Technology
Arts Sciences
TH Köln

Visualize Shared Mobility

Project I Documentation

created by

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submitted at the

TH Köln
Campus Gummersbach
Faculty of Information, Media
and Electrical Engineering

in the subject of
Media Informatics

Cologne, September 2022

Abstract

Riding bicycles on the road surrounded by cars can be a dangerous and for some people scary experience. This might also be a reason, for some, not to use a bicycle at all. In order to see whether there are enough bike lanes or if the city of cologne needs more, a visualization comparing bike friendly and bike usable routes is going to be created. In the following work, a foundation was created identifying stakeholders, the requirements for the visualization and data, a useable framework (d3.js or Jupyter) and analysing the Nextbike data and API that is going to be used for the visualization.

Contents

1. Introduction

The “Kölner Verkehrs Betribe“ (engl. Cologne traffic operator, short. KVB) has renewed their contract with bike rental provider Nextbike and is planning to further expand the service (Schwarze u. a., 2017). This aims to help the publicly announced goal of Cologne to reduce emissions by 80% to the year 2050, in comparison to 1990 (Anemüller, 2020). A great change of bicycle rentals is to increase the amount of riders and simultaneously reduce the number of cars on the road.

Accessibility and availability are however only parts of improving the widespread usage of bicycles. The safety and comfortability of cyclists is a major factor in increasing the number of used bikes and in order to increase those, bike lanes need to be sufficient and efficient. Meaning, that there are enough separated bike lanes and the time lost, using those instead of the conventional “car roads“ is not significantly bigger.

The aim of this project can be summarized as the following:

- The data provided by the Nextbike API or the collection of that data should be used.
- Incorporate other data, like a route planer API, to enrich the original data.
- Using that data, compare the routes using only bike lanes with those using all kinds of roads.
- Create a visualization for that comparison, which is usable in a political context/argument.
  - Especially in environmental and traffic policies.
- The visualization should contain a map display.
- In addition, information regarding length and time of the journeys should also be displayed.

2. Requirement management

The Requirement management was separated into two steps, firstly the stakeholder analysis and then the functional and non-functional requirements.

2.1. Stakeholders

Stakeholders are those who have an interest, claim, stake, or right in or with the project. It is important to identify the target group and other involved parties, in order to cater the project accordingly.

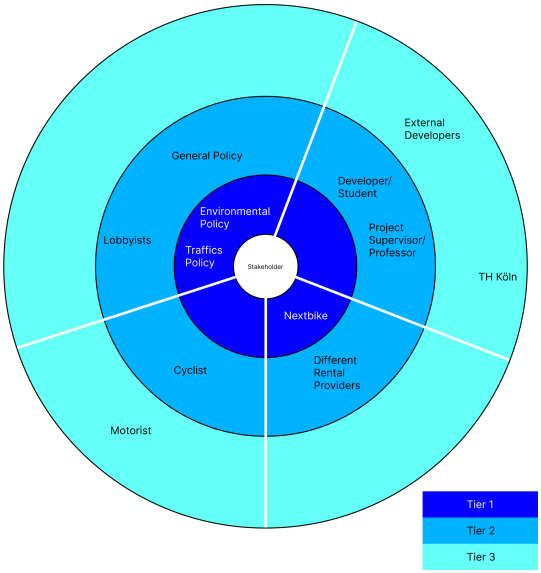
2.1.1. Table of stakeholders

To give a brief summary of the stakeholders, their priority for the project, their influence and their participation in that project, a table was created.

Priority (1-5)	**Name**	**Participation**	**Influence**
2	Cyclist	has interest	Low
1	Motorist	has interest	Low
3	General Policy	has interest	Medium
5	Traffics Policy	has interest has claim	High
5	Environmental Policy	has interest	High
3	Lobbyists	has interest	Medium
4	Nextbike	has interest has claim has stake	High
2	Different Rental Providers	has interest	Low
1	External Developers	has interest has claim	Low

2.1.2. Visualization of stakeholders

As well as a table, a visualization was created to give a quick and comprehensive overview of the stakeholders and their priority/influence (tiers 1-3).



2.1.3. Detailed stakeholder analysis

In the following stakeholder analysis, we use three different indicators for the participation a stakeholder can have. The weakest one is **interest**, which displays an interest in the project, without having any say or wishes for it. **Stake** indicates that the stakeholder has a right, by law, contract, or similar meaning this has the highest priority. In between those two lies the so-called **claim**, it is understood as a requirement for that party, while it doesn't have a right for it.

