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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.

Contents

Abstract	ii
Table of contents	iii
1 Introduction	1
1.1 Background and problem motivation	1
1.2 Overall aim	1
1.3 Scope	1
1.4 Detailed problem statement	1
1.5 Outline	2
1.6 Contributions	2
2 Related work	3
2.1 Graph theory	3
2.1.1 Graph representation	4
2.2 Map routing	5
2.2.1 Overview	5
2.2.2 Map representation	6
2.3 Map data	8
2.3.1 Projections	8
2.3.2 Topology	8
2.4 Available applications	8
2.5 Memory or database	8
3 Methodology	10
3.1 Behaviour and Test Driven Development	11
3.1.1 Tools, installation and usage	11
3.1.2 Alternatives	11
3.1.3 Remarks	12
3.2 Database	12
3.2.1 Tools, installation and usage	12
3.2.2 Loading map data	12
3.2.3 Building topology	13
3.2.4 Examining map data	14
3.2.5 Connecting to database	15
3.3 Configuration	16
3.3.1 Tools, installation and usage	16
3.3.2 Alternatives	17
3.4 Build Graph	17
4 Implementation	19
4.1 Design	19
4.1.1 Dynamic design	20
4.1.2 Static design	21
4.2 Project structure	22
4.2.1 <code>catchtest</code>	23
4.2.2 <code>config</code>	23
4.2.3 <code>doc</code>	23
4.2.4 <code>graph</code>	23
4.2.5 <code>lgu</code>	26
4.2.6 <code>mapprovider</code>	26
4.2.7 <code>osm</code>	27
4.2.8 <code>preparation</code>	27

4.2.9	util	28
4.3	Development environment	28
5	Results	30
5.1	Specification fulfillment	30
5.2	Visual examination	30
5.3	Performance	32
6	Discussion	34
6.1	Research	34
6.1.1	Graph theory	34
6.1.2	Map routing	34
6.1.3	Map data	34
6.1.4	Available applications	34
6.2	Methodology	34
6.3	Design	35
6.4	Development	35
6.4.1	Coding standard	35
6.4.2	Memory management	35
6.4.3	Tools	35
6.4.4	OpenStreetMap	36
6.5	Ethical aspects	36
6.6	Documentation	36
6.7	Results	36
	Bibliography	37
A	Specification	A-1
B	UML Diagrams	B-1
C	Directory listings	C-1
D	Source code	D-1

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.

A more formal specification from the company can be found in appendix A.

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.

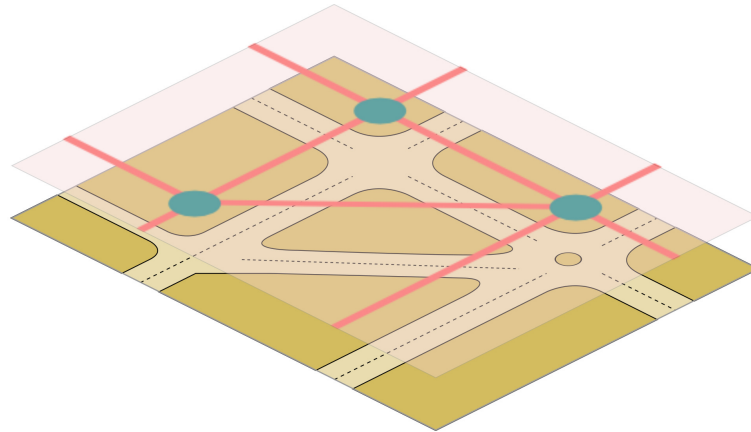


Figure 2.1: Graphs and road maps are a natural match.

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.

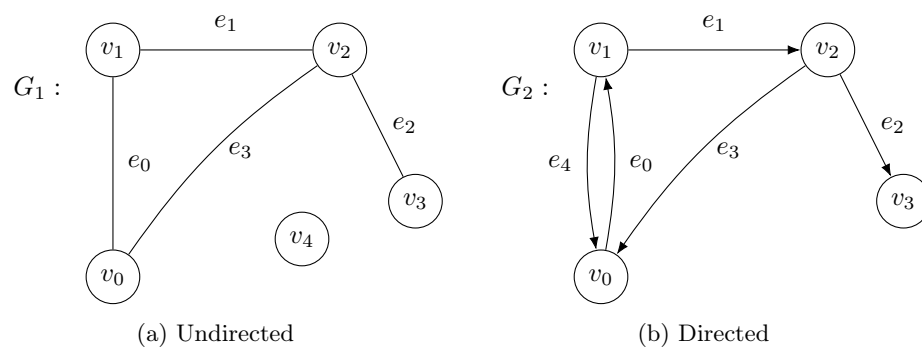


Figure 2.2: A *graph* with *vertices* and *edges*.

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 *bidirectional 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.

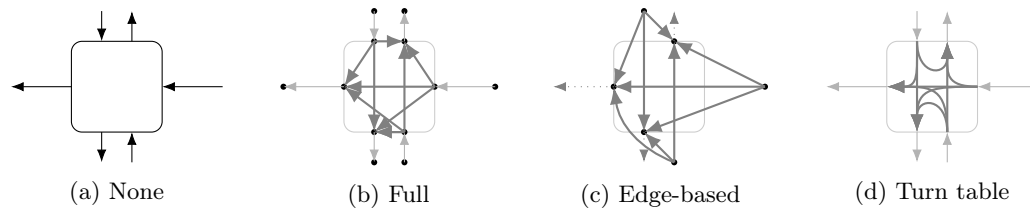


Figure 2.3: A closer look at a junction with two bidirectional and two unidirectional roads with different turn representations. (After [6, p.8].)

