Cartography M.Sc.

Why do the Route Planning Strategies of Machines Differ from Each Other and from Humans?

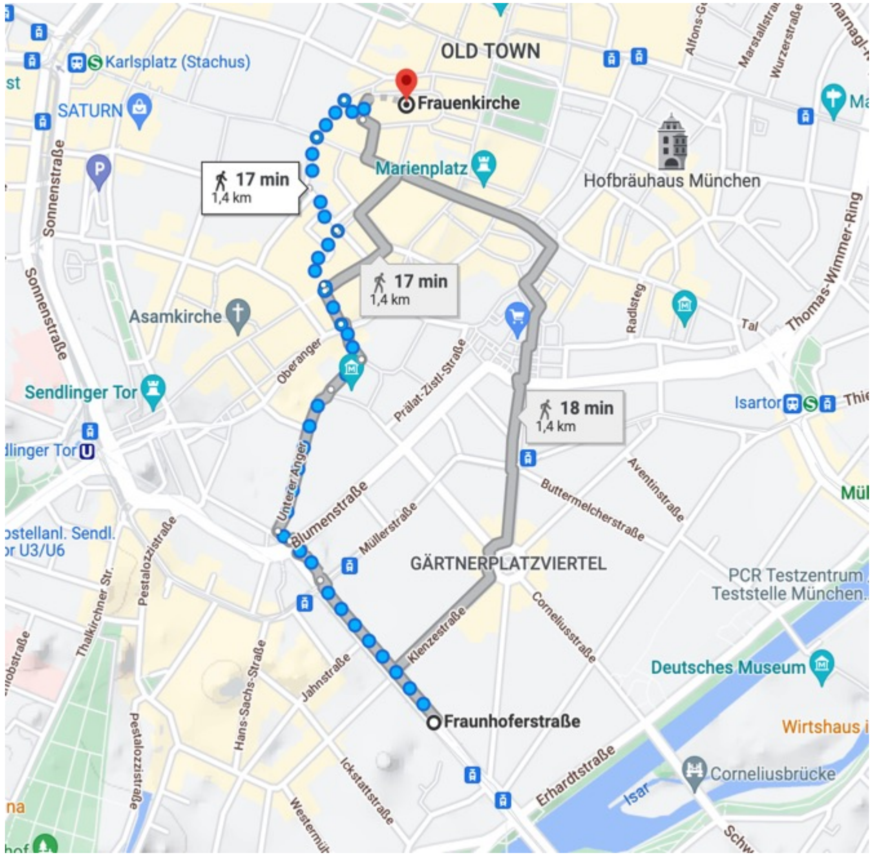

Image Courtesy: Google Maps

Thesis Presentation

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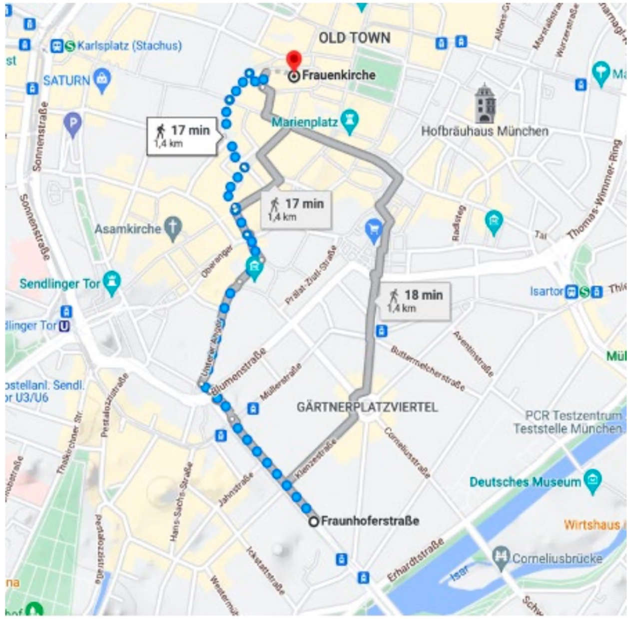
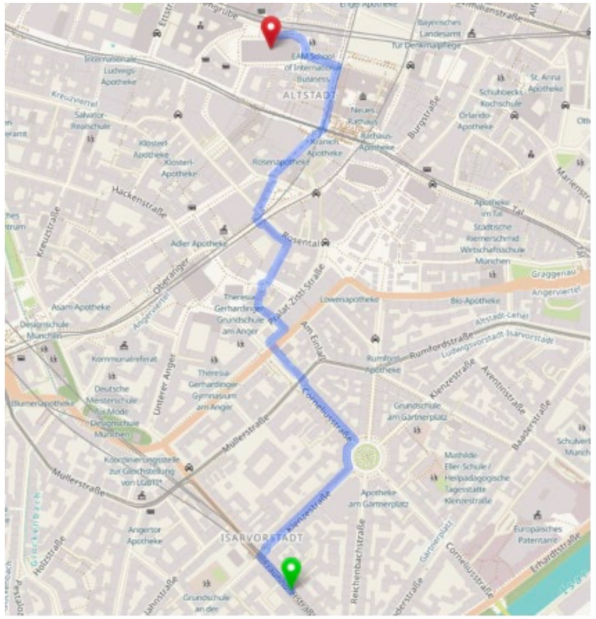
Agenda