The stakeholder analysis delivered nine parties, which interests, stakes, and claims will be detail in the following.

Starting with the **cyclist**, who have a low influence and a low priority.

- The cyclist has an interest in the project showing the difference between a full/mostly bike lanes using route and its time difference to the conventional route.
- The cyclist has an interest in the visualization showing which areas have the best coverage of bike lanes.
- The cyclist has an interest in the potential creation of new cycle paths following the publication of the visualization and its findings.
- The cyclist has an interest in the increase of security and reduction of accidents that could follow the extended use of cycle lanes instead of public roads.

On the other hand, the **motorist** will also have an interest in the project, while also being ranked low in both influence and priority.

- The motorist has an interest in the reduction of cyclists on the road, because of the traffic flow and safety conferences.

Another big stakeholder group are the **politics**, who could have different interests. In the following this group is separated into **traffic**, **environmental** and, to sum the rest up, **general** policy.

- The traffics policy has an interest in the visualization, to have a strong and easy to understand argument for the case of ether more cycle paths or the counter, that there are already enough.
- The traffics policy has an interest in increasing the use of cycle lanes to reduce the traffic on shared roads, which could lead to less traffic jams.
- The traffics policy has a claim in that the visualization and its data is correct and scientifically.
- The environmental policy has an interest in increasing the happiness and satisfaction cyclist have, to also increase the number of cyclists on the road.
- The environmental policy has an interest in reducing the number of motorists and cars on the road.
- The general policy has an interest in reducing the amount of cyclist on the road to increase the safety of both cyclist and motorist.

Another stakeholder are the **lobbyists**, they have different positions, but their priority and influence are at a medium level. The **environmental lobbyists** have an interest very similar to the ones of the policy stakeholder.

- Mostly the interest in lessening the emissions by reducing the number of cars on the road.
- The environmental lobbyists have an interest in reducing the traffic, because it would also lower emissions, by reducing the amount of time cars would be on the road.

The **motorist lobbyists** have different interest in the visualization as seen in the following.

- The motorist lobbyists have the interest in reducing the amount of bicycles on the road, as to reduce the traffic and accidents
- The motorist lobbyists have the interest in potentially showing, that there are enough bike lanes, and money should be spent on roads instead.

Lastly, the lobbyists who represent the **cyclists** and the bike manufactures might have an interest in increasing the amount of cyclist, to sell more bikes. Nextbike is another Stakeholder on the list. They have a strong influence, since a major part of the data used for the visualization is theirs.

- Nextbike has an interest in using the information won from the visualization to increase the bike present in the areas which have the highest come up.
- Nextbike has an interest in the number of cyclists increasing, resulting in more use of their service.
- Nextbike has a claim in their data being used in a correct, none altered way.
- Nextbike has a stake with their open data being used, forcing the visualization to comply by their rules.

Different Rental Providers could also be seen as stakeholder, with smaller priority and influence than Nextbike.

- Different Rental Providers have an interest in improving their coverage of cologne with the results of the visualization.
- Different Rental Providers have an interest in using the visualization with their own data.

External Developers might be considered as stakeholders.

- External Developers have an interest in using the visualization within a project of their own.
- External Developers have the claim, that there will be a useful and comprehensive Documentation for the visualization and its data/API's.

2.2. Functional and non-functional requirements

This chapter has been separated in requirements for the visualization and for the data processing. Separating these categories has been done in order to differentiate between these two steps, making it easier to understand each and separate their work.

2.2.1. Requirements for the visualization

The first subsection list all the functional and nonfunctional requirements for the visualization and additional requirements for the future add-ons.

Functional requirements of the visualization

- F01 The visualization must display a Map of the City of Cologne.
- F02 The visualization needs to be able to show multiple routes on the map while differentiating between those.
- F03 The visualization should be capable of showing the difference in time between bike friendly and bike usable routes.
- F04 The visualization should be capable of showing the difference in length between bike friendly and bike usable routes.

- F05 The visualization should be able to display the different types of Streets and Sidewalks (bike lanes, shared side walks, etc.
- F06 The visualization should be able to show the difference in time and Length between different Routs in additional graphs and diagrams.

