96     * @param AccessRule
97     * @return true if access is allowed, false if not
98     */
99     bool allowsAccess(AccessRule rule) const;
100
101     // ACCESS
102     /**
103     * @return The access type.
104     */
105     AccessType accessType() const;
106     // INQUIRY
107     protected:
108     private:
109         AccessType mType {YES};
```

```
110     static const std::string sTypeStrings[];
111 };
112
113 // INLINE METHODS
114 //
115
116 // EXTERNAL REFERENCES
117 //
118
119 #endif /* OSM_OSMACCESS_H_ */
```

D.12.3 OsmAccess.cc

```
1  /*
2   * OsmAccess.cc
3   *
4   * @author Jonas Bergman
5   */
6
7
8  #include "OsmAccess.h" // class implemented
9
10 // AccessRule -----
11 OsmAccess::AccessRule::AccessRule(
12     std::initializer_list<OsmAccess::AccessType> allowedTypes)
13     : allowAccessToTypes(allowedTypes)
14 {
15 }
16
17 bool
18 OsmAccess::AccessRule::hasAccess(OsmAccess::AccessType type) const
19 {
20     auto it = std::find(allowAccessToTypes.begin(),
21         allowAccessToTypes.end(),
22         type);
23     return it != allowAccessToTypes.end();
24 }
25
26
27 ////////////////////////////////// PUBLIC //////////////////////////////////
28
29 //===== LIFECYCLE =====
30 OsmAccess::OsmAccess(OsmAccess::AccessType type)
31     : mType(type)
32 {}
33
34 //===== OPERATORS =====
35
36 //static
37 OsmAccess::AccessType
38 OsmAccess::parseString(const std::string& rTypeString)
39 {
40     for(size_t i = 0; i < NR_ACCESS_TYPES; ++i)
41     {
42         if(rTypeString == OsmAccess::sTypeStrings[i])
43         {
44             return static_cast<AccessType>(i);
```

```
45     }
46 }
47     throw OsmException("OsmAccess:parseString: Unknown Access Type string.");
48 }
49
50 //static
51 std::string
52 OsmAccess::toString(OsmAccess::AccessType accessType)
53 {
54     if(accessType >= NR_ACCESS_TYPES)
55     {
56         throw OsmException("OsmAccess:toString: Unknown Access Type");
57     }
58     return OsmAccess::sTypeStrings[accessType];
59 }
60
61 std::string
62 OsmAccess::toString() const
63 {
64     return sTypeStrings[this->mType];
65 }
66
67 bool
68 OsmAccess::allowsAccess(OsmAccess::AccessRule rule) const
69 {
70     return rule.hasAccess(mType);
71 }
72
73 OsmAccess::AccessType
74 OsmAccess::accessType() const
75 {
76     return mType;
77 }
78
79 //===== OPERATIONS =====
80 //===== ACCESS =====
81 //===== INQUIRY =====
82 ////////////////////////////////// PROTECTED //////////////////////////////////
83
84 ////////////////////////////////// PRIVATE //////////////////////////////////
85 const std::string OsmAccess::sTypeStrings[] =
86 {
87     "yes",
88     "private",
89     "no",
90     "permissive",
91     "agricultural",
92     "use_sidepath",
93     "delivery",
94     "designated",
95     "dismount",
96     "discouraged",
97     "forestry",
98     "destination",
99     "customers"
100 };
```

D.12.4 OsmBarrier.h

```
1  /** Access to `Barrier` data from the OSM file.
2      *
3      * #include "OsmBarrier.h"
4      *
5      * @author Jonas Bergman
6      */
7
8  #ifndef OSM_OSBARRIER_H_
9  #define OSM_OSBARRIER_H_
10
11 // SYSTEM INCLUDES
12 //
13 #include <algorithm>
14 #include <initializer_list>
15 #include <map>
16 #include <string>
17 #include <vector>
18
19 // PROJECT INCLUDES
20 //
21
22 // LOCAL INCLUDES
23 //
24 #include "OsmException.h"
25 #include "../graph/Cost.h"
26
27 // FORWARD REFERENCES
28 //
29
30
31 /**
32  * Class to represent OSM key `barrier`.
33  */
34 class OsmBarrier
35 {
36 public:
37 // TYPES
38     enum BarrierType
39     {
40         NONE,
41         BLOCK,
42         BOLLARD,
43         BORDER_CONTROL,
44         BUMP_GATE,
45         BUS_TRAP,
46         CATTLE_GRID,
47         CHAIN,
48         CYCLE_BARRIER,
49         DEBRIS,
50         ENTRANCE,
51         FULLHEIGHT_TURNSTILE,
52         GATE,
53         HAMPSHIRE_GATE,
54         HEIGHT_RESTRICTOR,
55         HORSE_STILE,
56         JERSEY_BARRIER,
```

```
57     KENT_CARRIAGE_GAP,
58     KISSING_GATE,
59     LIFT_GATE,
60     LOG,
61     MOTORCYCLE_BARRIER,
62     ROPE,
63     SALLY_PORT,
64     SPIKES,
65     STILE,
66     SUMP_BUSTER,
67     SWING_GATE,
68     TOLL_BOOTH,
69     TURNSTILE,
70     YES,
71
72     NR_BARRIER_TYPES
73 };
74
75 /** Barriers which imposes restrictions on access.
76  */
77 struct RestrictionsRule
78 {
79     RestrictionsRule() = default;
80     RestrictionsRule(const RestrictionsRule& from) = default;
81     RestrictionsRule(std::initializer_list<BarrierType> restrictionTypes);
82
83     bool restrictsAccess(BarrierType type) const;
84
85     std::vector<BarrierType> restrictionTypes;
86 };
87
88 /** Barriers which infer costs.
89  */
90 struct CostsRule
91 {
92     CostsRule() = default;
93     CostsRule(const CostsRule& from) = default;
94
95     bool costsToPass(BarrierType type) const;
96     Cost getCost(BarrierType type) const;
97     void addCost(BarrierType type, Cost cost);
98
99     std::map<BarrierType, Cost> costs;
100 };
101
102 // LIFECYCLE
103 OsmBarrier() = delete;
104 OsmBarrier(BarrierType type);
105 OsmBarrier(const OsmBarrier& from) = default;
106 ~OsmBarrier() = default;
107
108 // OPERATORS
109 // OPERATIONS
110 /** Attempt to parse a string to a BarrierType
111  * @param rTypeString String which could contain a Barrier type
112  * @return A valid BarrierType
113  * @throw OsmException if invalid string.
```



```

114     */
115     static BarrierType  parseString(const std::string& rTypeString);
116
117     /** Convert a Barrier Type to a string representation.
118     * @param  barrierType    The type to convert.
119     * @return  string representation of the type.
120     * @throw   OsmException if unknown barrier type (out of bounds).
121     */
122     static std::string  toString(BarrierType barrierType);
123
124     /** Convert this BarrierType to a string.
125     * @return  string representation of this VehicleType.
126     */
127     std::string          toString() const;
128
129     /** See if this Barrier type permits access according to rule;
130     * @param  RestrictionRule
131     * @return  true if access is allowed, false if not
132     */
133     bool                  restrictsAccess(RestrictionsRule rule) const;
134
135     /** See if this Barrier type costs to pass according to rule;
136     * @param  RestrictionRule
137     * @return  true if access is allowed, false if not
138     */
139     bool                  costsToPass(CostsRule rule) const;
140
141     // ACCESS
142     // INQUIRY
143     protected:
144     private:
145         BarrierType          mType {NONE};
146         static const std::vector<std::string> sTypeStrings;
147         static const std::vector<std::string> sDisregardedTypes;
148     };
149
150     // INLINE METHODS
151     //
152
153     // EXTERNAL REFERENCES
154     //
155
156     #endif /* OSM_OSMBARRIER_H_ */

```

D.12.5 OsmBarrier.cc

```

1  /*
2  * OsmBarrier.cc
3  *
4  * @author  Jonas Bergman
5  */
6
7
8  #include "OsmBarrier.h" // class implemented
9
10 // RestrictionsRule -----
11 OsmBarrier::RestrictionsRule::RestrictionsRule(

```

```
12     std::initializer_list<OsmBarrier::BarrierType> restrictionTypes)
13     : restrictionTypes(restrictionTypes)
14 { }
15
16 bool
17 OsmBarrier::RestrictionsRule::restrictsAccess(OsmBarrier::BarrierType type) const
18 {
19     auto it = std::find(restrictionTypes.begin(), restrictionTypes.end(), type);
20     return it != restrictionTypes.end();
21 }
22
23 bool
24 OsmBarrier::CostsRule::costsToPass(OsmBarrier::BarrierType type) const
25 {
26     const auto& it = costs.find(type);
27     return it != costs.end();
28 }
29
30 Cost
31 OsmBarrier::CostsRule::getCost(OsmBarrier::BarrierType type) const
32 {
33     const auto& it = costs.find(type);
34     if(it != costs.end())
35     {
36         return it->second;
37     }
38     else
39     {
40         return 0;
41     }
42 }
43
44 void
45 OsmBarrier::CostsRule::addCost(OsmBarrier::BarrierType type, Cost cost)
46 {
47     costs.erase(type);
48     costs.insert({type, cost});
49 }
50
51 ////////////////////////////////// PUBLIC //////////////////////////////////
52
53 //===== LIFECYCLE =====
54 OsmBarrier::OsmBarrier(OsmBarrier::BarrierType type)
55     : mType(type)
56 {}
57
58 //===== OPERATORS =====
59
60 //static
61 OsmBarrier::BarrierType
62 OsmBarrier::parseString(const std::string& rTypeString)
63 {
64     for(size_t i = 0; i < sTypeStrings.size(); ++i)
65     {
66         if(rTypeString == OsmBarrier::sTypeStrings[i])
67         {
68             return static_cast<BarrierType>(i);
```