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

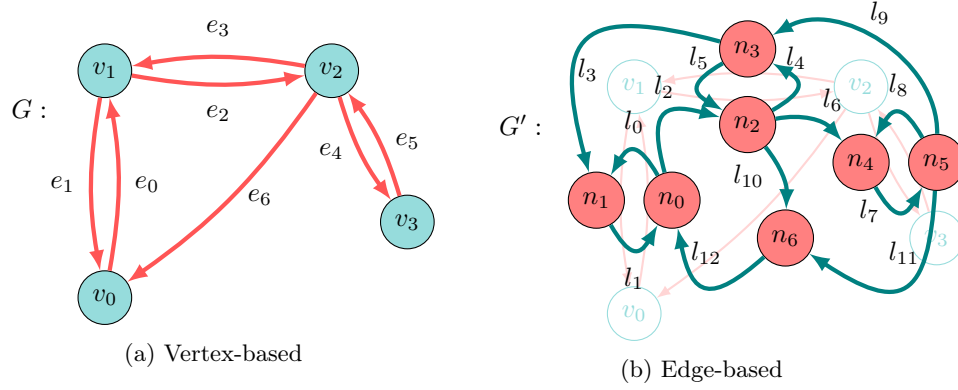


Figure 2.4: Transformation of a graph G to an *edge-based* graph G' .

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 methodology used in this project:

- Theory studies.
 - Graph theory.
 - Maps and routing.
- Analysis.
 - Tools.
 - Design.
- Development (incremental).
 - Coding.
 - Testing.
 - Documenting.
- Evaluation.

The “*Detailed problem statement*” in section 1.4 and the final specifications in appendix A resolves some of these steps: several of the tools are given, while the investigation for the others are described below.

The methodology to use for the development is also given, either *Behaviour Driven Development*, *BDD* or *Test Driven Development*, *TDD*, meaning all features of the module have either a *scenario* (BDD) or a *test case* (TDD) written. This is suitable to use with an incremental, iterative development model, where one is constantly re-evaluating and adding and testing new features. One could move the “design” step from “Analysis” and under “Development” as the design is allowed to change. The *coding standard* gives guidance on *coding* and *documentation*.

Another part of testing, is visual examination to see that the graphs looks like expected. There will also be performance tests, to see that the software fulfills the requirements for *soft real-time* execution. There will also be evaluation of fulfillment of the other requirements in the specification.

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  #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](https://github.com/cucumber/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.

