



# Cartography M.Sc.

## **Pedestrian routing of dynamic areas using Volunteered Geographical Information (OpenStreetMap)**

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1. Introduction and Background
2. Methodology
3. Case Study
4. Routing results
5. Discussion



Our real world is not static,  
changes **dynamically**

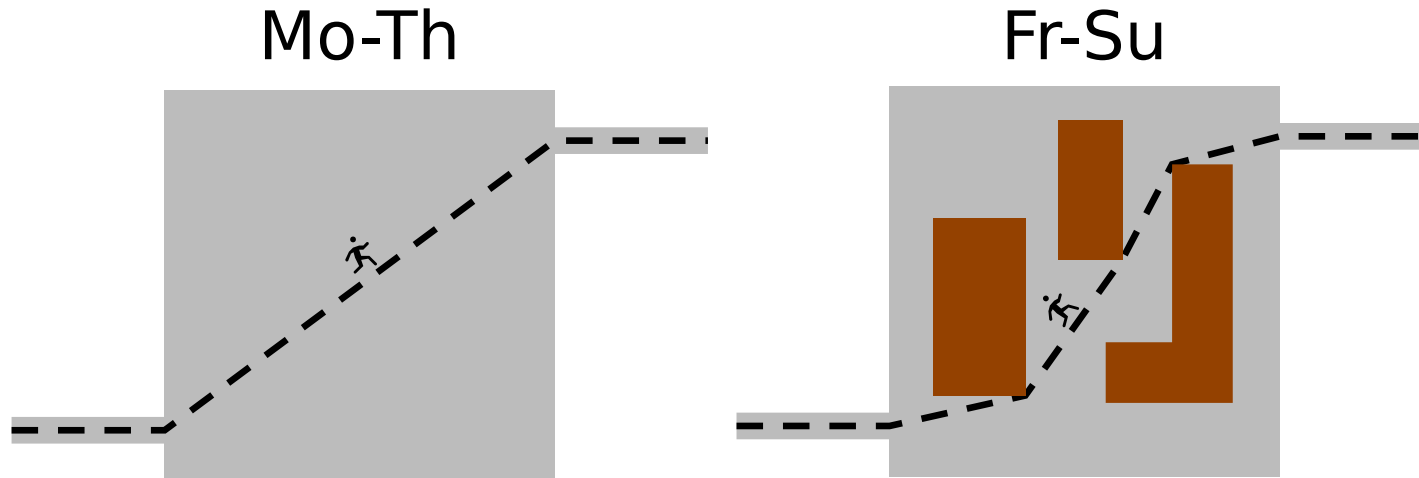
Pedestrians (vs. vehicles) have a  
higher degree of freedom, and can  
naturally move through **open spaces**

Routing networks have historically  
**ignored** pedestrian needs



Man Walking - Jeffrey Czum

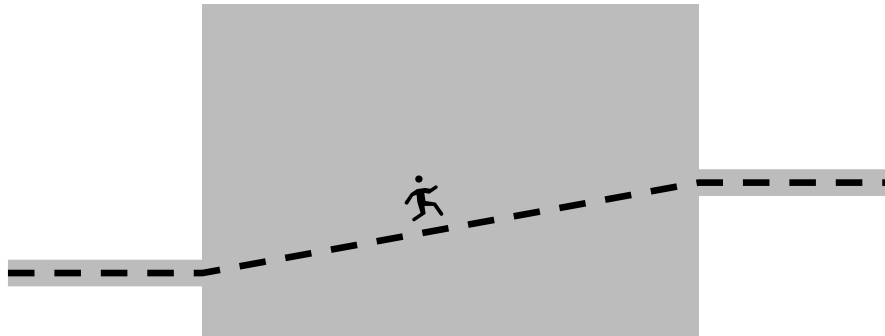
## Time dependent + open areas → Time Dependent Open Areas (TDOAs)



Example of a TDOA. A pedestrian square is fully traversable from Monday to Thursday. From Friday to Sunday, there is a weekly market that changes the areas that can be walked over, so a pedestrian would have to walk around the market stalls to reach the opposite end of the square.

# Time dependent + open areas → Time Dependent Open Areas (TDOAs)

## Usually



20XX-XX-XX  
to 20XX-XX-XX



Example of a TDOA. A pedestrian square is usually fully traversable. During some days, there is some construction work, so a pedestrian would have to walk around the construction site to reach the opposite end of the square.

## Newly introduced concept + Inexistent / Non accessible Commercial Solutions

**VGI** →

- Edited by individual users
- Fills the gap in the availability of digital information