```
69     }
70 }
71 // no match in types. Look if it is disregarded or unknown.
72 auto it = std::find(sDisregardedTypes.begin(),
73                   sDisregardedTypes.end(),
74                   rTypeString);
75 if(it != sDisregardedTypes.end())
76 {
77     return BarrierType::NONE;
78 }
79 throw OsmException("OsmBarrier::parseString: Unknown Barrier Type string: "
80                   + rTypeString);
81 }
82
83 //static
84 std::string
85 OsmBarrier::toString(OsmBarrier::BarrierType accessType)
86 {
87     if(accessType >= sTypeStrings.size())
88     {
89         throw OsmException("OsmBarrier::toString: Unknown Barrier Type");
90     }
91     return OsmBarrier::sTypeStrings[accessType];
92 }
93
94 std::string
95 OsmBarrier::toString() const
96 {
97     return sTypeStrings[this->mType];
98 }
99
100 bool
101 OsmBarrier::restrictsAccess(OsmBarrier::RestrictionsRule rule) const
102 {
103     return rule.restrictsAccess(mType);
104 }
105
106 bool
107 OsmBarrier::costsToPass(OsmBarrier::CostsRule rule) const
108 {
109     return rule.costsToPass(mType);
110 }
111
112 //===== OPERATIONS =====
113 //===== ACCESS =====
114 //===== INQUIRY =====
115 ////////////////////////////////// PROTECTED //////////////////////////////////
116
117 ////////////////////////////////// PRIVATE //////////////////////////////////
118 const std::vector<std::string> OsmBarrier::sTypeStrings
119 {
120     "none",
121     "block",
122     "bollard",
123     "border_control",
124     "bump_gate",
125     "bus_trap",
```

```
126     "cattle_grid",
127     "chain",
128     "cycle_barrier",
129     "debris",
130     "entrance",
131     "full-height_turnstile",
132     "gate",
133     "hampshire_gate",
134     "height_restrictor",
135     "horse_stile",
136     "jersey_barrier",
137     "kent_carriage_gap",
138     "kissing_gate",
139     "lift_gate",
140     "log",
141     "motorcycle_barrier",
142     "rope",
143     "sally_port",
144     "spikes",
145     "stile",
146     "sump_buster",
147     "swing_gate",
148     "toll_booth",
149     "turnstile",
150     "yes"
151 };
152
153 const std::vector<std::string> OsmBarrier::sDisregardedTypes
154 {
155     "cable_barrier",
156     "city_wall",
157     "ditch",
158     "fence",
159     "guard_rail",
160     "handrail",
161     "hedge",
162     "kerb",
163     "retaining_wall",
164     "wall",
165 };
```

D.12.6 OsmException.h

```
1  /** Exception thrown in the 'osm' package.
2   *
3   * #include "OsmException.h"
4   *
5   * @author Jonas Bergman
6   */
7
8  #ifndef OSM_OSMEXCEPTION_H_
9  #define OSM_OSMEXCEPTION_H_
10
11 // SYSTEM INCLUDES
12 //
13 #include <exception>
14 #include <string>
```

```
15
16 // PROJECT INCLUDES
17 //
18
19 // LOCAL INCLUDES
20 //
21
22 // FORWARD REFERENCES
23 //
24
25 /**
26  * Exception to throw in the 'osm' package.
27  * More information of the type of exception is given in the 'what()' message.
28  */
29 class OsmException : public std::exception
30 {
31 public:
32 // LIFECYCLE
33     /** Default constructor.
34     */
35     OsmException() = delete;
36
37     /** Constructor taking a message to display.
38     *
39     * @param message    The message to prepend when 'what()' is called.
40     */
41     OsmException(const std::string& rMessage) noexcept
42         : std::exception(), mMessage(rMessage)
43     {}
44
45 // OPERATORS
46 // OPERATIONS
47 // ACCESS
48 // INQUIRY
49     const char* what() const noexcept
50     { return (mMessage.c_str()); }
51
52 protected:
53 private:
54 // ATTRIBUTES
55     std::string    mMessage;
56 };
57
58 // INLINE METHODS
59 //
60
61 // EXTERNAL REFERENCES
62 //
63
64 #endif /* OSM_OSMEXCEPTION_H_ */
```

D.12.7 OsmHighway.h

```
1 /** Access to `Highway` data from the OSM file.
2  *
3  * #include "OsmHighway.h"
4  *
```

```
5  * @author Jonas Bergman
6  */
7
8  #ifndef OSM_OSMHIGHWAY_H_
9  #define OSM_OSMHIGHWAY_H_
10
11 // SYSTEM INCLUDES
12 //
13 #include <string>
14 #include <sstream>
15 #include <vector>
16
17 // PROJECT INCLUDES
18 //
19
20 // LOCAL INCLUDES
21 //
22 #include "OsmException.h"
23
24 // FORWARD REFERENCES
25 //
26
27
28 /**
29  * Class for categories of OSM `highway` and `surface`.
30  */
31 class OsmHighway
32 {
33 public:
34 // TYPES
35     enum HighwayType
36     {
37         // roads
38         MOTORWAY,
39         MOTORWAY_LINK,
40         TRUNK,
41         TRUNK_LINK,
42         PRIMARY,
43         PRIMARY_LINK,
44         SECONDARY,
45         SECONDARY_LINK,
46         TERTIARY,
47         TERTIARY_LINK,
48         UNCLASSIFIED,
49         RESIDENTIAL,
50         SERVICE,
51
52         // special types
53         LIVING_STREET,
54         BUS_GUIDEWAY,
55         ROAD,
56
57         NR_HIGHWAY_TYPES
58     };
59
60     enum SurfaceType
61     {
```

```
62         PAVED,
63         ASPHALT,
64         COBBLESTONE,
65         COBBLESTONE_FLATTENED,
66         SETT,
67         CONCRETE,
68         CONCRETE_LANES,
69         CONCRETE_PLATES,
70         PAVING_STONES,
71         METAL,
72         WOOD,
73
74         UNPAVED,
75         COMPACTED,
76         DIRT,
77         EARTH,
78         FINE_GRAVEL,
79         GRASS,
80         GRASS_PAVER,
81         GRAVEL,
82         GROUND,
83         ICE,
84         MUD,
85         PEBBLESTONE,
86         SALT,
87         SAND,
88         SNOW,
89         WOODCHIPS,
90
91         METAL_GRID,
92
93         NR_SURFACE_TYPES
94     };
95
96     enum JunctionType
97     {
98         ROUNDABOUT
99     };
100     static constexpr const char* JUNCTION_ROUNDABOUT = "roundabout";
101
102     // LIFECYCLE
103     OsmHighway() = delete;
104     OsmHighway(HighwayType type);
105     OsmHighway(const OsmHighway& from) = default;
106     ~OsmHighway() = default;
107
108     // OPERATORS
109     // OPERATIONS
110     /** Attempt to parse a string to a HighwayType
111     * @param rTypeString String which could contain a Highway type
112     * @return A valid HighwayType
113     * @throw OsmException if invalid string.
114     */
115     static HighwayType parseString(const std::string& rTypeString);
116
117     /** Attempt to parse a string to a SurfaceType
118     * @param rTypeString String which could contain a Surface type
```

```
119     * @return A valid SurfaceType
120     * @throw OsmException if invalid string.
121     */
122     static SurfaceType parseSurfaceString(const std::string& rSurfaceString);
123
124     /** Convert a Highway Type to a string representation.
125     * @param highwayType The type to convert.
126     * @return string representation of the type.
127     * @throw OsmException if unknown highway type (out of bounds).
128     */
129     static std::string toString(HighwayType highwayType);
130
131     /** Convert a SurfaceType to a string representation.
132     * @param surfaceType The type to convert.
133     * @return string representation of the type.
134     * @throw OsmException if unknown highway type (out of bounds).
135     */
136     static std::string toSurfaceString(SurfaceType surfaceType);
137
138     /** Convert this HighwayType to a string.
139     * @return string representation of this HighwayType.
140     */
141     std::string toString() const;
142
143 // ACCESS
144 /**
145     * @return A vector of all types as strings.
146     */
147     static const std::vector<std::string>& typeStrings();
148
149 /**
150     * @return A vector of all surface types as strings.
151     */
152     static const std::vector<std::string>& surfaceTypeStrings();
153
154 /** Return "(motorway, trunk...)".
155     * @return A string of all types, comma separated, with parentheses round.
156     */
157     static std::string typesAsCommaSeparatedString();
158
159 // INQUIRY
160 protected:
161 private:
162     HighwayType mType {ROAD};
163     static const std::vector<std::string> sTypeStrings;
164     static const std::vector<std::string> sSurfaceTypeStrings;
165 };
166
167 // INLINE METHODS
168 //
169
170 // EXTERNAL REFERENCES
171 //
172
173 #endif /* OSM_OSMHIGHWAY_H_ */
```


D.12.8 OsmHighway.cc