¹<http://www.catch-lib.net>

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

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](http://www.postgresql.org/)³, with the extension [PostGIS](http://postgis.net/)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.

```
$ 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](http://wiki.openstreetmap.org/wiki/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

³<http://www.postgresql.org/>

⁴<http://postgis.net/>

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

.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.

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.

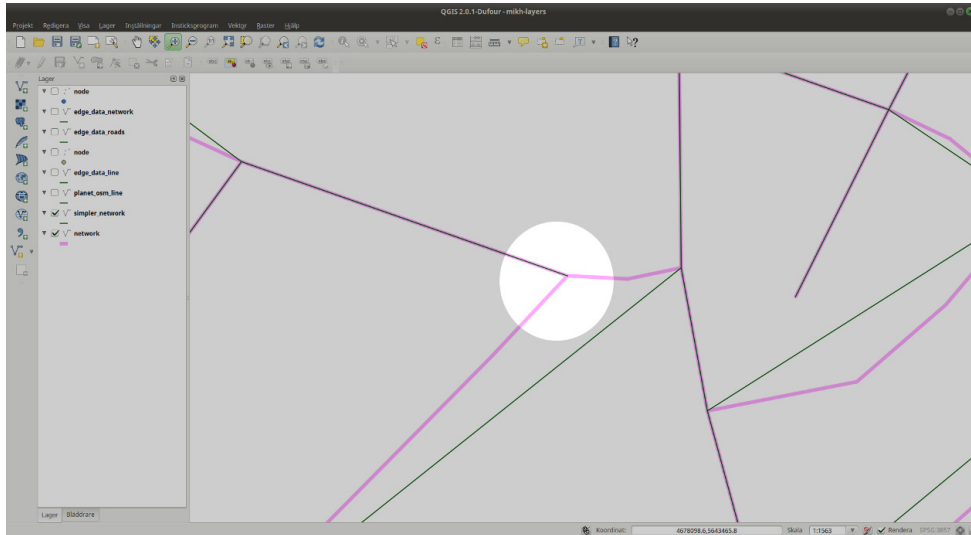


Figure 3.1: Error building topology with a node close but not connected.

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 led to the problem shown in figure 3.1, as there had been no “healing” of nodes first. One solution could of course be 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.

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.

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

⁷<http://pgrouting.org/index.html>

⁸<https://josm.openstreetmap.de/>

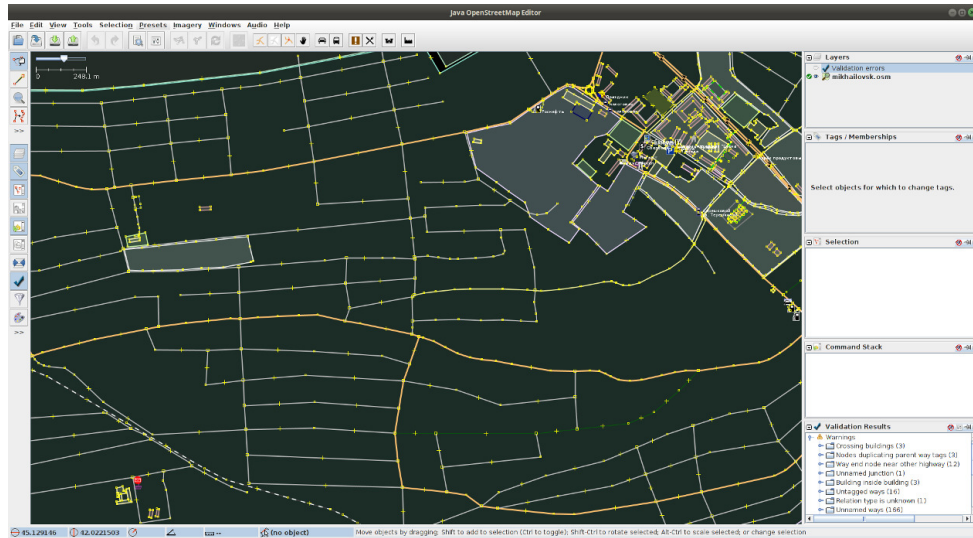


Figure 3.2: JOSM editor with Mikhailovsk map.

QGIS

[QGIS](http://www.qgis.org/)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.

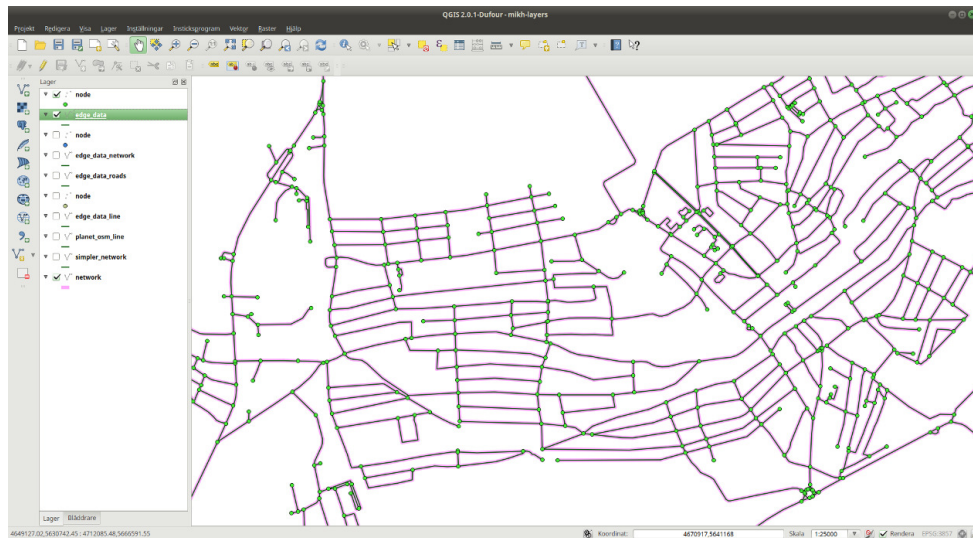


Figure 3.3: QGIS editor with Mikhailovsk map from PostGIS tables.

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

⁹<http://www.qgis.org/>

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

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.

```
$ 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.

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

```
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*” 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.

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

```
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.