- Introduction
- Research objective
- Background information
- Methodology & workflow
- Results & discussion
- Conclusion

Introduction

- With the increasing use of mobile devices and different routing apps, we heavily rely on them for routing and navigation.
- Increase in GNSS enabled smart devices such as mobile phones, smartwatches, and various fitness trackers.
- All the mobile routing apps and companies insist that they provide the most optimum route in a given condition. But do they?





A screenshot from Google Maps showing the optimum walking route from Fraunhoferstrase to Frauenkirche (Left). A screenshot of OpenStreetMap showing the optimum walking route for the same start and end points (Right) at the same time of the day.

Research objective

To develop a set of metric indicators that can evaluate routes suggested by different routing apps as well as humans for the same source-destination pair.

To answer this main research objective, the following sub-objectives & questions have been formed:

Research objective

RO1:
Analyse the routes suggested by two different apps under different scenarios.

RQ_1 Are the planned routes provided by dominant apps optimal? How are the optimum criteria defined here?

$RQ_{1.1}$ Do the apps always consider only “the shortest” route or “the fastest” ?

Research objective

RO2:
Formulations of metric indicators to assess the route generated by machines as well as humans.

RQ_2 Why do different apps provide different results?

$RQ_{2.1}$ Considering our set of metric indicators, how similar are the routes from two different apps?

Research objective

RO3:
Case study of routes generated based on human preferences under different scenarios to verify the feasibility of proposed indicators.

RQ_3 How will a human plan the same route under the same conditions? How different will it be from machine-generated routes?

$RQ_{3.1}$ What factors do humans take into account while planning routes in different scenarios?

Research objective

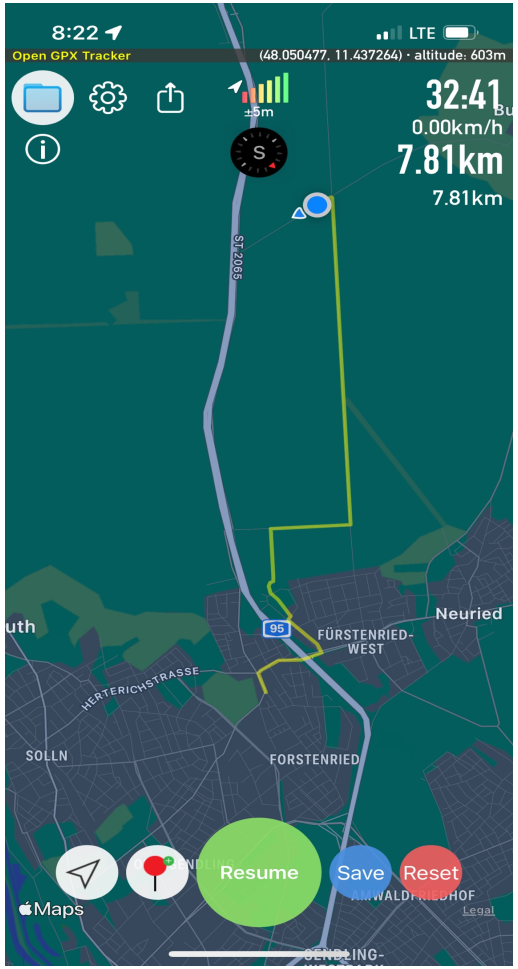
RO4:
Should we always follow machine generated routes.

RQ_4 Which route suggestions should we follow in a given scenario?

Background information

Tools used for this research:

- Google Maps & GraphHopper for machine generated routes.
- GPX Tracker (a free app for IOS & Android) for manually generated routes.
- QGIS for analysing results and generating maps.
- Microsoft forms for user surveys.