**OpenStreetMap (OSM)** → Biggest actor of VGI

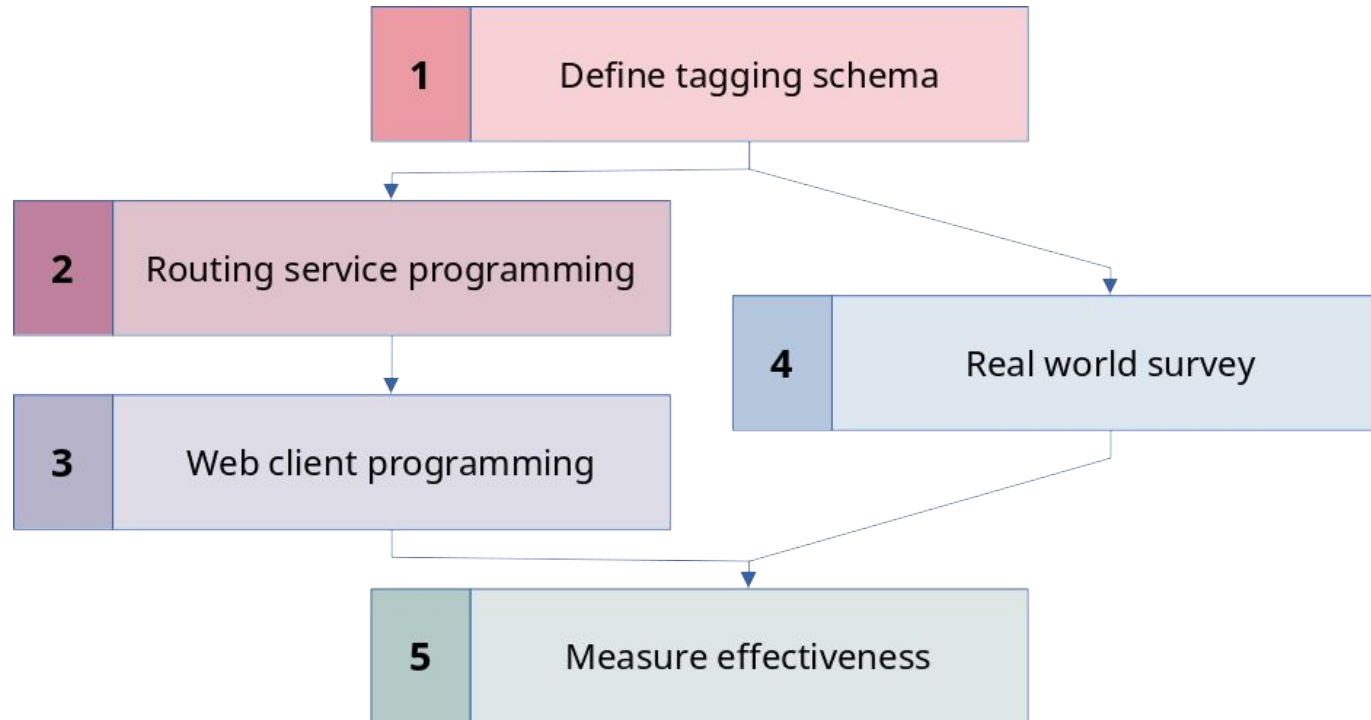
Huge “ecosystem” of applications built around it

Starting point for data + applications

**Q1** → How can a new schema for TDOAs be derived from current OSM time dependent and open area schemas?

**Q2** → How can we create a routing service that can route through TDOAs?

**Q3** → How effective are the proposed schema and routing service in a real world example?





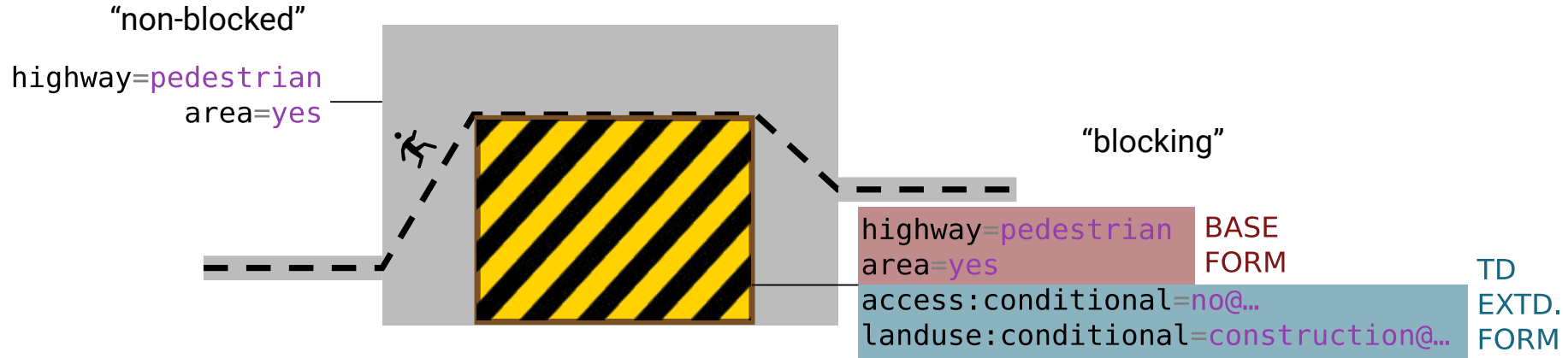
## Requirements for the schema:

- Futureproof - broad array of scenarios
- Routing systems that do not understand the new schema must still return a route
- It must follow OSM philosophy