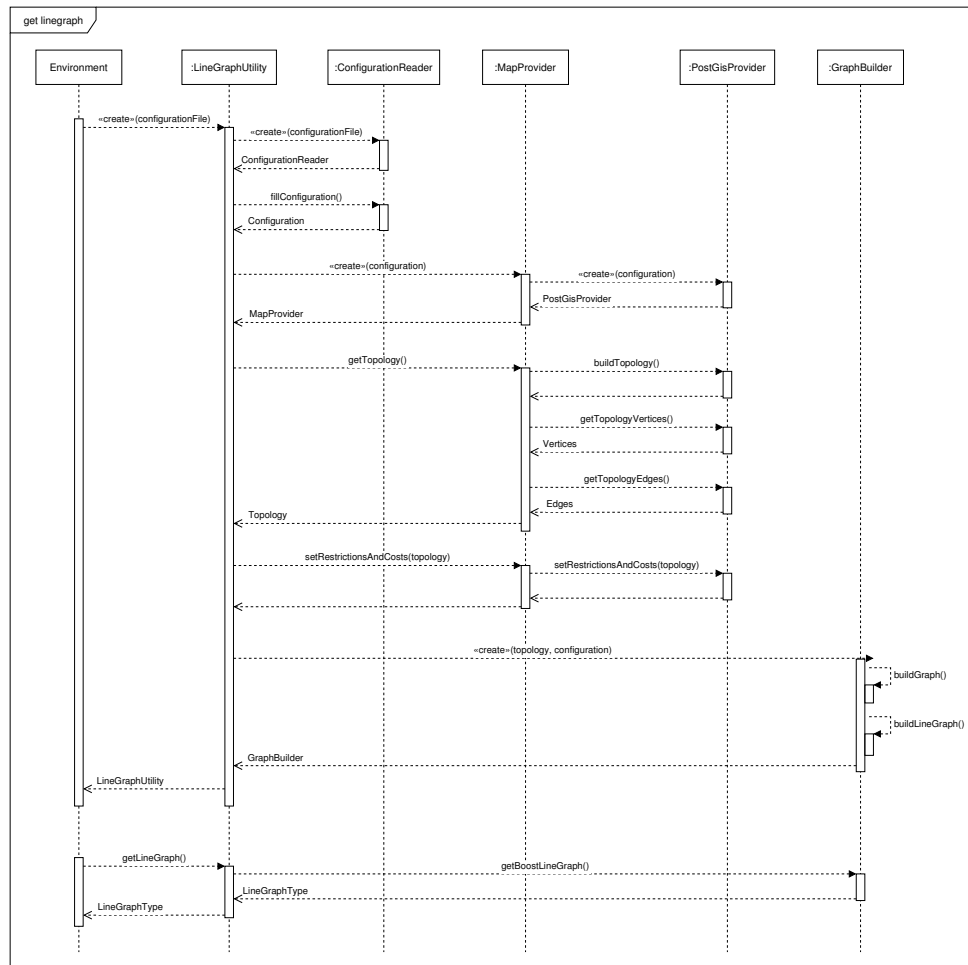


Figure 4.1: Sequence diagram of main use case to get a line graph.

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.

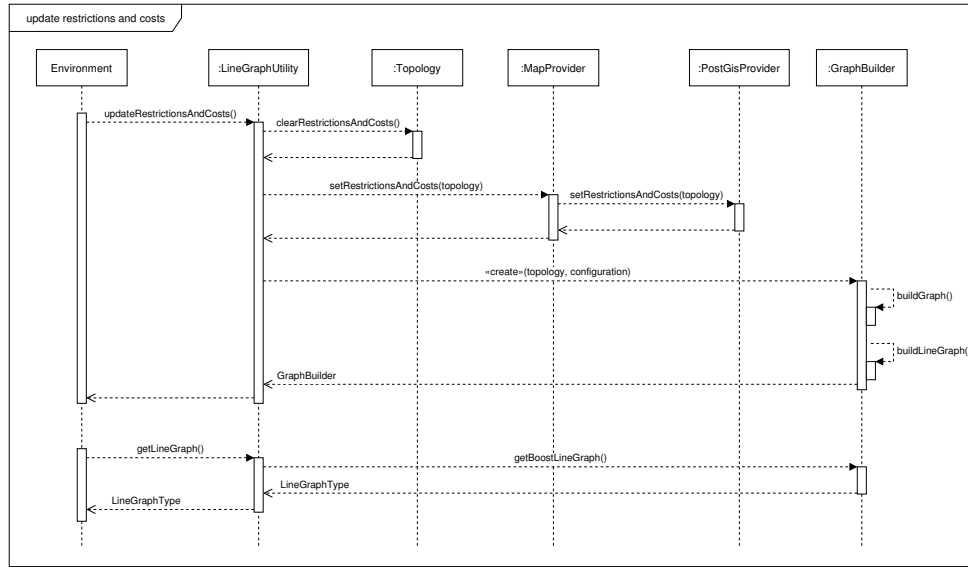


Figure 4.2: Sequence diagram of updating costs and restrictions on a topology.