```
1  /*
2   * OsmHighway.cc
3   *
4   * @author Jonas Bergman
5   */
6
7  #include "OsmHighway.h" // class implemented
8
9  ////////////////////////////////// PUBLIC //////////////////////////////////
10
11  //===== LIFECYCLE =====
12  OsmHighway::OsmHighway(OsmHighway::HighwayType type)
13      : mType(type)
14  {}
15
16  //===== OPERATORS =====
17  //===== OPERATIONS =====
18  //static
19  OsmHighway::HighwayType
20  OsmHighway::parseString(const std::string& rTypeString)
21  {
22      for(size_t i = 0; i < NR_HIGHWAY_TYPES; ++i)
23      {
24          if(rTypeString == OsmHighway::sTypeStrings[i])
25          {
26              return static_cast<HighwayType>(i);
27          }
28      }
29      throw OsmException("OsmHighway:parseString: Unknown Highway Type string.");
30  }
31
32  //static
33  OsmHighway::SurfaceType
34  OsmHighway::parseSurfaceString(const std::string& rSurfaceString)
35  {
36      for(size_t i = 0; i < NR_SURFACE_TYPES; ++i)
37      {
38          if(rSurfaceString == OsmHighway::sSurfaceTypeStrings[i])
39          {
40              return static_cast<SurfaceType>(i);
41          }
42      }
43      throw OsmException("OsmHighway:parseSurfaceString: Unknown Surface Type string.");
44  }
45
46  //static
47  std::string
48  OsmHighway::toString(OsmHighway::HighwayType highwayType)
49  {
50      if(highwayType >= NR_HIGHWAY_TYPES)
51      {
52          throw OsmException("OsmHighway:toString: Unknown Highway Type");
53      }
54      return OsmHighway::sTypeStrings[highwayType];
55  }
56
```

```
57 //static
58 std::string
59 OsmHighway::toSurfaceString(OsmHighway::SurfaceType surfaceType)
60 {
61     if(surfaceType >= NR_SURFACE_TYPES)
62     {
63         throw OsmException("OsmHighway::toSurfaceString: Unknown Surface Type");
64     }
65     return OsmHighway::sSurfaceTypeStrings[surfaceType];
66 }
67
68 std::string
69 OsmHighway::toString() const
70 {
71     return sTypeStrings[this->mType];
72 }
73
74 //===== ACCESS =====
75 //static
76 const std::vector<std::string>&
77 OsmHighway::typeStrings()
78 {
79     return OsmHighway::sTypeStrings;
80 }
81
82 //static
83 const std::vector<std::string>&
84 OsmHighway::surfaceTypeStrings()
85 {
86     return OsmHighway::sSurfaceTypeStrings;
87 }
88
89 // static
90 std::string
91 OsmHighway::typesAsCommaSeparatedString()
92 {
93     std::string cols;
94     std::stringstream ss;
95     ss << "(";
96     for(size_t i = 0; i < sTypeStrings.size(); ++i)
97     {
98         ss << " " << sTypeStrings[i] << " ";
99         if(i < sTypeStrings.size() - 1)
100         {
101             ss << ", ";
102         }
103     }
104     ss << ")";
105     return ss.str();
106 }
107 //===== INQUIRY =====
108 //===== PROTECTED =====
109
110 //===== PRIVATE =====
111 const std::vector<std::string> OsmHighway::sTypeStrings
112 {
113     "motorway",
```

```
114     "motorway_link",
115     "trunk",
116     "trunk_link",
117     "primary",
118     "primary_link",
119     "secondary",
120     "secondary_link",
121     "tertiary",
122     "tertiary_link",
123     "unclassified",
124     "residential",
125     "service",
126
127     "living_street",
128     "bus_guideway",
129     "road"
130 };
131
132 const std::vector<std::string> OsmHighway::sSurfaceTypeStrings
133 {
134     "paved",
135     "asphalt",
136     "cobblestone",
137     "cobblestone:flattened",
138     "sett",
139     "concrete",
140     "concrete:lanes",
141     "concrete:plates",
142     "paving_stones",
143     "metal",
144     "wood",
145
146     "unpaved",
147     "compacted",
148     "dirt",
149     "earth",
150     "fine_gravel",
151     "grass",
152     "grass_paver",
153     "gravel",
154     "ground",
155     "ice",
156     "mud",
157     "pebblestone",
158     "salt",
159     "sand",
160     "snow",
161     "woodchips",
162
163     "metal_grid"
164 };
```

D.12.9 OsmId.h

```
1  /*
2  * OsmId.h
3  *
```

```
4  * @author Jonas Bergman
5  */
6
7  #ifndef OSM_OSMID_H_
8  #define OSM_OSMID_H_
9
10 #include <limits>
11
12 typedef long long OsmIdType;
13
14 struct Osm
15 {
16     static const OsmIdType MAX_ID;
17 };
18
19
20
21 #endif /* OSM_OSMID_H_ */
```

D.12.10 OsmId.cc

```
1  /*
2  * OsmId.cc
3  *
4  * @author Jonas Bergman
5  */
6
7  #include "OsmId.h"
8
9  const OsmIdType Osm::MAX_ID = std::numeric_limits<OsmIdType>::max();
```

D.12.11 OsmTurningRestriction.h

```
1  /** Access to Turning restriction data from the OSM file.
2  *
3  * #include "OsmTurningRestriction.h"
4  *
5  * @author Jonas Bergman
6  */
7
8  #ifndef OSM_OSMTURNINGRESTRICTION_H_
9  #define OSM_OSMTURNINGRESTRICTION_H_
10
11 // SYSTEM INCLUDES
12 //
13 #include <algorithm>
14 #include <initializer_list>
15 #include <sstream>
16 #include <string>
17 #include <vector>
18
19 // PROJECT INCLUDES
20 //
21
22 // LOCAL INCLUDES
23 //
24 #include "OsmException.h"
```

```
25 #include "../graph/Edge.h"
26 #include "../graph/Vertex.h"
27
28 // FORWARD REFERENCES
29 //
30
31 /**
32  * Class for working with "turning restrictions" from OSM relations.
33  */
34 class OsmTurningRestriction
35 {
36 public:
37 // TYPES
38     enum TurningRestrictionType
39     {
40         NONE,
41         NO_LEFT_TURN,
42         NO_RIGHT_TURN,
43         NO_STRAIGHT_ON,
44         NO_U_TURN,
45         ONLY_RIGHT_TURN,
46         ONLY_LEFT_TURN,
47         ONLY_STRAIGHT_ON,
48         NO_ENTRY,
49         NO_EXIT,
50
51         NR_TURNING_RESTRICTION_TYPES
52     };
53
54     enum TurningViaType
55     {
56         VIA_NODE,
57         VIA_WAY
58     };
59
60 // LIFECYCLE
61     /** Constructor. Disabled*/
62     OsmTurningRestriction() = delete;
63
64     /** Constructor.
65      * Turning restriction via a vertex.
66      * @param type The type of turning restriction.
67      * @param fromEdgeId The Edge the turn starts at.
68      * @param viaVertexId The Vertex the turn travels via.
69      * @param toEdgeId The Edge the turn ends at.
70      */
71     OsmTurningRestriction(TurningRestrictionType type,
72                           EdgeIdType fromEdgeId,
73                           VertexIdType viaVertexId,
74                           EdgeIdType toEdgeId);
75
76     /** Constructor.
77      * Turning restriction via other Edges.
78      * @param type The type of turning restriction.
79      * @param fromEdgeId The Edge the turn starts at.
80      * @param viaOsmIds String with the OsmIds of roads the turn travels via.
81      * @param toEdgeId The Edge the turn ends at.
```