Background information

Data & study area: City of Munich,

two **walking** and one **cycling** route.

- For the purpose of this research, three different scenarios were considered.
- Only walking and biking routes were studied and analysed.
- Driving routes were intentionally left out to reduce complexity and time constrains

Background information

Data & study area:

Scenario 1: Leisure Walk

Scenario	Leisure walk
Start point	Drygalski-Allee, 81379 Munich 48.09945398, 11.50823486
End point	Fürstenried Palace, 81475 Munich 48.09426957, 11.48409976
Distance	3.32 km approx.
Time	30-40 min

Background information

Data & study area:

Scenario 2: Travelling to Work Place

Scenario	Office walk
Start point	Salzmesserstrasse 30, 81829 Munich 48.128294, 11.669236
End point	NXP Semiconductors, 81829 Munich 48.136913, 11.669449
Distance	1.35 km approx.
Time	15-18 min

Background information

Data & study area:

Scenario 3: Bike trip on a Weekend

Scenario	Bike trip
Start point	Hatzelweg, 81476 Munich 48.086976, 11.498021
End point	Eichelgarten, 82061 Munich 48.049447,11.437527
Distance	6-7 km approx.
Time	25-35 min

Methodology & workflow

Literature review

↓

Formulation of metric indicators

↓

First user study (validation of indicators)

↓

Analysis of results

↓

Field survey and route formulation (Based of first user study results)

↓

Second user study (validation of hypothesis)

↓

Results & discussion

Methodology

Formulation of metric indicators:

A slightly different set of metric indicators were created for each of the three scenarios.

N	Metric indicators	Traveling to work place	Leisure walk	Bike trip on a weekend
1	Type of the surface / wheelchair accessibility	✓	✓	✓
2	Total length of the route	✓	✓	✓
3	Number of turns / crossings	✓	✓	✓
4	Slope	✓	✓	✓
5	Air quality index / green area	✓	✓	✓
6	Noise level	✓	✓	✓
7	Amenities (benches, waste bins, public toilets, drinking water, shade, etc.)	✓	✓	✓
8	Estimated time of arrival	✓	✓	✓
9	Number of underpasses (underground crossings)	✓		
10	Sidewalk availability	✓	✓	
11	Illumination		✓	✓
12	Dedicated bike lane			✓

Methodology

First User study:

Survey participants: 34

Question types:

- Participant’s details (age group, gender, travel habits)
- 10 indicators for each scenario to arrange in their order of preference
- An open question for each scenario

* Required

Bike trip on a weekend

Section 3: Imagine a scenario where you are going for a bike trip on a day off or on a weekend

8. **While planning a bike trip I take into account the following:** *

Please order the answers by dragging them up and down as per your preferences; the item with the highest priority should be on the top:

- Number of turns / crossings
- Air quality index / green area
- Estimated time of arrival
- Type of surface
- Dedicated bike lanes
- Noise level
- Total length of the route
- Slope
- Illumination
- Amenities (benches, waste bins, public toilets, drinking water, shade, etc.)

9. **Anything else that you take into account in Scenario 3 but is not in the list:**

optional

Enter your answer

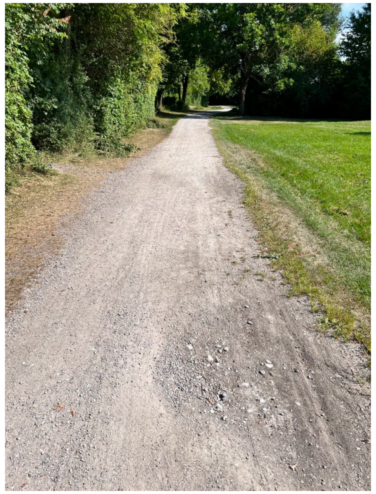
A screenshot of first user survey ; Scenario Bike Trip on a Weekend

Methodology

Field survey and route formulation:

- Based on the first user study results, the priorities of the human generated routes were finalized.
- Three different source-destination pair were selected taking into account the requirements of users.
- The manually generated walking and biking routes were recorded and exported as .gpx files to QGIS.
- Two different routes for each scenario were generated using Google Maps & GraphHopper and exported to QGIS as .gpx file.






Methodology

Non-quantifiable indicators:

Some of indicators such as **Illumination, Green Area, Surface Smoothness** & **Noise Level** were hard to quantify. A different approach was used for them:

Illumination: High, medium and low (4)

High illumination refers to streets with lights on both sides of the road in a continuous pattern such as main streets with 4 traffic lanes.