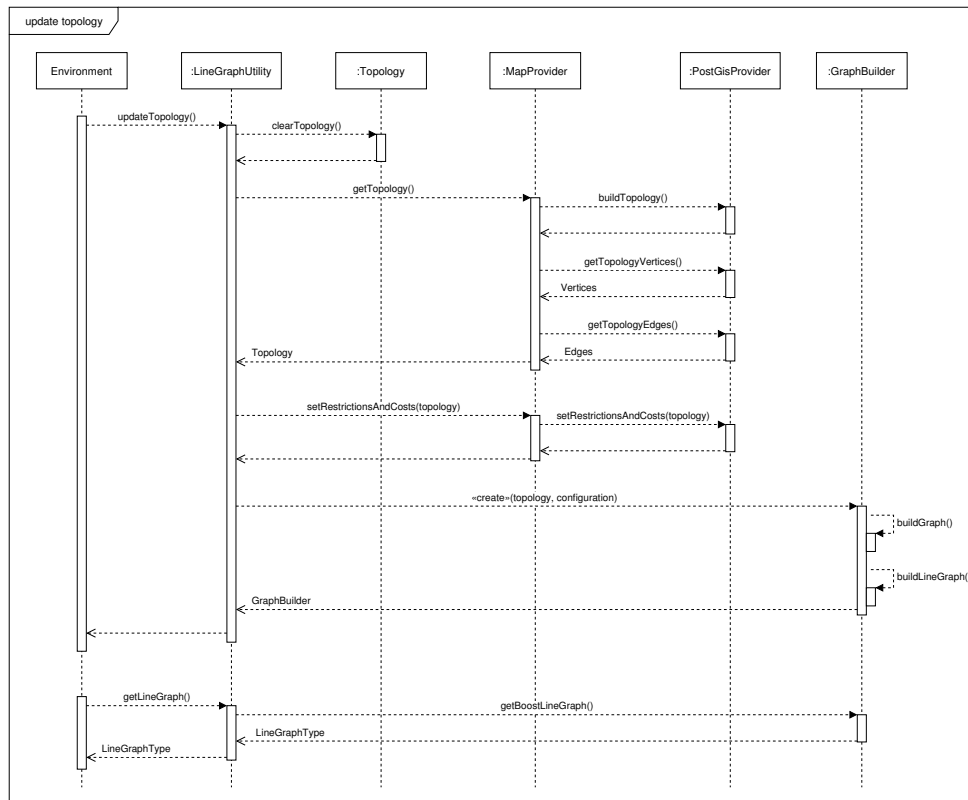


Figure 4.3: Sequence diagram of updating the topology.

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:

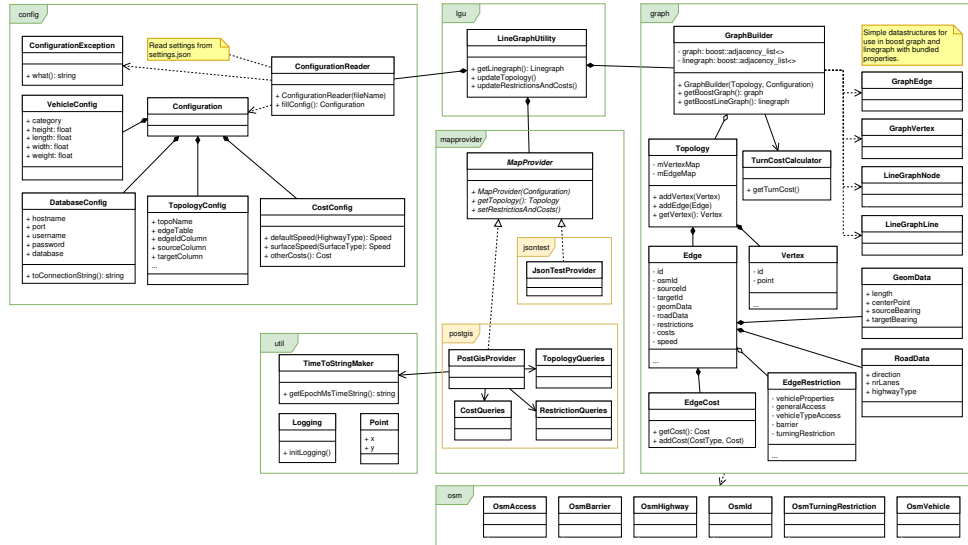


Figure 4.4: Class diagram of the *line graph utility*.

- 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 {edgeId \mapsto 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, {vertexId \mapsto vertex}. In addition there is a *multi-map* {osmId \mapsto 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 {topoVertexId \mapsto graphVertexDescriptor}, and a *multi-map* for *edges* such as {topoEdgeId \mapsto 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 {edgeId \mapsto 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, and also how the documentation should look (*javadoc*-like).

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.

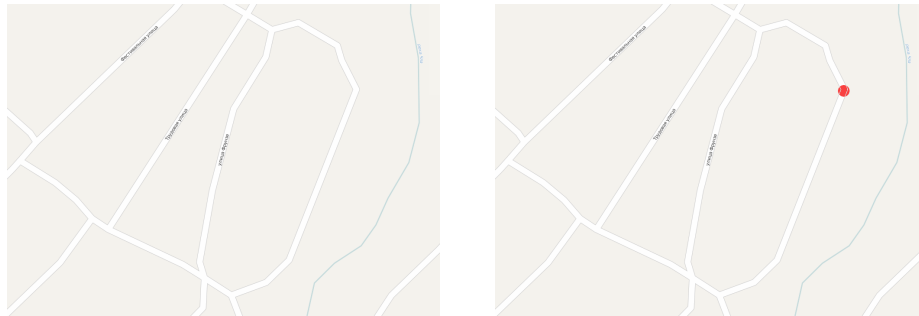
Section	Fulfills	Comment
1.2 Main use case		
1.2.1	X	As call to <code>LineGraphUtility::getLineGraph()</code> .
1.2.2	X	
1.2.3	X	
1.2.4	X	
1.3 Optional use case		
1.3.1	X	
1.3.2	X	
1.4 Functional requirements		
1.4.1		Lots of work remains to implement all restrictions.
1.4.2	X	
1.4.3	X	
1.4.4	X	Some 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 development was supposed to be test driven (either BDD or TDD), but to be honest, most tests were written after the implementation of a feature,

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

functioning 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 Ethical aspects

The larger application that this software module could be part of, has positive effects on the society, as it strives to make better use of public service vehicles. If there are less buses standing idle, then one could reduce the number of vehicles in the fleet, meaning less use of resources. It would also mean that they will use less fuel, just idling. All this is of course good for the environment, and it should also be good for the company’s economy and the greater public could benefit from lower fares and better service. In the long run it could mean that more people could use the public transportation service in favour of private vehicles, which will also be good for the local environment in the city.