## Two types of subareas:

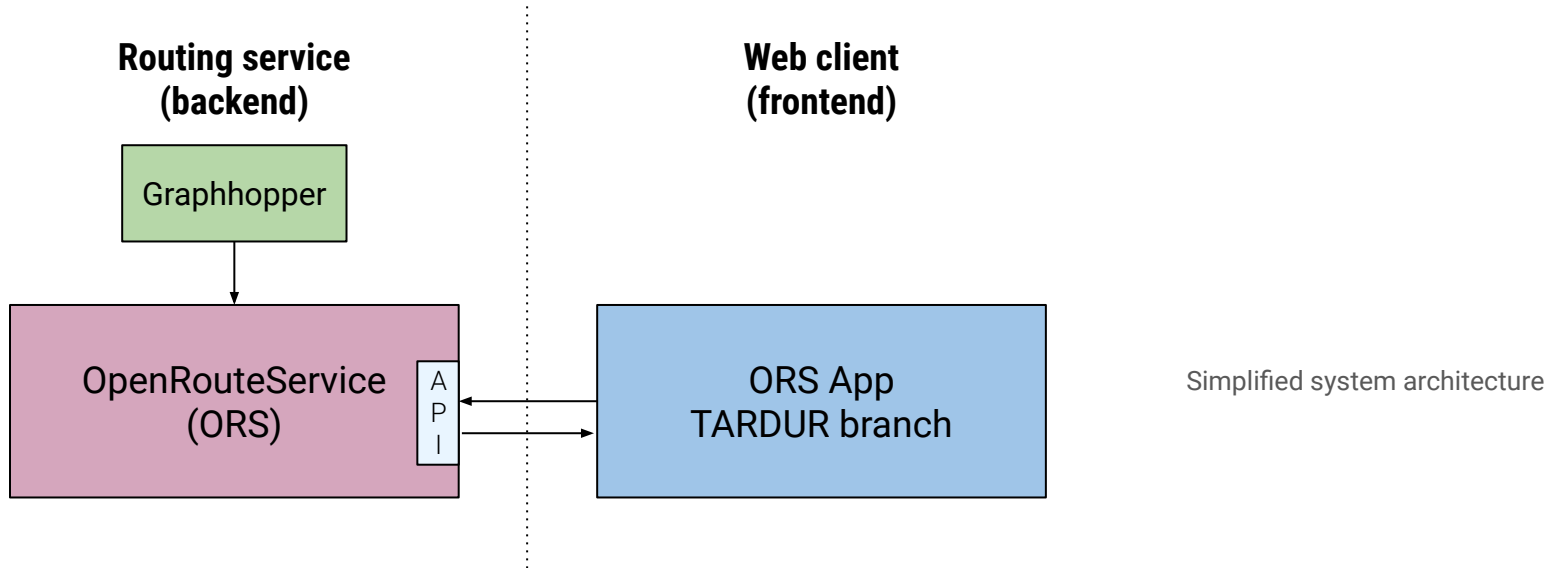
- “non-blocked”: stay unchanged
- “blocking”: access changes

Q1



Proposed tagging schema applied for the construction example

Q2



ORS and ORS App were extended to accept TDOAs

Changes were returned to the community → Pull Request 

### Routing service (backend)

Graphhopper








OpenRouteService  
(ORS)

A  
P  
I

Multipolygon routing started →  
Deemed too difficult →  
Future work

## Divide-and-conquer (*divide et impera*)


### Separate into subproblems:

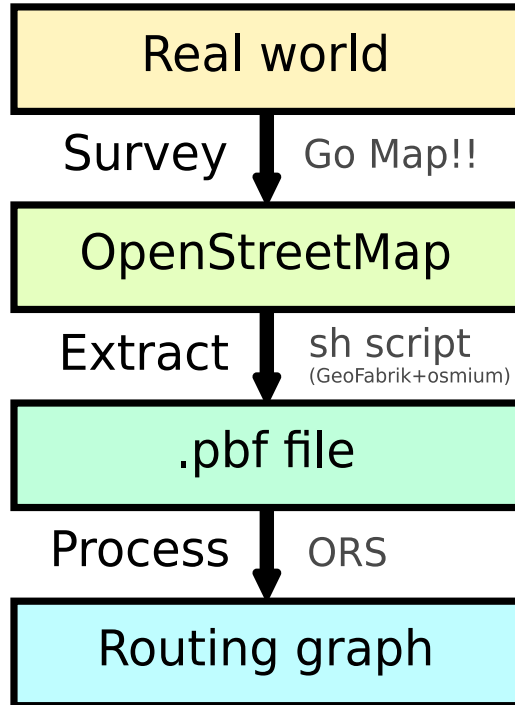
- Extend TD from    to   
(derive code from  flag encoder)  
 [GIScience/openrouteservice#1185](#) + [GIScience/graphhopper#53](#)
- Open Area routing for  , vis. alg. → 5  
(code already started, bug found, stated issue and fixed by HeiGIT, thanks guys 🙏)
- Combine both problems  
(trivial with closed ways OA)

Web client  
(frontend)

ORS App  
TARDUR branch

Made small adaptations:

- Worked right away, GeoJSON from API represented in web client
- Fixed year bug  
 [GIScience/openrouteservice-app#369](https://github.com/GIScience/openrouteservice-app#369)
- Small changes only in personal fork (just centered in the specific problem, no point in contributing them back)



Data flow diagram

Survey with mobile app (Go Map!!)