```
82     */
83     OsmTurningRestriction(TurningRestrictionType    type,
84                           EdgeIdType                fromEdgeId,
85                           std::string                viaOsmIds,
86                           EdgeIdType                toEdgeId);
87
88     /** Copy constructor. */
89     OsmTurningRestriction(const OsmTurningRestriction& from) = default;
90
91     /** Destructor. */
92     ~OsmTurningRestriction() = default;
93
94     // OPERATORS
95     // OPERATIONS
96     /** Attempt to parse a string to a TurningRestrictionType
97     * @param rTypeString String which could contain a Turning Restriction
98     * @return A valid TurningRestrictionType
99     * @throw OsmException if invalid string.
100    */
101    static TurningRestrictionType parseString(const std::string& rTypeString);
102
103    /** Convert a Turning Restriction Type to a string representation.
104    * @param turnRestrictionType The type to convert.
105    * @return string representation of the type.
106    * @throw OsmException if unknown turn restriction type (out of bounds).
107    */
108    static std::string toString(TurningRestrictionType turnRestrictionType);
109
110    /** Convert this TurningRestriction to a string.
111    * @return string representation of this turning restriction.
112    */
113    std::string toString() const;
114
115    /** Convert this TurningRestrictions type to a string.
116    * @return string representation of this turning restriction type.
117    */
118    std::string typeToString() const;
119
120    // ACCESS
121    /**
122     * @return The Edge Id of the 'from' edge
123     */
124    EdgeIdType fromEdgeId() const;
125
126    /**
127     * @return The Via type, 'way' or 'node'.
128     */
129    TurningViaType viaType() const;
130
131    /**
132     * @return The Ids of the Edges in a 'via way' relation.
133     */
134    std::string viaOsmIds() const;
135
136    /**
137     * @return The Vertex Id of the 'via' vertex.
138     */
```

```

139     VertexIdType      viaVertexId() const;
140
141     /**
142      * @return The Edge id of the 'to' Edge.
143      */
144     EdgeIdType      toEdgeId() const;
145
146 // INQUIRY
147 /** Check if an Edge is in this restriction.
148  * @param Edge Id to check.
149  * @return true if the edge is part of this restriction, false if not.
150  */
151 bool      isInRestriction(EdgeIdType edgeId) const;
152
153 /** Check if Travel from 'from' to 'to' is restricted.
154  * @param fromEdgeId Travel from edge.
155  * @param toEdgeId Travel to edge.
156  * @return true if travel is restricted.
157  */
158 bool      isRestricted(
159             EdgeIdType fromEdgeId,
160             EdgeIdType toEdgeId) const;
161
162 protected:
163 private:
164     TurningRestrictionType      mType {NONE};
165     EdgeIdType                  mFromEdgeId;
166     TurningViaType              mViaType {VIA_NODE};
167     std::string                  mViaOsmIds;
168     VertexIdType                mViaVertexId;
169     EdgeIdType                  mToEdgeId;
170     static std::vector<std::string> sTypeStrings;
171 };
172
173 // INLINE METHODS
174 //
175
176 // EXTERNAL REFERENCES
177 //
178
179 #endif /* OSM_OSMTURNINGRESTRICTION_H_ */

```

D.12.12 OsmTurningRestriction.cc

```

1  /*
2   * OsmTurningRestriction.cc
3   *
4   * @author Jonas Bergman
5   */
6
7  #include "OsmTurningRestriction.h" // class implemented
8
9  ////////////////////////////////// PUBLIC //////////////////////////////////
10
11  //===== LIFECYCLE =====
12  OsmTurningRestriction::OsmTurningRestriction(
13      OsmTurningRestriction::TurningRestrictionType type,

```

```
14     EdgeIdType                                fromEdgeId,
15     VertexIdType                              viaVertexId,
16     EdgeIdType                                toEdgeId)
17     : mType(type),
18       mFromEdgeId(fromEdgeId),
19       mViaType(VIA_NODE),
20       mViaOsmIds(),
21       mViaVertexId(viaVertexId),
22       mToEdgeId(toEdgeId)
23 {}
24
25 OsmTurningRestriction::OsmTurningRestriction(
26     OsmTurningRestriction::TurningRestrictionType type,
27     EdgeIdType                                fromEdgeId,
28     std::string                              viaOsmIds,
29     EdgeIdType                                toEdgeId)
30     : mType(type),
31       mFromEdgeId(fromEdgeId),
32       mViaType(VIA_WAY),
33       mViaOsmIds(viaOsmIds),
34       mViaVertexId(),
35       mToEdgeId(toEdgeId)
36 {}
37
38 //===== OPERATORS =====
39 //===== OPERATIONS =====
40 //static
41 OsmTurningRestriction::TurningRestrictionType
42 OsmTurningRestriction::parseString(const std::string& rTypeString)
43 {
44     for(size_t i = 0; i < sTypeStrings.size(); ++i)
45     {
46         if(rTypeString == OsmTurningRestriction::sTypeStrings[i])
47         {
48             return static_cast<TurningRestrictionType>(i);
49         }
50     }
51     throw OsmException(
52         "OsmTurningRestriction:parseString: "
53         "Unknown TurningRestriction Type string.");
54 }
55
56 //static
57 std::string
58 OsmTurningRestriction::toString(
59     OsmTurningRestriction::TurningRestrictionType turnRestrictionType)
60 {
61     if(turnRestrictionType >= sTypeStrings.size())
62     {
63         throw OsmException(
64             "OsmTurningRestriction:toString: Unknown TurningRestriction Type");
65     }
66     return OsmTurningRestriction::sTypeStrings[turnRestrictionType];
67 }
68
69 std::string
70 OsmTurningRestriction::toString() const
```



```
71 {
72     std::ostringstream oss;
73     oss << sTypeStrings[this->mType] << ": "
74         << "from: " << mFromEdgeId;
75
76     // via vertex
77     if(mViaType == VIA_NODE)
78     {
79         oss << ", via vertex: " << mViaVertexId;
80     }
81     else // via edges
82     {
83         oss << ", via edges: [" << mViaOsmIds << "]";
84     }
85
86     oss << ", to: " << mToEdgeId;
87
88     return oss.str();
89 }
90
91 std::string
92 OsmTurningRestriction::typeToString() const
93 {
94     return sTypeStrings[this->mType];
95 }
96 //===== ACCESS =====
97 EdgeIdType
98 OsmTurningRestriction::fromEdgeId() const
99 {
100     return mFromEdgeId;
101 }
102
103 OsmTurningRestriction::TurningViaType
104 OsmTurningRestriction::viaType() const
105 {
106     return mViaType;
107 }
108
109 std::string
110 OsmTurningRestriction::viaOsmIds() const
111 {
112     return mViaOsmIds;
113 }
114
115 VertexIdType
116 OsmTurningRestriction::viaVertexId() const
117 {
118     return mViaVertexId;
119 }
120
121 EdgeIdType
122 OsmTurningRestriction::toEdgeId() const
123 {
124     return mToEdgeId;
125 }
126 //===== INQUIRY =====
127 bool
```

```
128 OsmTurningRestriction::isInRestriction(EdgeIdType edgeId) const
129 {
130     if(edgeId == mFromEdgeId
131         || edgeId == mToEdgeId)
132     {
133         return true;
134     }
135     return false;
136 }
137
138 bool
139 OsmTurningRestriction::isRestricted(
140     EdgeIdType fromEdgeId,
141     EdgeIdType toEdgeId) const
142 {
143     if(mFromEdgeId == fromEdgeId && mToEdgeId == toEdgeId)
144     {
145         if(mType == NO_LEFT_TURN
146             || mType == NO_RIGHT_TURN
147             || mType == NO_STRAIGHT_ON
148             || mType == NO_U_TURN
149             || mType == NO_ENTRY
150             || mType == NO_EXIT)
151         {
152             return true;
153         }
154     }
155     return false;
156 }
157 ////////////////////////////////////////////////// PROTECTED //////////////////////////////////////
158
159 ////////////////////////////////////////////////// PRIVATE //////////////////////////////////////
160 // static
161 std::vector<std::string> OsmTurningRestriction::sTypeStrings
162 {
163     "none",
164     "no_left_turn",
165     "no_right_turn",
166     "no_straight_on",
167     "no_u_turn",
168     "only_right_turn",
169     "only_left_turn",
170     "only_straight_on",
171     "no_entry",
172     "no_exit"
173 };
```

D.12.13 OsmVehicle.h

```
1  /** Access to Vehicle data from the OSM file.
2   *
3   * #include "OsmVehicle.h"
4   *
5   * @author Jonas Bergman
6   */
7
8  #ifndef OSM_OSMVEHICLE_H_
```

```
9  #define OSM_OSMVEHICLE_H_
10
11  // SYSTEM INCLUDES
12  //
13  #include <string>
14
15  // PROJECT INCLUDES
16  //
17
18  // LOCAL INCLUDES
19  //
20  #include "OsmException.h"
21
22  // FORWARD REFERENCES
23  //
24
25  /**
26   * Class for working with different categories of vehicles.
27   */
28  class OsmVehicle
29  {
30  public:
31  // TYPES
32      enum VehicleType
33      {
34          MOTORCAR,
35          GOODS,
36          HGV,
37          PSV,
38          LHV,
39          MOTOR_VEHICLE,
40          VEHICLE,
41
42          NR_VEHICLE_TYPES
43      };
44
45  // LIFECYCLE
46      OsmVehicle() = delete;
47      OsmVehicle(VehicleType type);
48      OsmVehicle(const OsmVehicle& from) = default;
49      ~OsmVehicle() = default;
50
51  // OPERATORS
52  // OPERATIONS
53      /** Attempt to parse a string to a VehicleType
54       * @param rTypeString String which could contain a Vehicle type
55       * @return A valid VehicleType
56       * @throw OsmException if invalid string.
57       */
58      static VehicleType parseString(const std::string& rTypeString);
59
60      /** Convert a Vehicle Type to a string representation.
61       * @param vehicleType The type to convert.
62       * @return string representation of the type.
63       * @throw OsmException if unknown vehicle type (out of bounds).
64       */
65      static std::string toString(VehicleType vehicleType);
```