This particular software module makes use of open data and tools to help provide such a change; turning the crowd-sourced map data into a real service that could impact the everyday life in a city, improving the air quality and the possibilities to efficiently move around.

6.6 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 L^AT_EX, 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.

6.7 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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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.

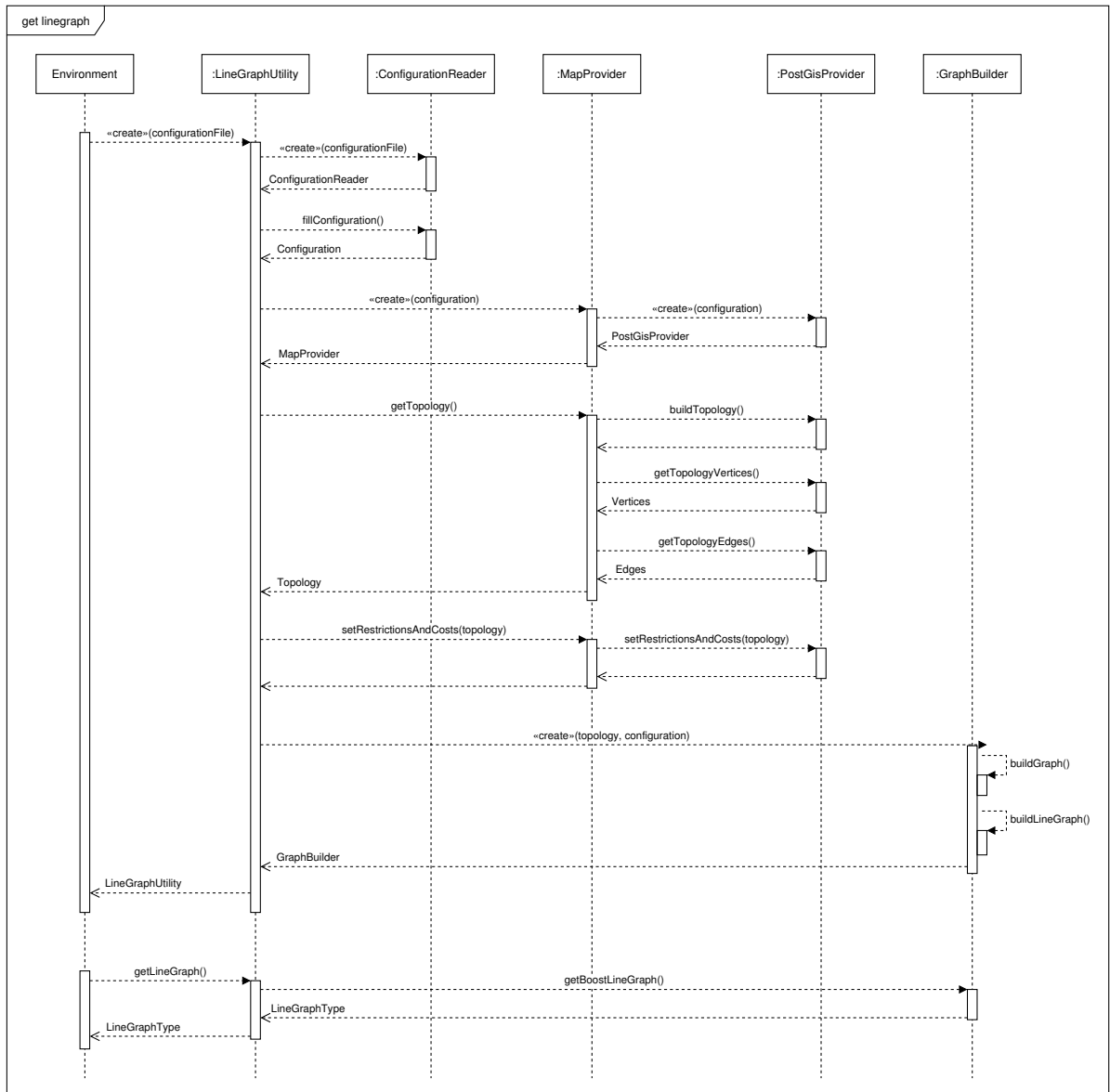


Figure B.1: Sequence diagram of main use case to get a line graph.