Medium illumination refers to streets where lights are only on one side and not very close to one another such as narrow streets or one way.

Low illumination refers to streets with almost no lights or where are lights are highly separated from one another such as state highways and inner roads.

Green area (2)

Expressed in percentage (%) and was calculated manually. Such as length of the route which has trees divided by total length of the route, multiplied by hundred to get a percentage. So if the total length of the route is 1500 meters and green area is about 400 – 450 meters then the route has been considered as 30% green. For the sake of minimizing errors, the percentages have been rounded off to the nearest multiple of five.

Examples of surface smoothness; Good, Average & Poor (Left to Right)

Noise level: High, medium and low (3)

High noise level refers to the two streets with general traffic flow around the clock. It includes major city roads.

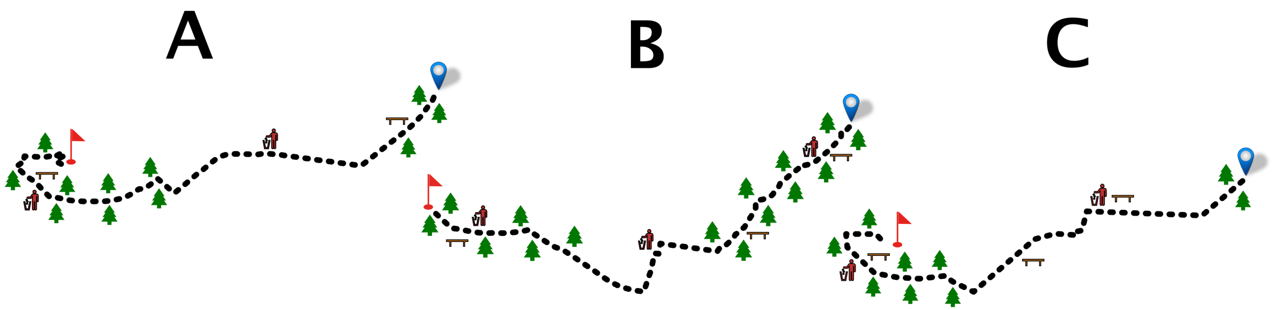
Medium noise level refers to streets where traffic flow is low in off peak hours and heavy vehicles such as bus and trucks are prohibited such as one-way streets.

Low noise level refers to streets where motor vehicles are not permitted and only pedestrian and cyclists are allowed.

Methodology

Map creation for second user study:

- Three different routes were generated for each of three scenarios.
- Users were provided with one map each for all three scenarios.
- The table below each route provides the relevant information about each route to help participants make a decision.



A

1	Green area	65 %
2	Noise level	Medium
3	Illumination	Medium
4	Length	2.97 Km
5	ETA	36 min
6	Benches	9
7	Trash bin	6
8	Smoothness	Good

B

1	Green Area	80%
2	Noise level	Low
3	Illumination	Medium
4	Length	3.22 Km
5	ETA	40 min
6	Benches	12
7	Trash bin	8
8	Smoothness	Average

C

1	Green Area	55%
2	Noise level	Medium
3	Illumination	Medium
4	Length	2.75 Km
5	ETA	38 min
6	Benches	8
7	Trash bin	6
8	Smoothness	Good

Map legend: Track Starting point Trash bin Bench Green area Destination

Map created for Leisure walk scenario for the second user survey.