```
66
67     /** Convert this VehicleType to a string.
68      * @return string representation of this VehicleType.
69      */
70     std::string      toString() const;
71
72     // ACCESS
73     // INQUIRY
74     protected:
75     private:
76         VehicleType      mType {VEHICLE};
77         static const std::string sTypeStrings[];
78     };
79
80     // INLINE METHODS
81     //
82
83     // EXTERNAL REFERENCES
84     //
85
86     #endif /* OSM_OSMVEHICLE_H_ */
```

D.12.14 OsmVehicle.cc

```
1     /*
2      * OsmVehicle.cc
3      *
4      * @author Jonas Bergman
5      */
6
7     #include "OsmVehicle.h" // class implemented
8
9     ////////////////////////////////// PUBLIC //////////////////////////////////
10
11     //===== LIFECYCLE =====
12     OsmVehicle::OsmVehicle(OsmVehicle::VehicleType type)
13         : mType(type)
14     {}
15
16     //===== OPERATORS =====
17
18     //static
19     OsmVehicle::VehicleType
20     OsmVehicle::parseString(const std::string& rTypeString)
21     {
22         for(size_t i = 0; i < NR_VEHICLE_TYPES; ++i)
23         {
24             if(rTypeString == OsmVehicle::sTypeStrings[i])
25             {
26                 return static_cast<VehicleType>(i);
27             }
28         }
29         throw OsmException("OsmVehicle:parseString: Unknown Vehicle Type string.");
30     }
31
32     //static
33     std::string
```

```
34 OsmVehicle::toString(OsmVehicle::VehicleType vehicleType)
35 {
36     if(vehicleType >= NR_VEHICLE_TYPES)
37     {
38         throw OsmException("OsmVehicle::toString: Unknown Vehicle Type");
39     }
40     return OsmVehicle::sTypeStrings[vehicleType];
41 }
42
43 std::string
44 OsmVehicle::toString() const
45 {
46     return sTypeStrings[this->mType];
47 }
48
49 //===== OPERATIONS =====
50 //===== ACCESS =====
51 //===== INQUIRY =====
52 ////////////////////////////////// PROTECTED //////////////////////////////////
53
54 ////////////////////////////////// PRIVATE //////////////////////////////////
55 const std::string OsmVehicle::sTypeStrings[] =
56 {
57     "motorcar",
58     "goods",
59     "hgv",
60     "psv",
61     "lhv",
62     "motor_vehicle",
63     "vehicle"
64 };
```

D.12.15 OsmAccess_test.cc

```
1  /*
2   * OsmAccess_test.cc
3   *
4   * @author Jonas Bergman
5   */
6
7  #include "../OsmAccess.h"
8  #include "../../catchtest/catch.hpp"
9
10 SCENARIO ("OsmAccess functionality testing", "[osm][access]")
11 {
12     try
13     {
14         // -----
15         GIVEN ("a valid string of an access type")
16         {
17             std::string type_string("designated");
18
19             // .....
20             WHEN ("parsing string to an AccessType")
21             {
22                 OsmAccess::AccessType type =
23                     OsmAccess::parseString(type_string);
```

```
24         THEN ("we should get the corresponding type")
25     {
26         REQUIRE (type == OsmAccess::AccessType::DESIGNATED);
27     }
28 }
29
30
31 // -----
32 GIVEN ("an invalid string of an access type")
33 {
34     std::string type_string("foo");
35
36     // .....
37     WHEN ("parsing string to a AccessType")
38     {
39         THEN ("we should get an OsmException")
40         {
41             REQUIRE_THROWS_AS (OsmAccess::parseString(type_string),
42                                 OsmException&);
43         }
44     }
45 }
46
47 // -----
48 GIVEN ("an access type")
49 {
50     OsmAccess type(OsmAccess::DELIVERY);
51
52     // .....
53     WHEN ("converting type to a string")
54     {
55         THEN ("we should the corresponding string")
56         {
57             REQUIRE (type.toString() == "delivery");
58         }
59     }
60 }
61
62 // -----
63 GIVEN ("an access rule")
64 {
65     OsmAccess::AccessRule rule({OsmAccess::YES, OsmAccess::PERMISSIVE});
66
67     // .....
68     WHEN ("checking for access for type not in rule")
69     {
70         OsmAccess type(OsmAccess::DELIVERY);
71
72         THEN ("we should not be allowed access")
73         {
74             REQUIRE_FALSE (type.allowsAccess(rule));
75         }
76     }
77 }
78 }
79 catch (OsmException& oe)
80 {
```

```
81     INFO(oe.what());
82     REQUIRE (false);    // force output of error and failure
83 }
84 catch (const std::exception& e)
85 {
86     INFO(e.what());
87     REQUIRE (false);    // force output of error and failure
88 }
89 }
90 }
```

D.12.16 OsmBarrier_test.cc

```
1  /*
2   * OsmBarrier_test.cc
3   *
4   * @author Jonas Bergman
5   */
6
7  #include "../OsmBarrier.h"
8  #include "../../catchtest/catch.hpp"
9
10 SCENARIO ("OsmBarrier functionality testing", "[osm][barrier]")
11 {
12     try
13     {
14         // -----
15         GIVEN ("a valid string of an access type")
16         {
17             std::string type_string("swing_gate");
18
19             //.....
20             WHEN ("parsing string to a BarrierType")
21             {
22                 OsmBarrier::BarrierType type =
23                     OsmBarrier::parseString(type_string);
24                 THEN ("we should get the corresponding type")
25                 {
26                     REQUIRE (type == OsmBarrier::BarrierType::SWING_GATE);
27                 }
28             }
29         }
30
31         // -----
32         GIVEN ("an invalid string of a barrier type")
33         {
34             std::string type_string("foo");
35
36             //.....
37             WHEN ("parsing string to a BarrierType")
38             {
39                 THEN ("we should get an OsmException")
40                 {
41                     REQUIRE_THROWS_AS (OsmBarrier::parseString(type_string),
42                                         OsmException&);
43                 }
44             }
45         }
46     }
47 }
```

```
45     }
46
47     // -----
48     GIVEN ("a barrier type")
49     {
50         OsmBarrier type(OsmBarrier::CATTLE_GRID);
51
52         //.....
53         WHEN ("converting type to a string")
54         {
55             THEN ("we should the corresponding string")
56             {
57                 REQUIRE (type.toString() == "cattle_grid");
58             }
59         }
60     }
61
62     // -----
63     GIVEN ("a restriction rule")
64     {
65         OsmBarrier::RestrictionsRule rule({OsmBarrier::YES, OsmBarrier::BOLLARD});
66
67         //.....
68         WHEN ("checking if access is restricted for type not in rule")
69         {
70             OsmBarrier type(OsmBarrier::SPIKES);
71
72             THEN ("we should be told there is no restriction on access")
73             {
74                 REQUIRE_FALSE (type.restrictsAccess(rule));
75             }
76         }
77         //.....
78         WHEN ("checking if access is restricted for type in rule")
79         {
80             OsmBarrier type(OsmBarrier::BOLLARD);
81
82             THEN ("we should be told there restriction on access")
83             {
84                 REQUIRE (type.restrictsAccess(rule));
85             }
86         }
87     }
88
89     // -----
90     GIVEN ("a cost rule")
91     {
92         // OsmBarrier::CostsRule rule({OsmBarrier::GATE, OsmBarrier::DEBRIS});
93         OsmBarrier::CostsRule rule;
94         rule.addCost(OsmBarrier::GATE, 10);
95         rule.addCost(OsmBarrier::DEBRIS, 10);
96
97         //.....
98         WHEN ("checking if access costs for type not in rule")
99         {
100             OsmBarrier type(OsmBarrier::YES);
101
```



```
102         THEN ("we should be told there is no cost on access")
103         {
104             REQUIRE_FALSE (type.costsToPass(rule));
105         }
106     }
107     //.....
108     WHEN ("checking if access costs for type in rule")
109     {
110         OsmBarrier type(OsmBarrier::DEBRIS);
111
112         THEN ("we should be told there is cost on access")
113         {
114             REQUIRE (type.costsToPass(rule));
115         }
116     }
117 }
118 }
119 catch (OsmException& oe)
120 {
121     INFO(oe.what());
122     REQUIRE (false);    // force output of error and failure
123 }
124 catch (const std::exception& e)
125 {
126     INFO(e.what());
127     REQUIRE (false);    // force output of error and failure
128 }
129 }
130 }
```

D.12.17 OsmHighway_test.cc