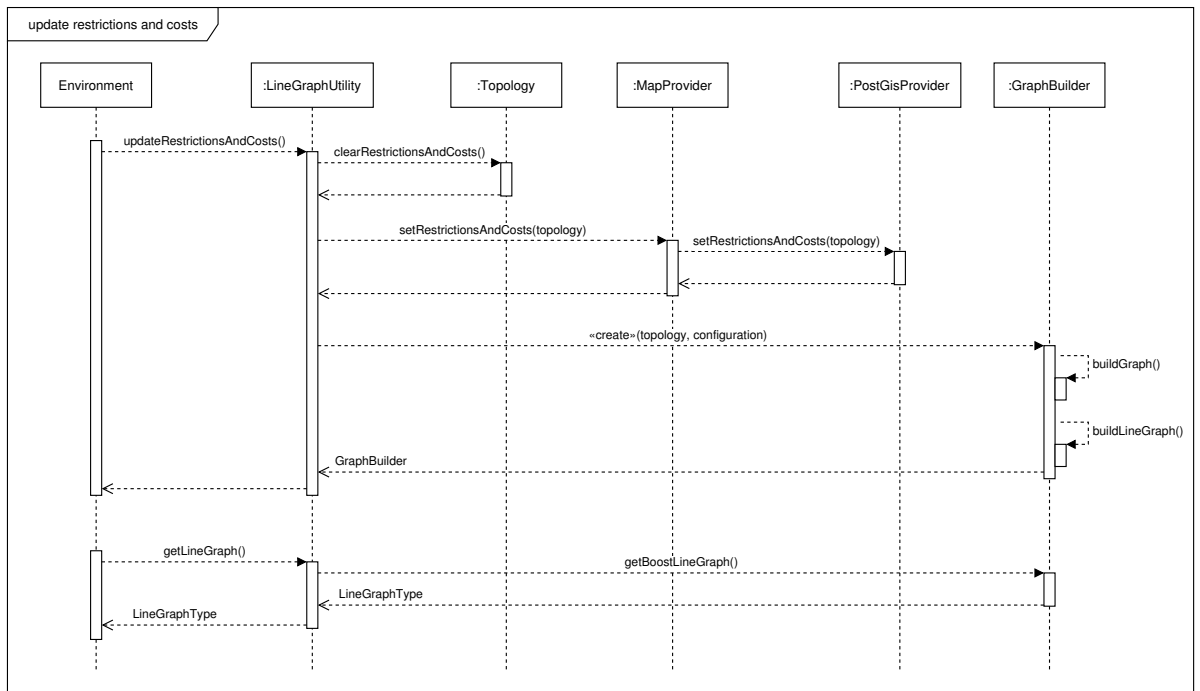


Figure B.2: Sequence diagram of updating costs and restrictions on a topology.

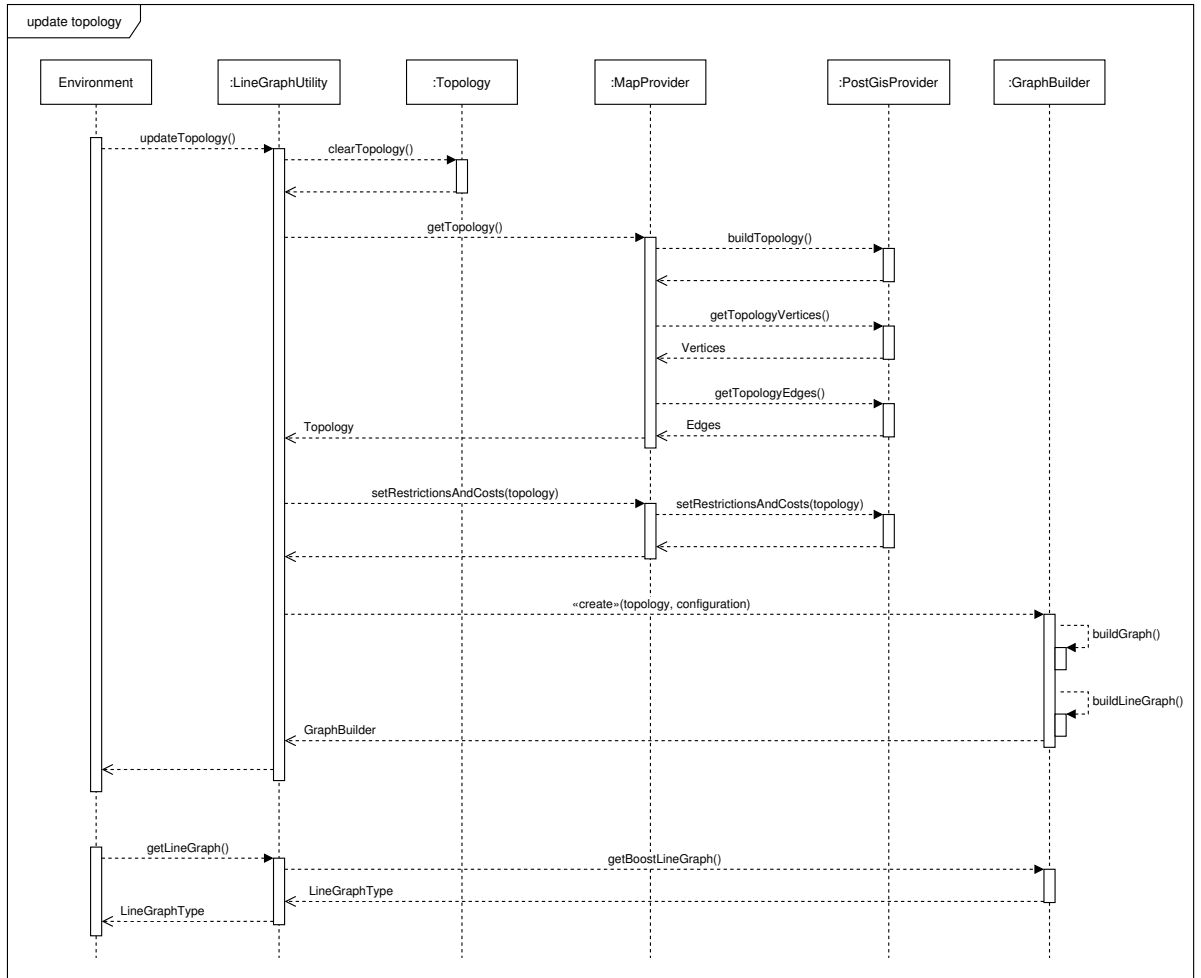


Figure B.3: Sequence diagram of updating the topology.