Main focus is not accuracy, just to showcase possible TDOA scenarios

More accurate surveying could be done in the future if city councils or interested stakeholders get involved

Schottenring U-Bahn station [TD]



Rathausplatz [OA]

Altgasse, Hietzing  
(weekly market)

Mariahilferstraße (U2 construction)



Data from 31st August, 19:00 GMT, city boundary of Vienna  
Computer: Lenovo 80XE, Intel Core i3-7100U, 4GB RAM, EndeavourOS

TD	OA	Graph generation time (s)	Graph size (MB)	Graph edges
X	X	45.996	23.03	195251
✓	X	46.958	27.03	195251
X	✓	71.134	24.03	220546
✓	✓	73.118	28.03	220546

Comparison of graph generation time and graph size with the different options activated or deactivated





## Schottenring U-Bahn station [TD]



Highways relevant for tagging at the Schottenring case study

1

2

3

## 4. Routing results

5

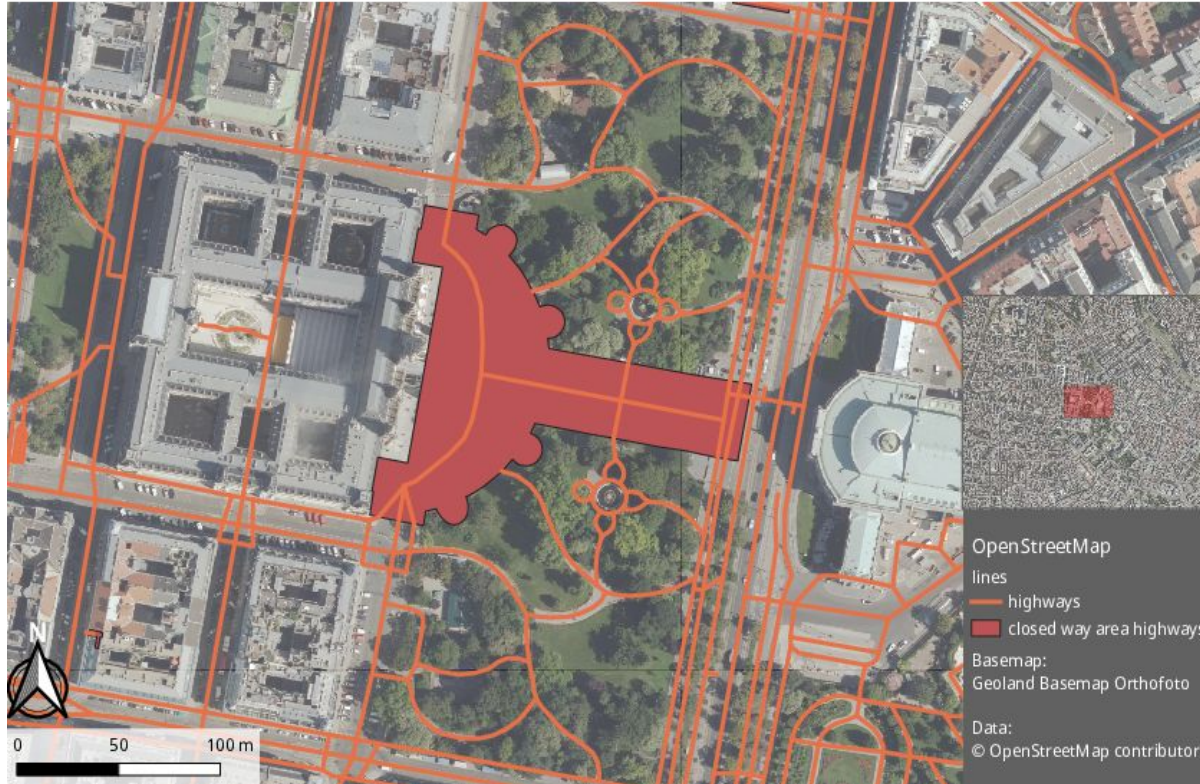
### Schottenring U-Bahn station [TD]



TD	OA	Departure time	Route length (m)	% optimal
X	X	Not applicable	73	optimal
✓	X	Tue, Aug 30th 2022, 15:00	73	optimal
✓	X	Tue, Aug 30th 2022, 02:00	118	+62%