```
1  /*
2   * OsmHighway_test.cc
3   *
4   * @author Jonas Bergman
5   */
6
7  #include "../OsmHighway.h"
8  #include "../../catchtest/catch.hpp"
9
10 SCENARIO ("OsmHighway functionality testing", "[osm][highway]")
11 {
12     try
13     {
14         // -----
15         GIVEN ("a valid string of a highway type")
16         {
17             std::string type_string("primary");
18
19             //.....
20             WHEN ("parsing string to a HighwayType")
21             {
22                 OsmHighway::HighwayType type =
23                     OsmHighway::parseString(type_string);
24                 THEN ("we should get the corresponding type")
25                 {
```

```
26         REQUIRE (type == OsmHighway::HighwayType::PRIMARY);
27     }
28 }
29
30
31 // -----
32 GIVEN ("an invalid string of a highway type")
33 {
34     std::string type_string("foo");
35
36     // .....
37     WHEN ("parsing string to a HighwayType")
38     {
39         THEN ("we should get an OsmException")
40         {
41             REQUIRE_THROWS_AS (OsmHighway::parseString(type_string),
42                               OsmException&);
43         }
44     }
45 }
46
47 // -----
48 GIVEN ("a highway type")
49 {
50     OsmHighway type(OsmHighway::PRIMARY);
51
52     // .....
53     WHEN ("converting type to a string")
54     {
55         THEN ("we should the corresponding strng")
56         {
57             REQUIRE (type.toString() == "primary");
58         }
59     }
60 }
61
62 catch (OsmException& oe)
63 {
64     INFO(oe.what());
65     REQUIRE (false);    // force output of error and failure
66 }
67 catch (const std::exception& e)
68 {
69     INFO(e.what());
70     REQUIRE (false);    // force output of error and failure
71 }
72 }
73 }
```

D.12.18 OsmTurningRestriction_test.cc

D.12.19 OsmVehicle_test.cc

```
1  /*
2   * OsmVehicle_test.cc
3   *
4   * @author Jonas Bergman
```

```
5  */
6
7  #include "../OsmVehicle.h"
8  #include "../../catchtest/catch.hpp"
9
10 SCENARIO ("OsmVehicle functionality testing", "[osm][vehicle]")
11 {
12     try
13     {
14         // -----
15         GIVEN ("a valid string of a vehicle type")
16         {
17             std::string type_string("motorcar");
18
19             // .....
20             WHEN ("parsing string to a VehicleType")
21             {
22                 OsmVehicle::VehicleType type =
23                     OsmVehicle::parseString(type_string);
24                 THEN ("we should get the corresponding type")
25                 {
26                     REQUIRE (type == OsmVehicle::VehicleType::MOTORCAR);
27                 }
28             }
29         }
30
31         // -----
32         GIVEN ("an invalid string of a vehicle type")
33         {
34             std::string type_string("foo");
35
36             // .....
37             WHEN ("parsing string to a VehicleType")
38             {
39                 THEN ("we should get an OsmException")
40                 {
41                     REQUIRE_THROWS_AS (OsmVehicle::parseString(type_string),
42                                         OsmException&);
43                 }
44             }
45         }
46
47         // -----
48         GIVEN ("a Vehicle type")
49         {
50             OsmVehicle type(OsmVehicle::PSV);
51
52             // .....
53             WHEN ("converting type to a string")
54             {
55                 THEN ("we should the corresponding string")
56                 {
57                     REQUIRE (type.toString() == "psv");
58                 }
59             }
60         }
61     }
}
```

```
62     catch (OsmException& oe)
63     {
64         INFO(oe.what());
65         REQUIRE (false);    // force output of error and failure
66     }
67     catch (const std::exception& e)
68     {
69         INFO(e.what());
70         REQUIRE (false);    // force output of error and failure
71     }
72 }
73 }
```

D.13 preparation

D.13.1 README.md

Preparing database
=====

The preparation differs depending on how you import the map data and build the
↪ topology. So far in this project import has been done with `osm2pgsql` and
↪ topology built with `postgis_topology`.

Preparation for `osm2pgsql` and `postgis_topology`

To prepare the database for this software module when using `osm2pgsql` as
↪ importer of OpenStreetMap data into the database, we need to install
↪ extensions for:

- `postgis`
- `postgis_topology`
- `hstore`

and a couple of custom functions for finding turning restrictions:

- function `find_topo_edges_at_turning_restriction()`
- function `find_osm_turning_restrictions()`

The steps to follow are (assuming `mikhailovsk.osm` as source for OpenStreetMap
↪ data, and `tester` as a user with administrative rights in database, and
↪ `mikh_0530` as name of database):

1. Create database

```
$ createdb mikh_0530 -U tester
```

2. Install extensions and functions

```
$ psql -U tester -d mikh_0530 -f init_osm2pgsql_postgis_topology.sql
```

3. Import OSM data

```
$ osm2pgsql -U tester -d mikh_0530 -s -k -S LGU.style mikhailovsk.osm
```

This uses the tool `osm2pgsql` to parse the osm-file into database tables.
The flags are

- `-s` slim, keeping extra tables.
- `-k` keeping tags in `hstore` if not in their own column.
- `-S` Style file, configuring which tags to have columns or not.

4. Building topology

This step is optional. It should be efficient and safe to build the topology once
→ and for all after importing as differing conditions and temporary closures
→ could be specified with costs and restrictions instead of via topology. But
→ one can also configure the tool to build topology on each call, see the
→ `configuration` package.

```
$ psql -U tester -d mikh_0530 -f build_postgis_topology.sql
```

This step creates a table `public.highways_lgu` and adds a new schema called
→ `topo_lgu` which contains tables for the topology.

Test databases

During testing different databases has been tested, they were created so:

`mikh_style`

```
$ createdb mikh_style -U jonas
$ psql -U jonas -d mikh_style -c "CREATE extension postgis;"
$ psql -U jonas -d mikh_style -c "CREATE extension postgis_topology;"
$ psql -U jonas -d mikh_style -c "CREATE extension hstore;"
$ psql -U jonas -d mikh_style -c "SET search_path=topology,public
$ osm2pgsql -U jonas -d mikh_style -s -k -S new.style mikhailovsk.osm
$ psql -U jonas -d mikh_style -c "CREATE TABLE highways_test AS SELECT * FROM
→ planet_osm_line WHERE highway IS NOT NULL;"
$ psql -U jonas -d mikh_style -c "SELECT topology.CreateTopology('topo_test',
→ 900913);"
$ psql -U jonas -d mikh_style -c "SELECT
→ topology.AddTopoGeometryColumn('topo_test', 'public', 'highways_test',
→ 'topo_geom', 'LINESTRING');"
$ psql -U jonas -d mikh_style -c "UPDATE highways_test SET topo_geom =
→ topology.toTopoGeom(way, 'topo_test', 1, 1.0);"
```

`mikh_0522`

```
$ createdb mikh_0522 -U jonas
$ psql -U jonas -d mikh_0522 -c "CREATE EXTENSION postgis;"
$ psql -U jonas -d mikh_0522 -c "CREATE EXTENSION postgis_topology;"
$ psql -U jonas -d mikh_0522 -c "CREATE EXTENSION hstore;"
$ osm2pgsql -U jonas -d mikh_0522 -s -k -S LGU.style mikhailovsk.osm
$ psql -U jonas -d mikh_0522 -c "CREATE TABLE highways_test AS SELECT * FROM
→ planet_osm_line WHERE highway IS NOT NULL;"
$ psql -U jonas -d mikh_0522 -c "SELECT topology.CreateTopology('topo_test',
→ 900913);"
$ psql -U jonas -d mikh_0522 -c "SELECT
→ topology.AddTopoGeometryColumn('topo_test', 'public', 'highways_test',
→ 'topo_geom', 'LINESTRING');"
```

```
$ psql -U jonas -d mikh_0522 -c "UPDATE highways_test SET topo_geom =  
↪ topology.toTopoGeom(way, 'topo_test', 1, 1.0);"
```

```
#### `mikh_0530`  
Described above.
```

```
#### `mikh_restr_0602`  
As `mikh_0530` but using the modified osm-file `mikhailovsk-turnrestriction.osm`  
↪ instead. That file has been modified with a turn restriction for testing  
↪ purposes.
```

```
#### `mikh_restr_0617`  
As `mikh_0602` but extra columns in `planet_osm_point` to get point restrictions.
```

D.13.2 build_postgis_topology.sql

```
1 CREATE TABLE highways_lgu  
2 AS SELECT *  
3 FROM planet_osm_line  
4 WHERE highway IS NOT NULL;  
5  
6 SELECT topology.CreateTopology('topo_lgu', 900913);  
7  
8 SELECT topology.AddTopoGeometryColumn('topo_lgu',  
9                                         'public',  
10                                        'highways_lgu',  
11                                        'topo_geom',  
12                                        'LINESTRING');  
13  
14 UPDATE highways_lgu SET topo_geom = topology.toTopoGeom(way, 'topo_lgu', 1, 1.0);
```

D.13.3 init_osm2pgsql_postgis_topology.sql