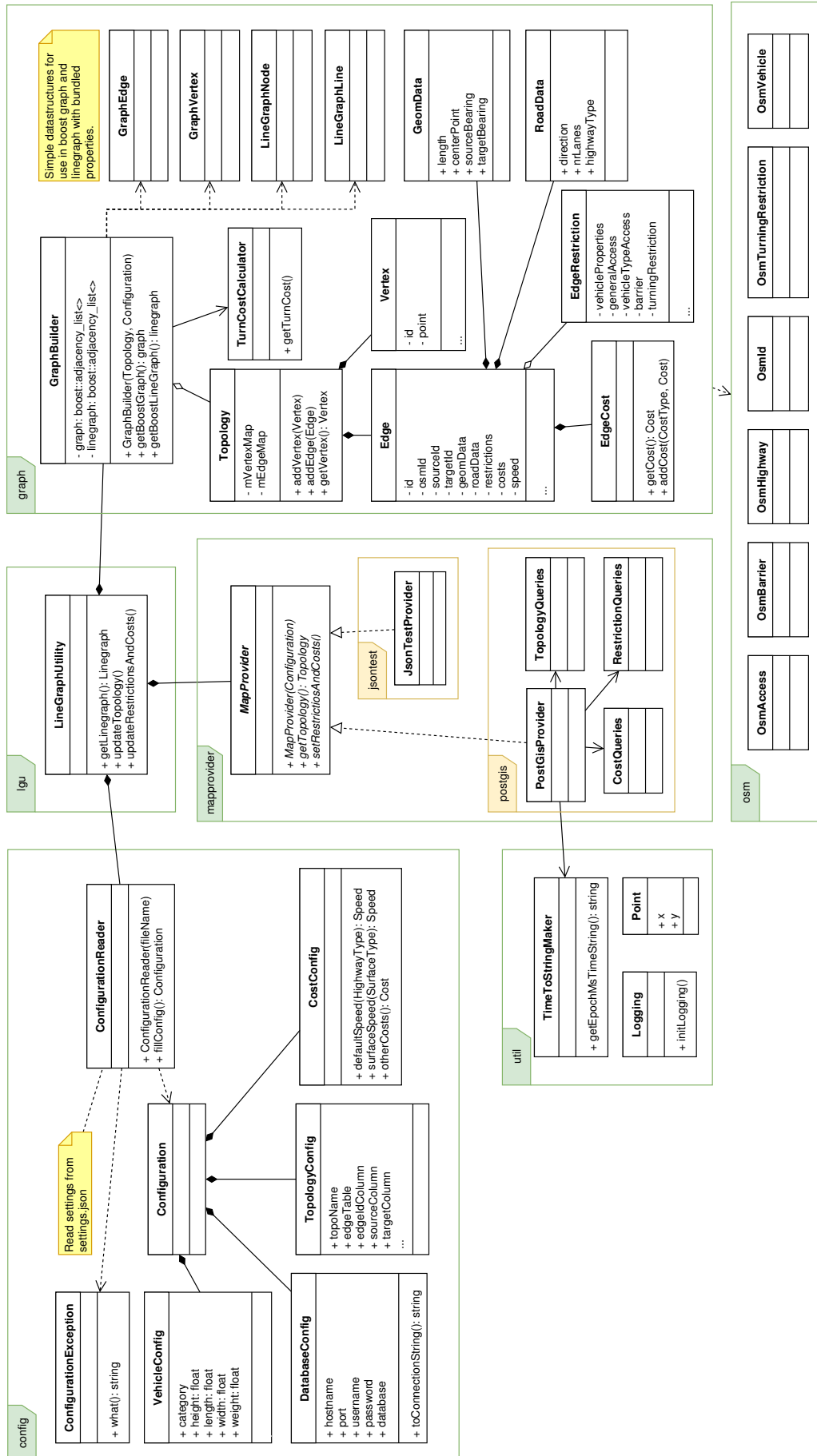


Figure B.4: Class diagram of the *line graph utility*.

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_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 }

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.
- ****"jsontest"**:**
 - ****"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](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 }
```

```
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](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](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_T0;
87 e1.setRoadData(rd1);
88
89 Edge::RoadData rd2;
90 rd2.direction = Edge::DirectionType::FROM_T0;
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_T0;
111 rd1.nrLanes = 2;
112 e1.setRoadData(rd1);
113
114 Edge::RoadData rd2;
115 rd2.direction = Edge::DirectionType::FROM_T0;
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 }
255 }
```

```
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& dbex)
1065 {
1066 INFO(dbex.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 propmt,
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/TimeStringMaker.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 rOsmPointTable 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 return static_cast<AccessType>(0);
48 }
```

```
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_OSMBARRIER_H_
9 #define OSM_OSMBARRIER_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_PAVES,
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 //////////////////////////////////
```