Non-functional requirements of the visualization

- N01 In order to be used as a political argument or to support an argumentation, the visualization must be able to have a strong message, while still being easy to understand.
- N02 The system should have a good and clean documentation, in order to allow different/external developers to integrate it in different Systems.
- N03 The visualization must use the Data in a correct and non-distorted way.
- N04 The visualization should be easy and quick to comprehend for Spectators of all ranches of experience.
- N05 The visualization should incorporate colour as a component to highlight different aspects of the Shown Data.

Functional and Non-functional requirements of potential improvements/vision for the future of the visualization

- VF01 The System should offer the possibility, to add new routes o the visualization.
- VF02 The System should offer the possibility, to compare routes for different parts of Cologne and display them.
- VF03 The visualization should have filter options for the Graphs comparing the different routes.
- VN01 The System should have intuitive controls and an easy usability for the end user.

2.2.2. Requirements for the data processing

In this subsection the requirements for the data processing, the data itself and the APIs are being presented.

Functional requirements for the data processing and the API

- F01 The data must have information about the start and finish of a route.
- F02 The location specific data should be available as coordinates.
- F03 The data should be collected over a longer time, as to not have a biased regard, weekdays, weather, events, etc.

- F04 The data should be compressed to clusters as to eliminate outliers that could corrupt the result.
- F05 The data should be compressed to clusters in order to be able to see the most common routes used by the users.
- F06 The system must be able to use the start and finish data to calculate a bike friendly and bike usable route.
- F07 The system should be able to calculate the distance between start and finish using the data.
- F08 The system should be able to estimate the time a route takes through an API.
- F09 The calculated routes should carry information in form of handles (0-4), which type of streets were used (shared Sidewalks, bike lanes, etc.).
- F10 The data must be checked for errors and cleaned of potential unintended mistakes and bugs.

Non-functional requirements for the data processing and the API

- N01 The data must be checked for various errors, like gaps in the data, as to keep the integrity of the hole project.
- N02 The data should be double-checked through comparisons with other available statistics, ride time calculators, etc.
- N03 The clustering of the data must be done without selective biased.
- N04 The system or the API it uses should have up-to-date information about the bike lanes in order to calculate the best routes.
- N05 The system should have an extensive documentation regarding errors or gaps of any form.

Functional and Non-functional requirements of potential improvements/vision for the future of the visualization

- VF01 The data should include/ be enriched with additional information regarding weather, temperature, time, day of the week, etc.

3. Market Research

As the work for this semester is based upon a specific set of data, there isn't a direct comparison. However, in the following chapter certain partial aspects of the project will be examined.

3.1. Using mental mapping to unpack perceived cycling risk

In a 2016 publication titled "Using mental mapping to unpack perceived cycling risk" in the 88 Volume of "Accident Analysis & Prevention" by Richard Manton et al. (Manton u. a., 2016), a study was complete where participants ranked the risk, they associate with different parts of their cycling journeys. While the city in question isn't cologne, it is still clear to see which streets are the ones with the most perceived risk. As well as this, there is also a coloured visualization of one route Figure 3.1. This visualization is a great example of using traffic light colours for the route with a greyscale map, to strengthen the focus on the displayed route.

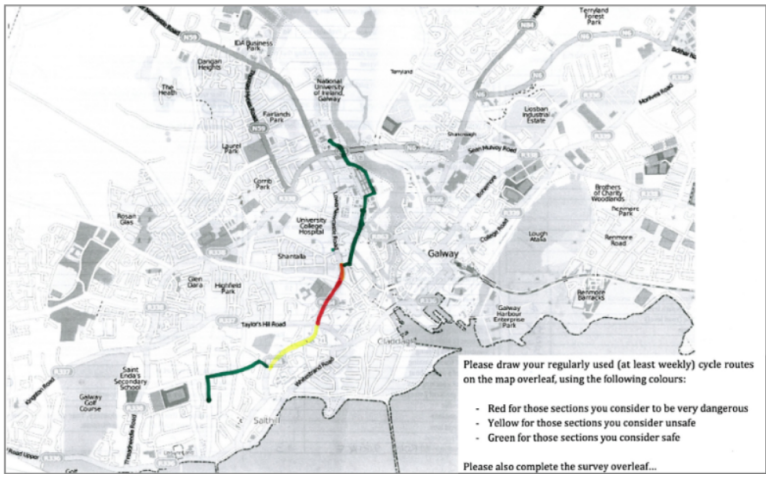


Figure 3.1.: perceived risk of a bike route (Manton u. a., 2016)

3.2. Cycle Route Planner NRW

Routes are visualized by all kinds of route planners and map services. The route planner like the state of Northrhine Westphalia, which uses an interactive map, meaning you can choose to display more or less information on the map. In addition, the map is coloured and uses a typical road and map display Figure 3.2. An alternative would be a satellite map or a topographic display, but those would complicate the visualization and therefore make no sense.