## Rathausplatz [OA]



Highways relevant for tagging at the Rathausplatz case study

1 2 3 4. Routing results 5

# Rathausplatz [OA]



TD	OA	Route length (m)	% optimal
X	X	281	+19%
X	✓	237	optimal



## Altgasse, Hietzing (weekly market)



Highways relevant for tagging at the Altgasse, Hietzing case study

1

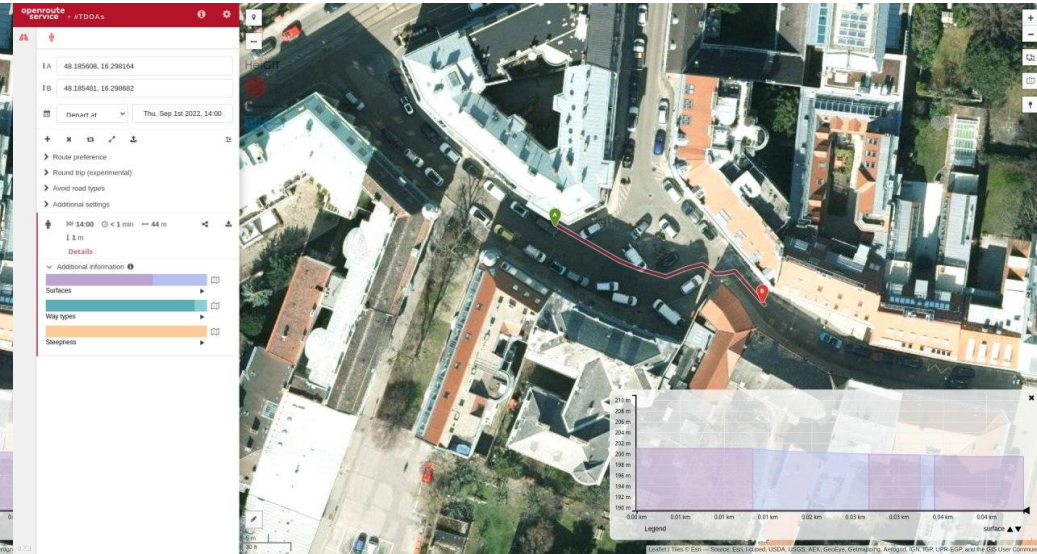
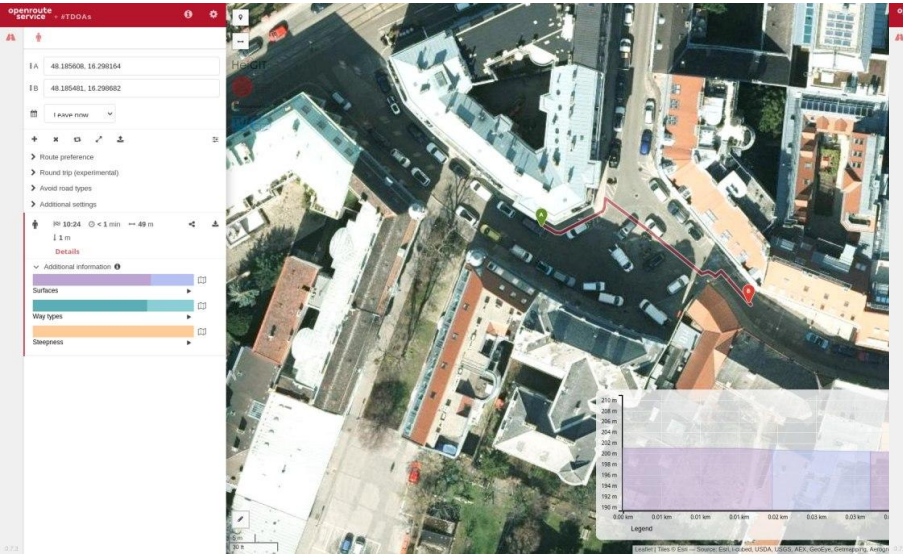
2

3

## 4. Routing results

5

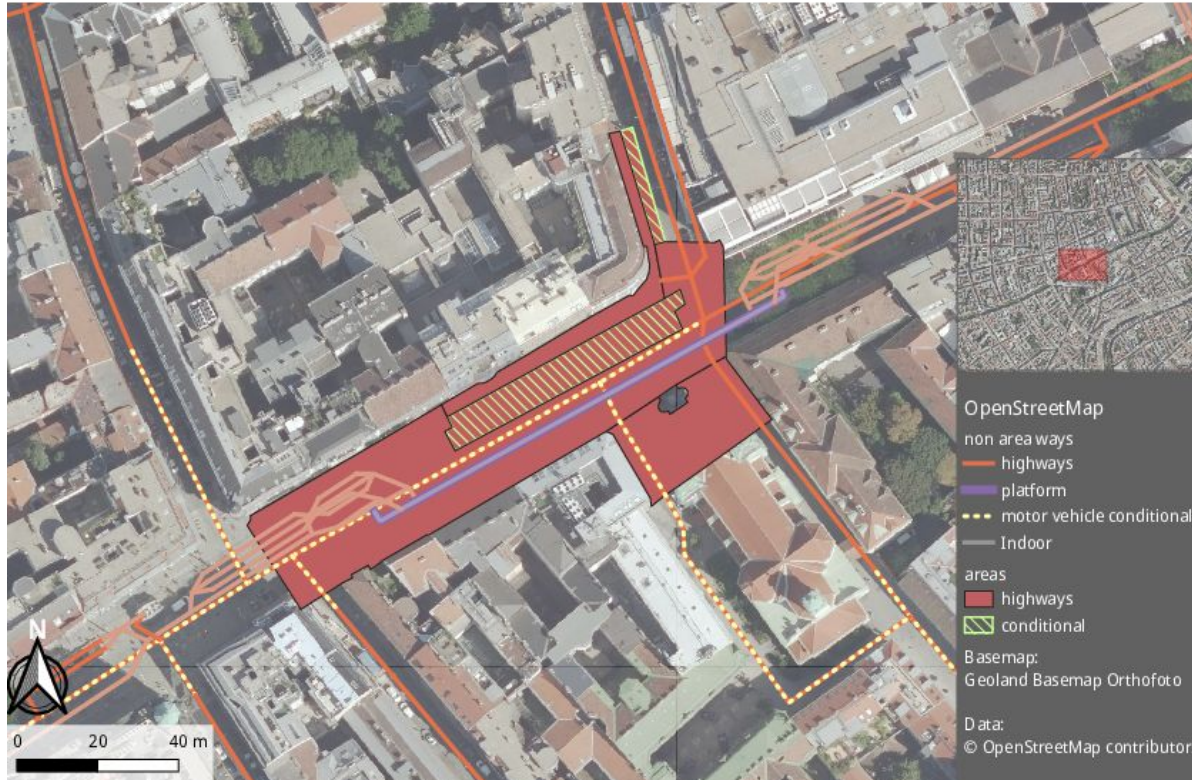
Altgasse, Hietzing (weekly market)