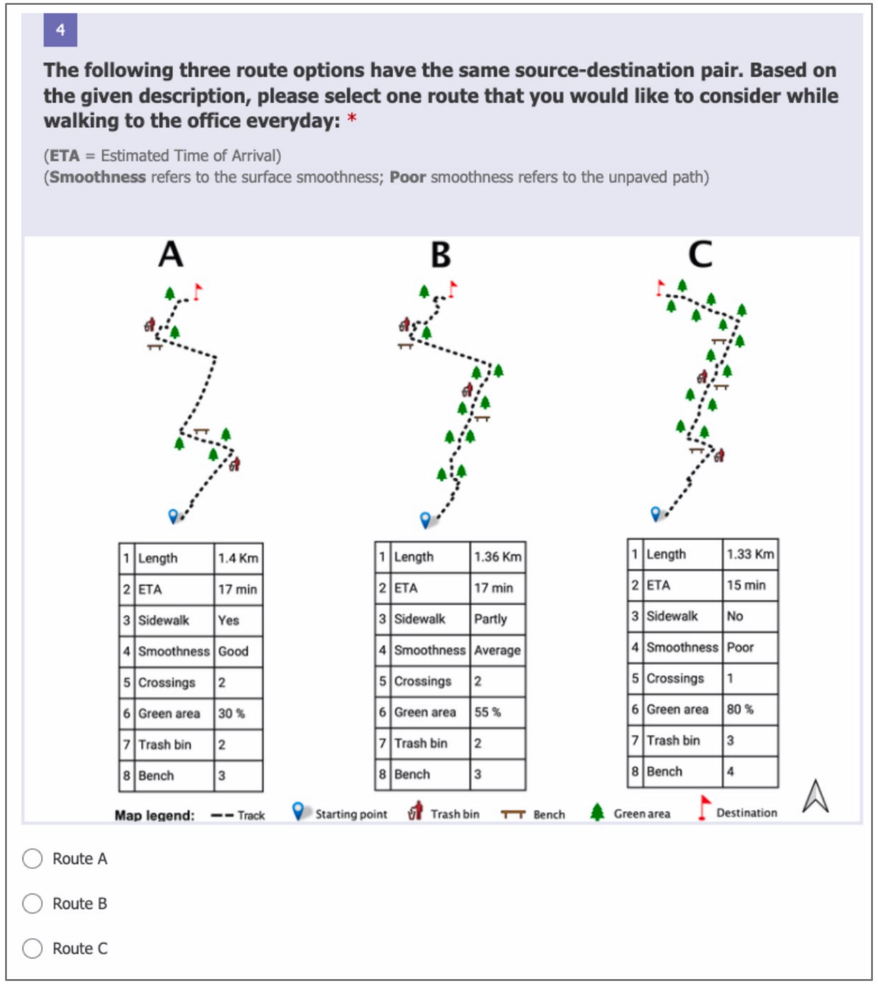
Methodology

Second User study:

Survey participants: 28

Question types:

- Participant's details (age group, gender, travel habits)
- To choose one route in each of the three given scenarios.
- An open question for each scenario.



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The following three route options have the same source-destination pair. Based on the given description, please select one route that you would like to consider while walking to the office everyday: *

(**ETA** = Estimated Time of Arrival)
(**Smoothness** refers to the surface smoothness; **Poor** smoothness refers to the unpaved path)

A

1	Length	1.4 Km
2	ETA	17 min
3	Sidewalk	Yes
4	Smoothness	Good
5	Crossings	2
6	Green area	30 %
7	Trash bin	2
8	Bench	3

B

1	Length	1.36 Km
2	ETA	17 min
3	Sidewalk	Partly
4	Smoothness	Average
5	Crossings	2
6	Green area	55 %
7	Trash bin	2
8	Bench	3