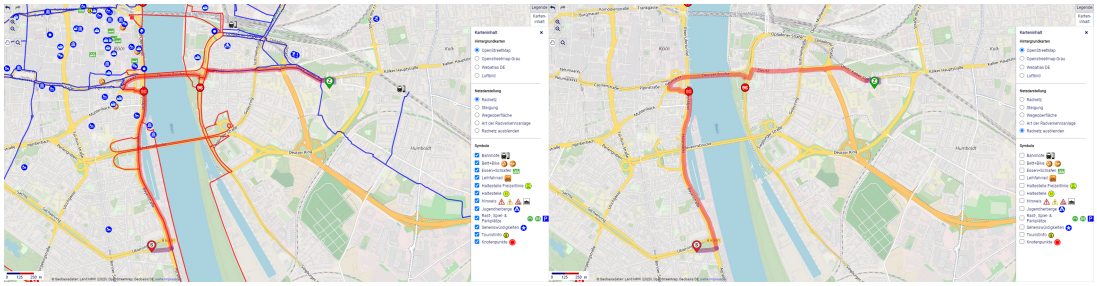


Figure 3.2.: Screenshots from `https://www.radroutenplaner.nrw.de/`

3.3. Case Study: Bike Sharing-Visualization

The project is supposed to, in addition to the map with the routes, also have additional graphs and information. In a lengthy case study from December 2021 Irakla Bulia (Bulia, 2021) shared his visualization on the topic of bike sharing. While a lot of those visualizations aren't directly comparable with the aim or even scope of this Project, one can learn from some of those visualizations.

3.4. Visualizing Bike Mobility in London using Interactive Maps and Animations

Another interesting way to visualize data is by using clusters on a map, in an article called "Visualizing Bike Mobility in London using Interactive Maps and Animations" by Eden Au (Au, 2019), one can see different types of map visualizations which could find a potential use in the project visualization.

3.5. GeoEngine

GeoEngine has also written an example and guide on how to properly display clustering on a map without overlaying or overcomplicating the visualization (geoengine, unko).

3.6. Uber Movement

There are several different tools that use maps and similar visualizations to what is planned in the project, for example "Uber Movement"[1]. But science those are more interactive tools, and the focus lies with the other aforementioned examples.

3.7. Lessons Learned from Analysing Over a Million Points of GPS Data

"Lessons Learned from Analysing Over a Million Points of GPS Data" is an article by Peter Murray discussing the process and challenges in visualizing a big chunk of data (Murray, 2017a). The article and the coherent project (Murray, 2017b) are in a lot of ways similar to the one in this work. Those two artefacts could help build a better and cleaner visualization and, as Murray said, "tell a story that engages audiences and encourages action."

3.8. Mapping and documenting a year of travels.

While the following image is not from a single route visualization, but instead is a collection of routes travelled by cartographer Andy Woodruff, one can see the difference a black background makes in comparison to Figure 3.1.(Woodruff, 2011).

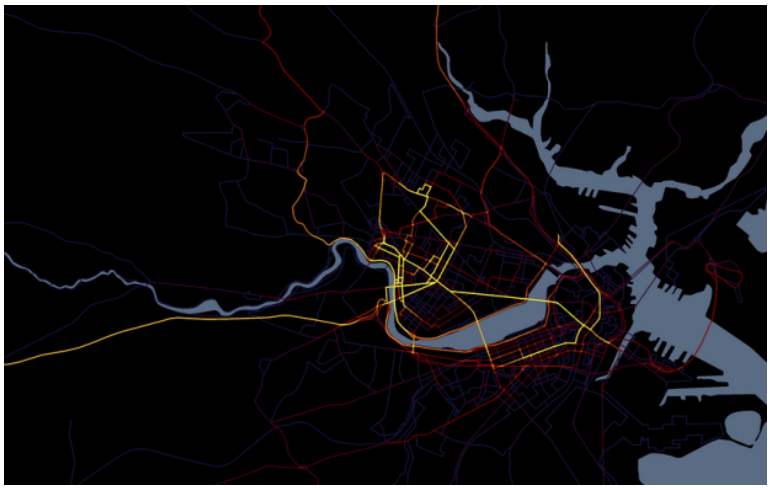


Figure 3.3.: Visualization of years of travel (Woodruff, 2011)