```
1 CREATE EXTENSION postgis;  
2 CREATE EXTENSION postgis_topology;  
3 CREATE EXTENSION hstore;  
4  
5 DROP TABLE IF EXISTS turning_restrictions;  
6 CREATE TABLE turning_restrictions(  
7     from_osm_id      bigint,  
8     to_osm_id        bigint,  
9     via_osm          varchar,  
10    edge_ids          integer[],  
11    restriction_type  varchar);  
12  
13 --  
14 -- Find the topology edge ids affected by osm turn restrictions.  
15 --  
16 CREATE OR REPLACE FUNCTION  
17     find_topo_edges_at_turning_restriction(  
18         osm_edges_table text,  
19         from_osm_id bigint,  
20         to_osm_id bigint,  
21         topo_edges_table text)  
22 RETURNS setof RECORD  
23 AS $$
```

```
24 BEGIN
25     RETURN QUERY EXECUTE format('
26         SELECT edge_id
27         FROM %4$s
28         WHERE ST_DWithin (
29             geom,
30             ( SELECT ST_Intersection(a.way, b.way)
31               FROM %1$I a, %1$I b
32               WHERE a.osm_id = %2$s AND b.osm_id = %3$s
33             ),
34             1.0
35         );'
36     , osm_edges_table, from_osm_id, to_osm_id, topo_edges_table);
37 END;
38 $$ LANGUAGE 'plpgsql';
39
40
41 --
42 -- Find all the restrictions and put them in table 'turning_restrictions'
43 --
44 CREATE OR REPLACE FUNCTION
45     find_osm_turning_restrictions(osm_edges_table text, topo_edges_table text)
46 RETURNS integer
47 AS $$
48 DECLARE
49     nrFindings integer := 0;
50     nrFrom integer := 0;
51     nrTo integer := 0;
52     restrictionRecord record;
53     ix integer;
54     id bigint;
55     fromOsmId bigint;
56     toOsmId bigint;
57     viaText text := '';
58     restrictions text[] := '{
59         "no_right_turn",
60         "no_left_turn",
61         "no_u_turn",
62         "no_straight_on",
63         "only_right_turn",
64         "only_left_turn",
65         "only_straight_on",
66         "no_entry",
67         "no_exit"
68     }';
69     restrType text;
70     edgeId integer;
71     edges integer[];
72
73 BEGIN
74     FOR restrictionRecord IN
75         SELECT *
76         FROM planet_osm_rels
77         WHERE (
78             SELECT 'restriction' = ANY(tags)
79         )
80         AND ( -- check that the restriction type is given in tags
```

```
81     SELECT restrictions && tags
82 )
83 LOOP
84     -- look through 'members' in all restrictions, must have at least 6 elements
85     -- {from_id, from, via_id, via, to_id, to}
86     IF (array_upper(restrictionRecord.members, 1) >= 6) THEN
87
88         nrFrom := 0;
89         nrTo := 0;
90
91         -- look for type: from, via, to
92         FOR ix IN 1..(array_length(restrictionRecord.members, 1)-1)
93         LOOP
94             IF restrictionRecord.members[ix+1] LIKE 'from' THEN
95                 fromOsmId :=
96                     trim(leading 'wn' from restrictionRecord.members[ix])::bigint;
97                 nrFrom := nrFrom + 1;
98             ELSIF restrictionRecord.members[ix+1] LIKE 'to' THEN
99                 toOsmId :=
100                     trim(leading 'wn' from restrictionRecord.members[ix])::bigint;
101                 nrTo := nrTo + 1;
102             ELSIF restrictionRecord.members[ix+1] LIKE 'via' THEN
103                 viaText := viaText || restrictionRecord.members[ix] || ',';
104             END IF;
105         END LOOP;
106
107         IF (nrFrom != 1 OR nrTo != 1) THEN
108             CONTINUE;
109         END IF;
110
111         -- look for restriction type
112         FOR ix IN 1..array_upper(restrictions, 1)
113         LOOP
114             IF (SELECT restrictions[ix] = ANY(restrictionRecord.tags)) THEN
115                 restrType := restrictions[ix];
116                 EXIT;
117             END IF;
118         END LOOP;
119
120         -- find topology edge ids that might be affected
121         -- each osm edge could have two topology edges (in and out at vertex)
122         -- and there is no really easy way of finding who is who?
123         FOR edgeId IN
124             SELECT *
125             FROM find_topo_edges_at_turning_restriction(
126                 osm_edges_table,
127                 fromOsmId,
128                 toOsmId,
129                 topo_edges_table)
130             AS f(id integer)
131         LOOP
132             edges := array_append(edges, edgeId);
133         END LOOP;
134
135         -- store findings
136         INSERT INTO turning_restrictions
137             VALUES (fromOsmId, toOsmId, viaText, edges, restrType);
```



```
138         nrFindings := nrFindings + 1;
139     END IF;
140 END LOOP;
141 RETURN nrFindings;
142 END;
143 $$ LANGUAGE 'plpgsql';
```

D.13.4 LGU.style

```
1  # This is the default osm2pgsql .style file that comes with osm2pgsql.
2  #
3  # A .style file has 4 columns that define how OSM objects end up in tables in
4  # the database and what columns are created. It interacts with the command-line
5  # hstore options.
6  #
7  # Columns
8  # =====
9  #
10 # OsmType: This is either "node", "way" or "node,way" and indicates if this tag
11 # applies to nodes, ways, or both.
12 #
13 # Tag: The tag
14 #
15 # DataType: The type of the column to be created. Normally "text"
16 #
17 # Flags: Flags that indicate what table the OSM object is moved into.
18 #
19 # There are 5 possible flags. These flags are used both to indicate if a column
20 # should be created, and if ways with the tag are assumed to be areas. The area
21 # assumptions can be overridden with an area=yes/no tag
22 #
23 # polygon - Create a column for this tag, and objects the tag with are areas
24 #
25 # linear - Create a column for this tag
26 #
27 # phstore - Don't create a column for this tag, but objects with the tag are areas
28 #
29 # delete - Drop this tag completely and don't create a column for it. This also
30 # prevents the tag from being added to hstore columns
31 #
32 # nocache - Deprecated and does nothing
33 #
34 # If an object has a tag that indicates it is an area or has area=yes/1,
35 # osm2pgsql will try to turn it into an area. If it succeeds, it places it in
36 # the polygon table. If it fails (e.g. not a closed way) it places it in the
37 # line table.
38 #
39 # Nodes are never placed into the polygon or line table and are always placed in
40 # the point table.
41 #
42 # Hstore
43 # =====
44 #
45 # The options --hstore, --hstore-match-only, and --hstore-all interact with
46 # the .style file.
47 #
48 # With --hstore any tags without a column will be added to the hstore column.
```

```

49 # This will also cause all objects to be kept.
50 #
51 # With --hstore-match-only the behavior for tags is the same, but objects are
52 # only kept if they have a non-NULL value in one of the columns.
53 #
54 # With --hstore-all all tags are added to the hstore column unless they appear
55 # in the style file with a delete flag, causing duplication between the normal
56 # columns and the hstore column.
57 #
58 # Special database columns
59 # =====
60 #
61 # There are some special database columns that if present in the .style file
62 # will be populated by osm2pgsql.
63 #
64 # These are
65 #
66 # z_order - datatype int4
67 #
68 # way_area - datatype real. The area of the way, in the units of the projection
69 # (e.g. square mercator meters). Only applies to areas
70 #
71 # osm_user - datatype text
72 # osm_uid - datatype integer
73 # osm_version - datatype integer
74 # osm_changeset - datatype integer
75 # osm_timestamp - datatype timestampz(0).
76 # Used with the --extra-attributes option to include metadata in the database.
77 # If importing with both --hstore and --extra-attributes the meta-data will
78 # end up in the tags hstore column regardless of the style file.
79
80 # OsmType   Tag                      DataType   Flags
81 #####
82 node,way    access                    text       linear
83 node,way    barrier                   text       linear
84 node        crossing                 text       linear
85 node,way    disused                   text       linear
86 node,way    emergency                  text       linear
87 node,way    highway                   text       linear
88 node,way    incline                    text       linear
89 way         junction                  text       linear
90 way         lanes                    text       linear
91 way         maxheight                 text       linear
92 way         maxlength                 text       linear
93 way         maxspeed                  text       linear
94 way         minspeed                  text       linear
95 way         maxweight                 text       linear
96 way         maxwidth                  text       linear
97 node,way    noexit                     text       linear
98 way         oneway                    text       linear
99 node,way    public_transport             text       linear
100 node,way    restriction                   text       linear
101 node,way    railway                       text       linear # :level_crossing, tram, tram_stop
102 way         surface                    text       linear
103 node        toll                      text       linear
104 way         tracktype                  text       linear
105 node,way    traffic_calming                 text       linear

```