TD	OA	Departure time	Route length (m)	% optimal
X	X	Not applicable	49	+11%
✓	✓	Thu, Sep 1st 2022, 14:00	44	optimal ⚠
✓	✓	Sat, Sep 3rd 2022, 12:00	44	optimal



## Mariahilferstraße (U2 construction)



Highways relevant for tagging at the Mariahilferstraße case study

1

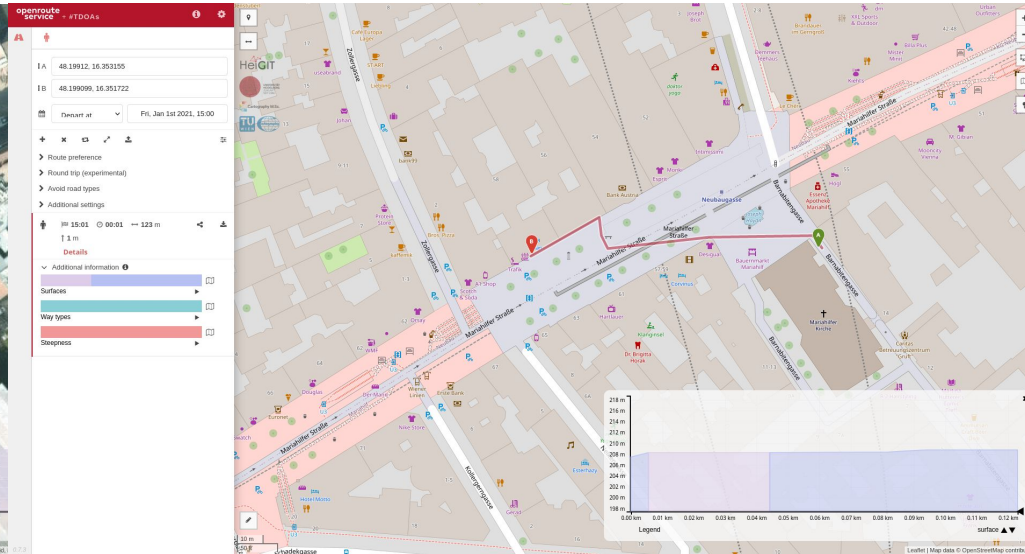
2

3

## 4. Routing results

5

## Mariahilferstraße (U2 construction)



TD	OA	Departure time	Route length (m)	% optimal
X	X	Not applicable	153	+24%
✓	✓	Fri, Jan 1st 2021, 15:00	123	optimal !
✓	✓	Tue, Aug 30th 2022, 15:00	123	optimal