C

1	Length	1.33 Km
2	ETA	15 min
3	Sidewalk	No
4	Smoothness	Poor
5	Crossings	1
6	Green area	80 %
7	Trash bin	3
8	Bench	4

Map legend: Track, Starting point, Trash bin, Bench, Green area, Destination

Route A

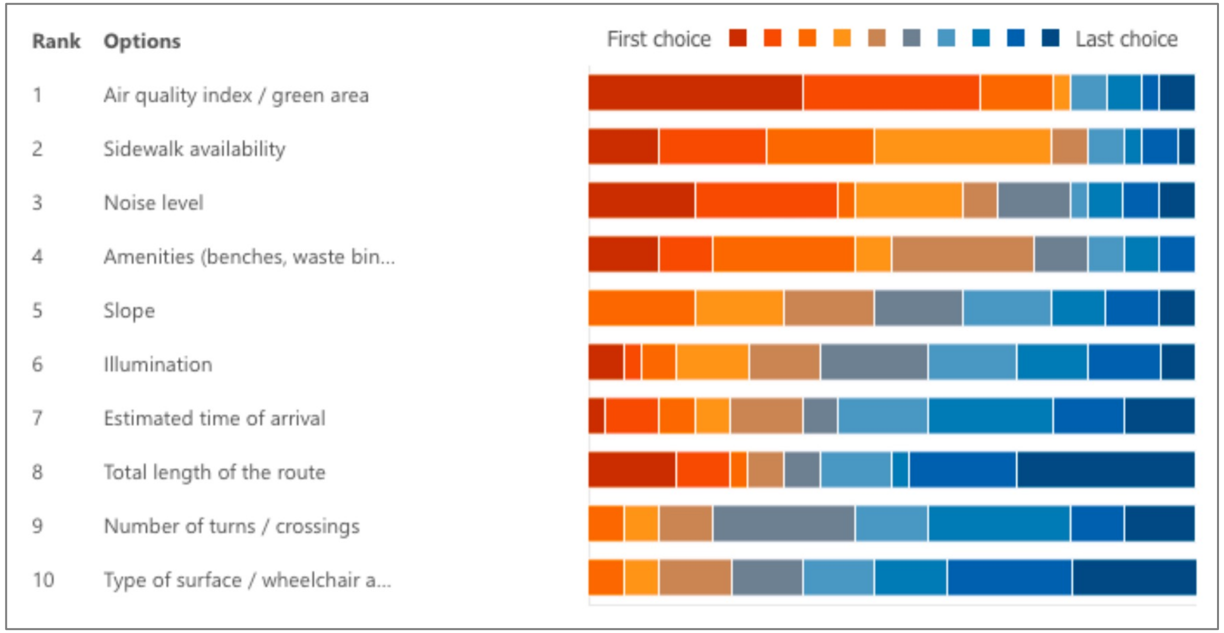
Route B

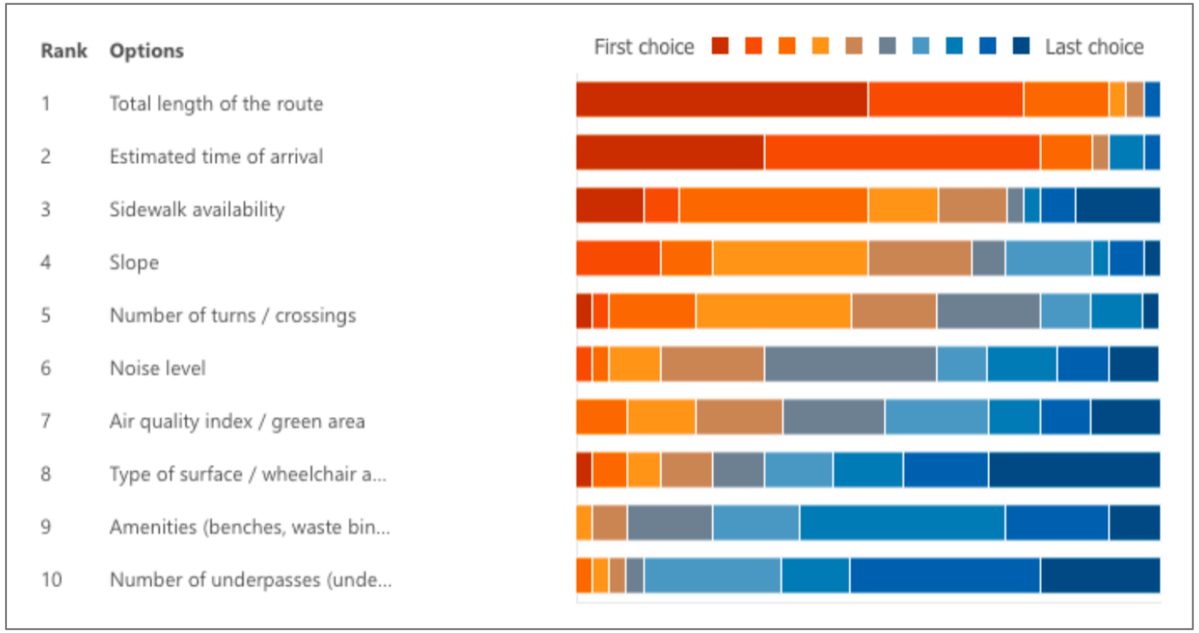
Route C

A screenshot of second user study form; Scenario Travelling to Work Place.

Results & discussion

First user study: Leisure Walk (Left) & Travelling to Work Place (Right)