[1] https://movement.uber.com/ (last accessed 22.09.2022)

3.9. Various examples from tableau public

Various examples of visualizing routes can be found on open sites like tableau public. The city of Edmonton for example published the bike routes and its classes as a map with filters and a legend. The extensive use of colours to represent all different kinds of types of roads, make it hard to comprehend everything at a moment's notice (of Edmonton, 2018).
In contrast, another visualization called "the cycle route and open space" uses very little colour and has a pale/grey look, which could potentially reduce the first impression/impact a visualization might have. (WX, 2021)

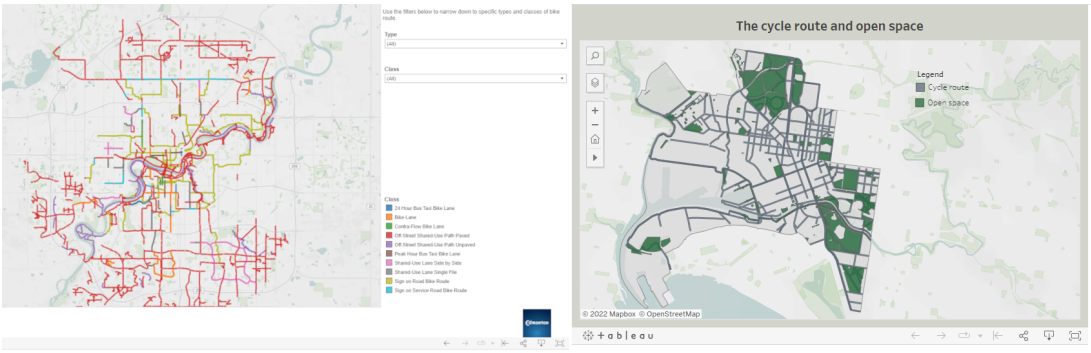


Figure 3.4.: left (of Edmonton, 2018), right (WX, 2021)

An interesting colour choice, which helps the map stand out, is having a black background.An interesting for the use case of this project is the visualization shown in Figure 3.5 displaying the different types of streets in New York City.(Rocchetti, 2021)

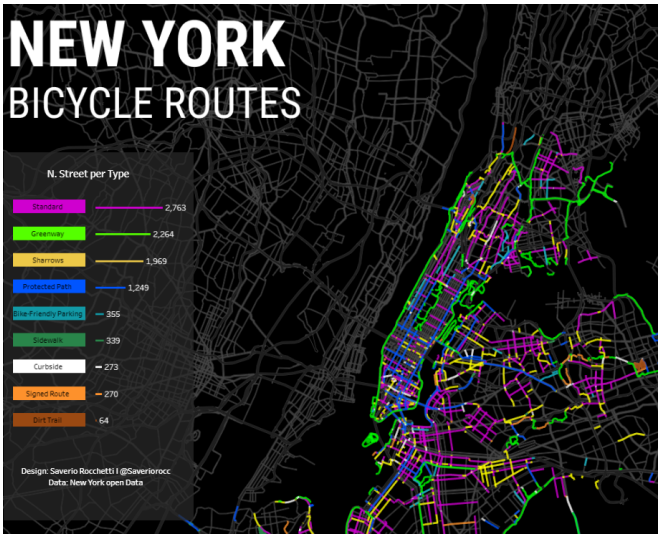


Figure 3.5.: Part of the Visualization from (Rocchetti, 2021)

4. Framework analysis

A crucial step in developing a visualization is to select the framework. In this chapter, different frameworks will be compared, and a selection of frameworks will be given, which are capable of being used for the planned visualization.

4.1. List of examined frameworks

Following the selection of frameworks which were examined. This should help as a quick reference for the selection of this chapter.

- **d3.js** (`https://d3js.org`)
- **Chart.js** (`https://chartjs.org`)
- **Observable** (`https://observablehq.com`)
- **Tableau** (`https://tableau.com`)
- **Carto** (`https://carto.com`)
- **Jupyter** (`https://jupyter.org`)
- **GeoPandas** (`https://geopandas.org/`)
- **Folium** (`http://python-visualization.github.io/folium/`)

4.2. Preselection/elimination of frameworks

Not all of the above listed frameworks can be used for the planned scope of the project, or have different reason of not being selected. For that matter, they were discarded. In this chapter, those frameworks and the reasoning will be displayed.