1

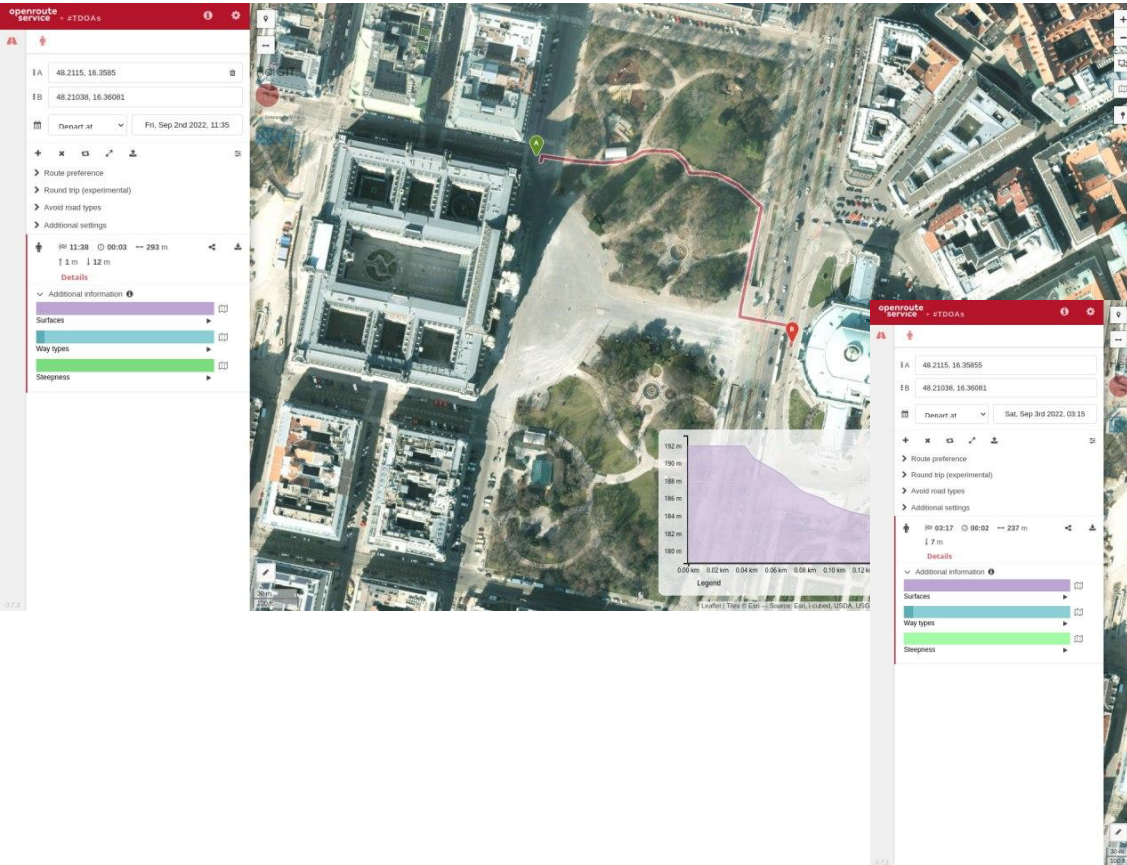
2

3

## 4. Routing results

5




## Rathausplatz - EXTRA!!







But it works... 🤔

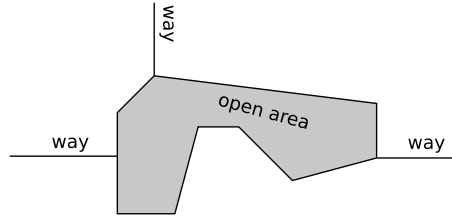


- Develop a tagging schema for TDOAs in OSM 

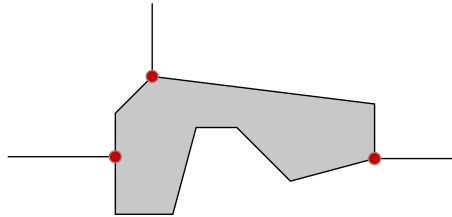
- Develop a tagging schema for TDOAs in OSM 
- Make a routing service understand the schema  

- Develop a tagging schema for TDOAs in OSM 
- Make a routing service understand the schema  
- Make a routing service return the correct route at all times   
Something is still wrong... but it is not TD+OAs routing

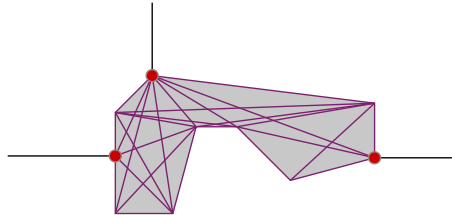
It's OAs routing on its own (visibility algorithm)

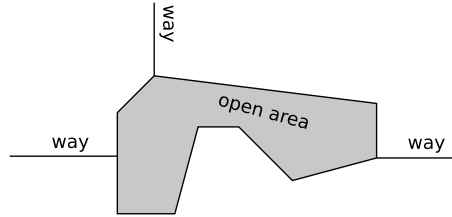


Tower nodes (junctions)

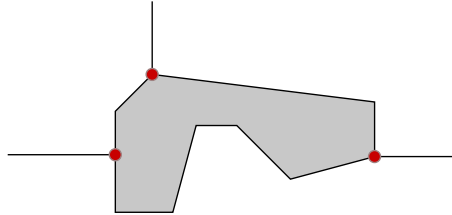


Local graph (connect every node, add edge if fully inside area)

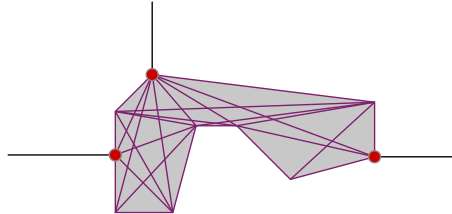




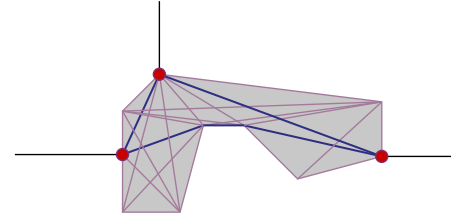
Tower nodes (junctions)



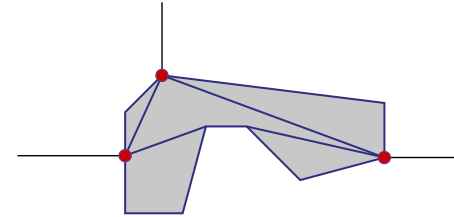
Local graph (connect every node, add edge if fully inside area)



Compute routes between tower nodes



Final graph (perimeter + computed routes)

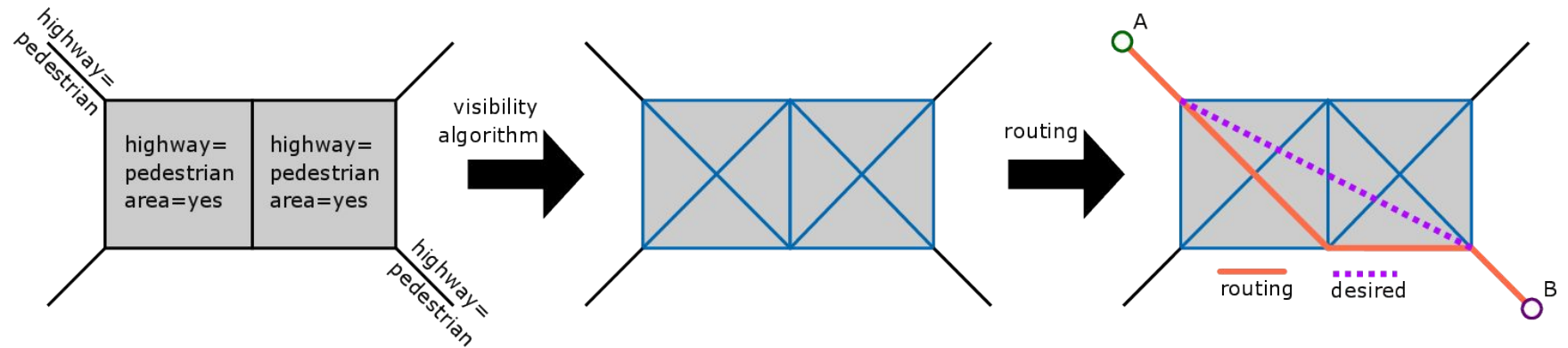


Why vis. alg.?