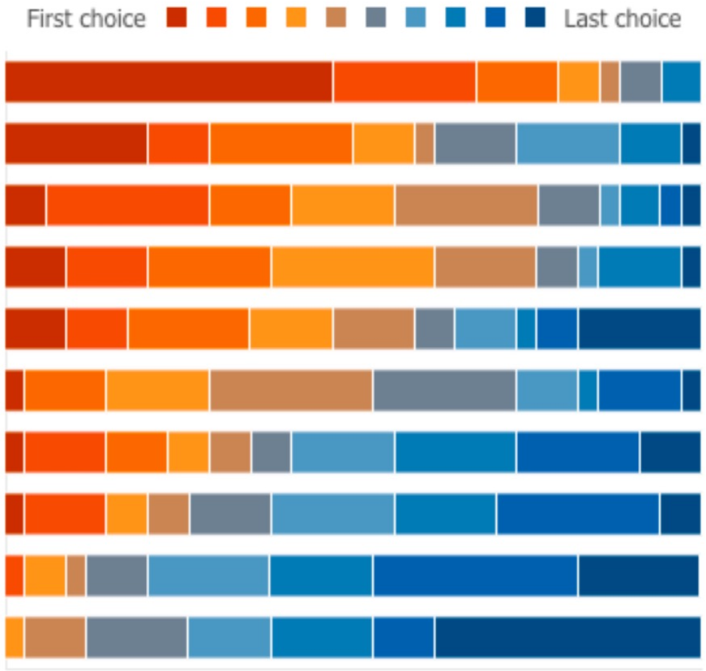


- Change of preferences in two different walking scenarios.

Results & discussion

First user study: Bike Trip on a Weekend

Rank	Options
1	Dedicated bike lanes
2	Air quality index / green area
3	Type of surface
4	Slope
5	Total length of the route
6	Number of turns / crossings
7	Estimated time of arrival
8	Noise level
9	Illumination
10	Amenities (benches, waste bin...



- Dedicated bike lane was chosen as the most popular first choice.

Results & discussion

Second user study: Leisure walk

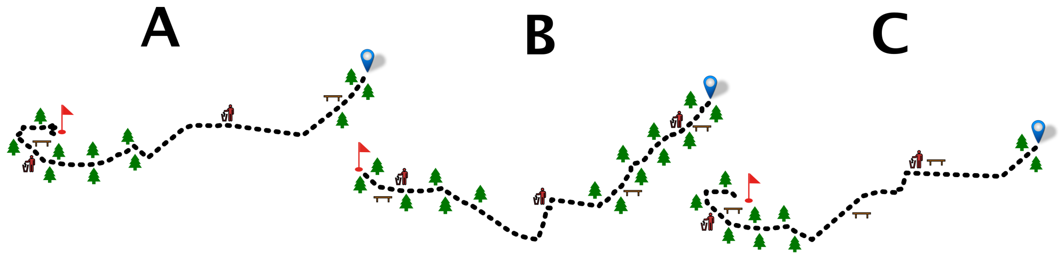
Route A: Google Maps

Route B: Manually

Route C: GraphHopper

In this scenario, Route B emerged as a clear choice and it supported the findings of the first user study.

Inline with user’s preferences for this scenario, GraphHooper emerged as the worst match.



1	Green area	65 %
2	Noise level	Medium
3	Illumination	Medium
4	Length	2.97 Km
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8	Smoothness	Good

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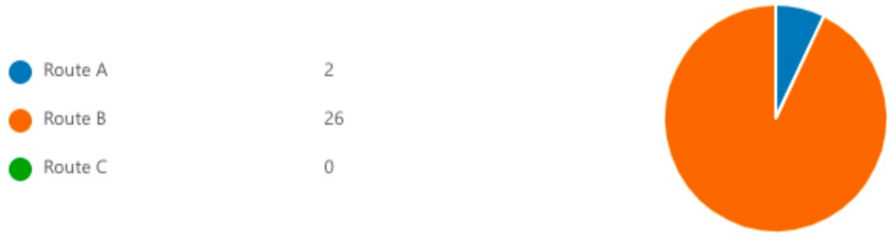


Results & discussion

Second user study: Travelling to Work Place

Route A: Google Maps

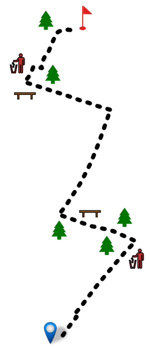
Route B: GraphHopper

Route C: Manually

In this scenario, Route A emerged as a most popular choice and it contradicted the findings of the first user study.

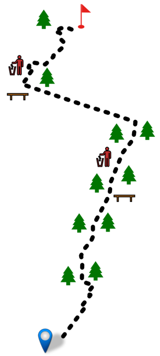
Even though the manually generated route was the fastest, most participant's decided to choose Google Maps due to Sidewalk availability and surface smoothness.