```
106 node,way    traffic_sign    text    linear
107
108 # Access restrictions for vehicle types
109 node,way    goods            text    linear
110 node,way    hgv              text    linear
111 node,way    lhv              text    linear
112 node,way    motorcar         text    linear
113 node,way    motor_vehicle    text    linear
114 node,way    psv              text    linear
115 node,way    vehicle          text    linear
116
117
118
119 # Deleted tags
120 # These are tags that are generally regarded as useless for most rendering.
121 # Most of them are from imports or intended as internal information for mappers
122 # Some of them are automatically deleted by editors.
123 # If you want some of them, perhaps for a debugging layer, just delete the lines.
124
125 # These tags are used by mappers to keep track of data.
126 # They aren't very useful for rendering.
127 node,way    note             text    delete
128 node,way    note:*           text    delete
129 node,way    source           text    delete
130 node,way    source_ref       text    delete
131 node,way    source:*         text    delete
132 node,way    attribution      text    delete
133 node,way    comment          text    delete
134 node,way    fixme            text    delete
135
136 # Tags generally dropped by editors, not otherwise covered
137 node,way    created_by       text    delete
138 node,way    odb1             text    delete
139 node,way    odb1:note        text    delete
140 node,way    SK53_bulk:load    text    delete
141
142 # Lots of import tags
143 # TIGER (US)
144 node,way    tiger:*          text    delete
145
146 # NHD (US)
147 # NHD has been converted every way imaginable
148 node,way    NHD:*            text    delete
149 node,way    nhd:*            text    delete
150
151 # GNIS (US)
152 node,way    gnis:*           text    delete
153
154 # Geobase (CA)
155 node,way    geobase:*        text    delete
156 # NHN (CA)
157 node,way    accuracy:meters  text    delete
158 node,way    sub_sea:type      text    delete
159 node,way    waterway:type     text    delete
160
161 # KSJ2 (JA)
162 # See also note:ja and source_ref above
```

```

163 node,way    KSJ2:*          text      delete
164 # Yahoo/ALPS (JA)
165 node,way    yh:*           text      delete
166
167 # osak (DK)
168 node,way    osak:*         text      delete
169
170 # kms (DK)
171 node,way    kms:*          text      delete
172
173 # ngbe (ES)
174 # See also note:es and source:file above
175 node,way    ngbe:*         text      delete
176
177 # naptan (UK)
178 node,way    naptan:*       text      delete
179
180 # Corine (CLC) (Europe)
181 node,way    CLC:*         text      delete
182
183 # misc
184 node,way    3dshapes:ggmodelk text      delete
185 node,way    AND_nosr_r     text      delete
186 node,way    import         text      delete
187 node,way    it:fvg:*       text      delete

```

D.13.5 mikhailovsk.osm

The file used during testing was supplied by the company, and is an edited version. But it is not necessary to put 2.1 MiB of *xml* data here. A new file, containing more information, can be downloaded, see listing D.1:

```
$ wget -O mikhailovsk.osm "http://overpass-api.de/api/map?bbox=41.9491,45.0918,42.1151,45.173"
```

Listing D.1: Download Mikhailovsk map data.

D.13.6 partille.osm

The file used during testing was supplied by the company, and is an edited version. But it is not necessary to put 4.4 MiB of *xml* data here. A new file, containing more information, can be downloaded, see listing D.2:

```
$ wget -O partille.osm "http://overpass-api.de/api/map?bbox=12.0873,57.7168,12.1703,57.7475"
```

Listing D.2: Download Partille map data.

D.14 util

D.14.1 Logging.h

```

1 /* Use Boost logging, and handle setup in this file.
2  *
3  * #include "Logging.h"
4  *
5  * Needs a lot of linking to work:
6  * -lboost_log -lboost_log_setup -lboost_thread -lboost_system -lpthread
7  *

```

```
8  * @author Jonas Bergman
9  *
10 */
11
12 #ifndef LGU_LOGGING_H_
13 #define LGU_LOGGING_H_
14
15 #include <boost/log/common.hpp>
16 #include <boost/log/core.hpp>
17 #include <boost/log/expressions.hpp>
18 #include <boost/log/sinks/text_file_backend.hpp>
19 #include <boost/log/sources/severity_logger.hpp>
20 #include <boost/log/support/date_time.hpp>
21 #include <boost/log/utility/setup/file.hpp>
22 #include <boost/log/utility/setup/common_attributes.hpp>
23 #include <boost/log/trivial.hpp>
24
25 /** To simplify the set up of logging in the application: include this file
26  * and call the 'initLogging()' function.
27  */
28 struct Logging
29 {
30     static void initLogging()
31     {
32         if(isInited)
33         {
34             return;
35         }
36
37         boost::log::add_file_log(
38             boost::log::keywords::file_name = "lgu.log",
39             boost::log::keywords::format = "[%TimeStamp%]: %Message%"
40         );
41         boost::log::core::get()->set_filter(
42             boost::log::trivial::severity >= boost::log::trivial::info
43         );
44
45         isInited = true;
46     }
47
48     Logging() = delete;
49     Logging(const Logging& from) = delete;
50
51 private:
52     static bool isInited;
53 };
54
55 #endif /* LGU_LOGGING_H_ */
```

D.14.2 Logging.cc

```
1  /*
2  * Logging.cc
3  */
4
5  #include "Logging.h"
6
```

```
7 //static
8 bool Logging::isInitd {false};
```

D.14.3 Point.h

```
1 /** Data structure for Point.
2  *
3  * #include "Point.h"
4  *
5  * @author Jonas Bergman
6  */
7
8 #ifndef UTIL_POINT_H_
9 #define UTIL_POINT_H_
10
11 // SYSTEM INCLUDES
12 //
13 #include <ostream>
14
15 // PROJECT INCLUDES
16 //
17
18 // LOCAL INCLUDES
19 //
20
21 // FORWARD REFERENCES
22 //
23
24 struct Point
25 {
26     // ATTRIBUTES
27     double x {0.0};
28     double y {0.0};
29
30     Point(double x, double y) : x(x), y(y) {}
31     Point() = default;
32     Point(const Point&) = default;
33
34     // OPERATORS
35     friend std::ostream& operator<<(std::ostream& os, const Point& rPoint)
36     {
37         os << std::fixed << "Point [x: " << rPoint.x << ", y: " << rPoint.y << "]\n";
38         return os;
39     }
40
41     bool operator==(const Point& rhs) const
42     {
43         return (rhs.x == x) && (rhs.y == y);
44     }
45 };
46
47 // INLINE METHODS
48 //
49
50 // EXTERNAL REFERENCES
51 //
52
```

```
53 #endif /* UTIL_POINT_H_ */
```

D.14.4 TimeToStringMaker.h

```
1  /** Static class to provide strings based on time.
2   *
3   * #include "TimeToStringMaker.h"
4   *
5   * @author Jonas Bergman
6   */
7
8  #ifndef UTIL_TIMETOSTRINGMAKER_H_
9  #define UTIL_TIMETOSTRINGMAKER_H_
10
11 // SYSTEM INCLUDES
12 //
13 #include <string>
14
15 // PROJECT INCLUDES
16 //
17
18 // LOCAL INCLUDES
19 //
20
21 // FORWARD REFERENCES
22 //
23
24 /**
25  * Class who provide strings from times.
26  */
27 class TimeToStringMaker
28 {
29 public:
30 // LIFECYCLE
31
32     /** Default constructor.
33     */
34     TimeToStringMaker() = delete;
35
36     /** Copy constructor */
37     TimeToStringMaker(const TimeToStringMaker& from) = delete;
38
39 // OPERATORS
40 // OPERATIONS
41
42     /** Get the current time as a string.
43     *
44     * @return A string representation of the time.
45     */
46     static std::string getEpochMsTimeString();
47
48 // ACCESS
49 // INQUIRY
50
51 protected:
52
53 private:
```

```
54 };
55
56 // INLINE METHODS
57 //
58
59 // EXTERNAL REFERENCES
60 //
61
62 #endif /* UTIL_TIMETOSTRINGMAKER_H_ */
```

D.14.5 TimeToStringMaker.cc

```
1  /*
2   * TimeToStringMaker.cc
3   *
4   * @author Jonas Bergman
5   */
6
7
8  #include "TimeToStringMaker.h" // class implemented
9
10 #include <chrono>
11
12 ////////////////////////////////// PUBLIC //////////////////////////////////
13
14 //===== LIFECYCLE =====
15
16 //===== OPERATORS =====
17
18 //===== OPERATIONS =====
19 //static
20 std::string
21 TimeToStringMaker::getEpochMsTimeString()
22 {
23     using namespace std::chrono;
24     milliseconds ms = duration_cast< milliseconds >(
25         system_clock::now().time_since_epoch());
26     return std::to_string(ms.count());
27 }
28
29 //===== ACCESS =====
30 //===== INQUIRY =====
31 ////////////////////////////////// PROTECTED //////////////////////////////////
32
33 ////////////////////////////////// PRIVATE //////////////////////////////////
```