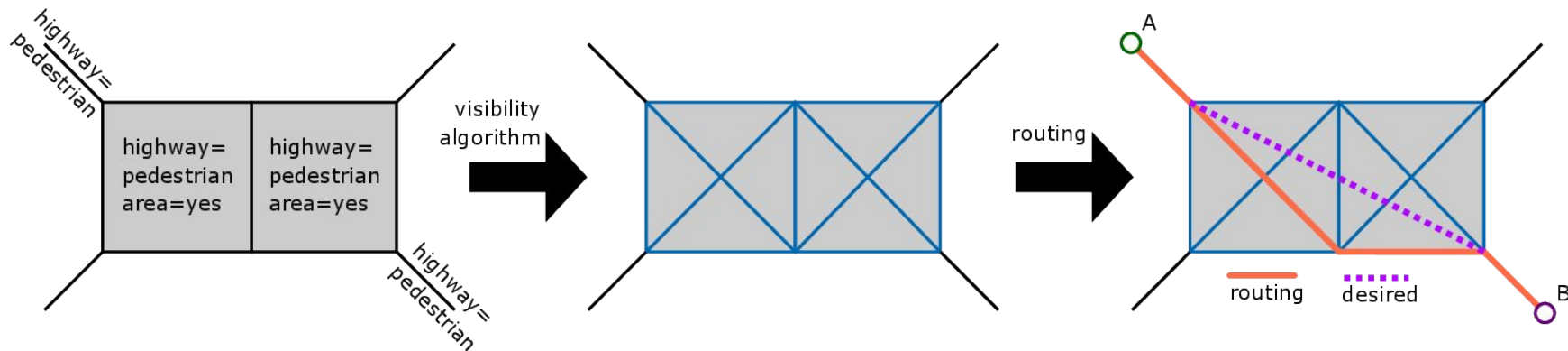
Graser, 2016

Hahmann et al., 2017

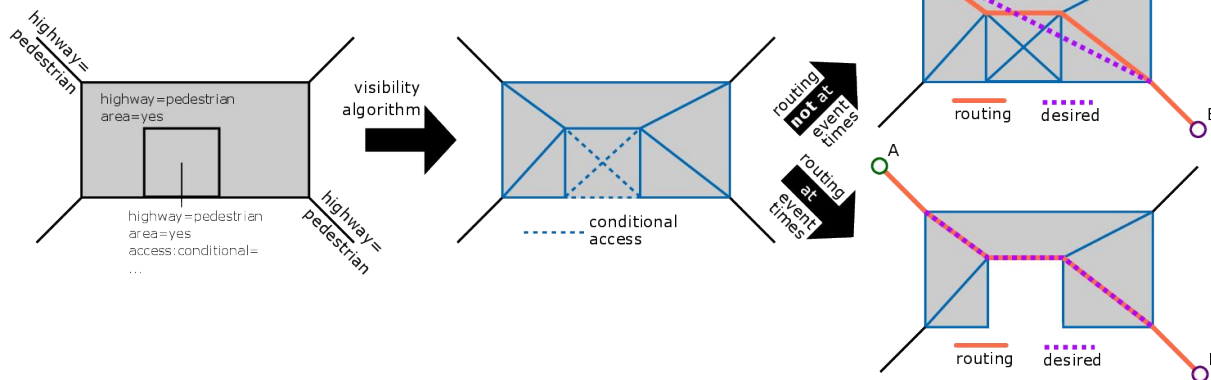
BORDER PROBLEM



## BORDER PROBLEM



## WITH TDOAs BECOMES MORE OBVIOUS





## Future work

- Fix border problem, add multipolygons
- Real time events (outside OSM)
- Get stakeholders involved (e.g. city councils)
- Dynamic tiles to represent dynamic realities
- Behavioural studies, how do people navigate through dynamic environments



# References



**Goodchild, M. F. (2007).** Citizens as sensors: The world of volunteered geography. *GeoJournal*, 69 (4), 211–221. <https://doi.org/10.1007/s10708-007-9111-y>

**Graser, A. (2016).** Integrating Open Spaces into OpenStreetMap Routing Graphs for Realistic Crossing Behaviour in Pedestrian Navigation. *GI\_Forum 2016*, 4, 217–230. [https://doi.org/10.1553/giscience2016\\_01\\_s217](https://doi.org/10.1553/giscience2016_01_s217)

**Hahmann, S., Miksch, J., Resch, B., Lauer, J., & Zipf, A. (2017).** Routing through open spaces – a performance comparison of algorithms. *Geo-spatial Information Science*, 21 (3), 247–256. <https://doi.org/10.1080/10095020.2017.1399675>

**OpenStreetMap Wiki. (2022).** *About OpenStreetMap - OpenStreetMap Wiki*. Retrieved April 4, 2022, from [https://wiki.openstreetmap.org/wiki/About\\_OpenStreetMap](https://wiki.openstreetmap.org/wiki/About_OpenStreetMap)





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Danke  
Thank you  
Gracias  
Bedankt  
ধন্যবাদ