A



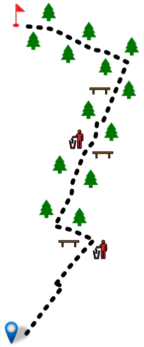
1	Length	1.4 Km
2	ETA	17 min
3	Sidewalk	Yes
4	Smoothness	Good
5	Crossings	2
6	Green area	30 %
7	Trash bin	2
8	Bench	3

B



1	Length	1.36 Km
2	ETA	17 min
3	Sidewalk	Partly
4	Smoothness	Average
5	Crossings	2
6	Green area	55 %
7	Trash bin	2
8	Bench	3

C



1	Length	1.33 Km
2	ETA	15 min
3	Sidewalk	No
4	Smoothness	Poor
5	Crossings	1
6	Green area	80 %
7	Trash bin	3
8	Bench	4

Map legend: Track, Starting point, Trash bin, Bench, Green area, Destination

Results & discussion

Second user study: Bike Trip on a Weekend

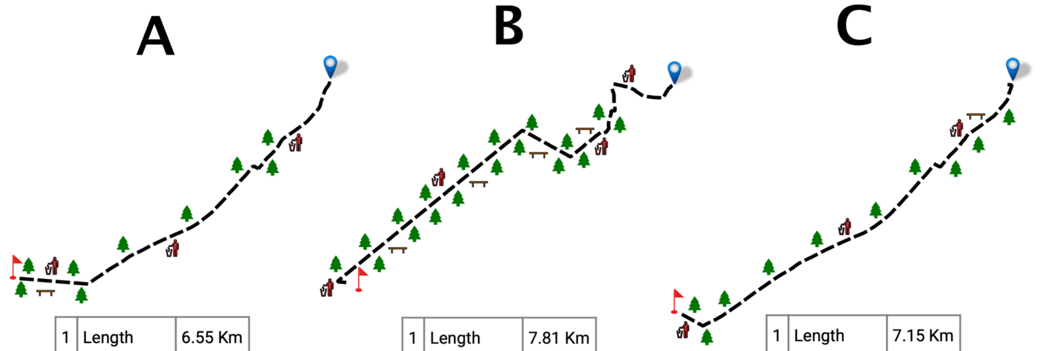
Route A: Google Maps

Route B: Manually

Route C: GraphHopper

In this scenario, Route B emerged as a most popular choice and it supported the findings of the first user study.

Google Maps was the worst performer inline with user's preferences for this scenario.



Route A

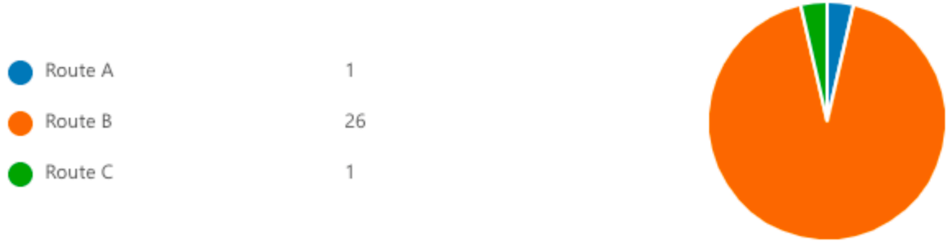
1	Length	6.55 Km
2	ETA	22 min
3	Bike lane	No
4	Green Area	25%
5	Illumination	Low
6	Noise level	Medium
7	Trash bin	3
8	Benches	4

Route B

1	Length	7.81 Km
2	ETA	32 min
3	Bike lane	Yes
4	Green Area	90%
5	Illumination	Low
6	Noise level	Low
7	Trash bin	4
8	Benches	6

Route C

1	Length	7.15 Km
2	ETA	28 min
3	Bike lane	No
4	Green Area	30%
5	Illumination	Low
6	Noise level	Medium
7	Trash bin	3
8	Benches	3



Conclusion

Scenario based observations:

Travelling to Work Place

Google Maps results were most **optimum** and **in-line** with **users preferences** in this scenario.

Leisure Walk

No routing apps were **in-line** with **users preferences** in this scenario. They **never** give **priority** to low noise, illumination, green area & weather.

Bike trip on a Weekend

The **routes** suggested by **routing apps** were **far away** from **users expectations** and preferences in this scenario. **None** of them considered ***Dedicated bike lanes*** for this routing, which was very much possible.

Conclusion

General observations:

- User's choice of route preferences **vary with the scenario.**
- Walking routes suggested by **Google Maps** were most **optimum** for **all-weather** routing.
- **Google Maps** consider ***Travel time* over *Route length*** while **GraphHopper** consider ***Route length* over *Travel time***.
- These two **routing apps** always **prioritize travel time** and **distance** over all the other factors.

If you have no time constrains, using these routing apps might not be a pleasant and healthy choice!

Thank you ☺

Questions?