4.2.1. Chart.js

While Chart.js has some great advantages like:

- Open source
- Official documentation and big support community
- Simple and easy to create bar charts, line charts, scatter charts and other simple charts.

While the reason for Chart.js can be good for some projects, especially the last point is a problem for the visualization, because the result of this point is:

- Limited range of the base capabilities
- The more difficult the project, the more complicated the solution in chart.js gets (3rd party add ones etc.)

4.2.2. Tableau

The problem of Tableau is, that it is a commercial product, resulting in negative points such as:

- "Only" free student licence, which could hinder the later use of the created visualization
- Tableau is its own software, which makes an integration in websites or other programs harder, if not impossible
- Not being an open source project, limits the capabilities as well

4.2.3. Carto

Similar to Tableau, Carto is once again a standalone program, contributing to the negative aspects like:

- Only" individual student accounts via "GitHub Student Developer Pack"
- Integration or customization hard, if not impossible because of Carto being its own Program

4.2.4. Conclusion

Despite that the in this section mentioned frameworks, have good aspects, which weren't all mentioned, they are either not or only hardly usable for the planned project. Despite that, they could be used in other project and were definitely worth looking into.

4.3. Analysis of fitting Frameworks

In order to have a quick overview, major aspects of the remaining frameworks are being listed in a table. This should help give an overview to make a first selection. The full table can be found in the Appendix A.

As a summary of the table, both Folium and GeoPandas, while having good licences and an official documentation, are still in early stages, which can be seen in the smaller communities and unfinished documentations. Observable was also eliminated, because one, it only has a free licence for up to five users per notebook and two, because it is not open source, the flexibility and customisability is lacking.

The two remaining frameworks, d3.js and Juypter are both more than capable to be used for the planned visualization. because of their Open Source licences, large documentations and communities, as well as a good/great level of customizability.

4.3.1. Conclusion

All of the above examined frameworks have the capabilities to produce a visualization as planned in this project. However, there are disadvantages for some options, which remove them from the recommendation of this chapter.

- **Observables** limited expandability and non-open licence
- **GeoPandas** small community support, combined with the complexity of it using a variety of different frameworks to function itself.
- **Folium** has a lacking documentation and community, both attributed to the early stage of development it is in (0.12.1).

The recommendation for the framework to be used in the progression of this project, is either **d3.js** or **Jupyter**. Both are capable frameworks, allowing the user to create the visualization. The recommendation includes the two of them, as the developer might have previous experience in JavaScript/Python or the usage of conventional code/notebooks.

5. Data acquisition and pre-processing

A major part of this project is the usage of Nextbike's API or the previously collected data. In the following sections, the Nextbike data and an API used for the route planning will be explored and presented.

5.1. Nextbike

Nextbike is a Bike-Sharing company from Germany, that publishes part of their collected data via an API.[1] In a previous work by Nada Jelcic this access was used to collect data from 2019 until 2022. The data was then filtered, to only save the information seen in Figure 5.1. For a more detailed description of the data collection, see (Jelici, 2022).

lat_begin	lng_begin	lat_end	lng_end	ride_begin	ride_end	ride_time_minutes	distance	uid_begin	uid_end	standing_before_ride	name
5092161798	6,93324E+16	5091304873	6,92249E+15	01/07/2020 09:31	01/07/2020 09:49	180	12150	31804315	31819860	5710	BIKE 22933
5091304873	6,92249E+15	5091079415	6,94197E+16	01/07/2020 10:35	01/07/2020 10:44	90	13890	31819860	31821838	460	BIKE 22933
5091079415	6,94197E+16	5093139497	6,91823E+16	01/07/2020 11:32	01/07/2020 11:55	230	28320	31821838	31824497	480	BIKE 22933
5093139497	6,91823E+16	5092981638	6913806	01/07/2020 12:03	01/07/2020 12:24	210	3560	31824497	31825694	80	BIKE 22933
5092981638	6913806	509298229	6,91362E+15	01/07/2020 17:59	01/07/2020 18:05	60	130	31825694	31843292	3350	BIKE 22933
509298229	6,91362E+15	5092357367	69519946	01/07/2020 18:19	01/07/2020 18:37	180	27790	31843292	31845584	140	BIKE 22933
5092357367	69519946	5093325355	6,92364E+15	01/07/2020 18:44	01/07/2020 18:59	150	22610	31845584	31847145	70	BIKE 22933
5093325355	6,92364E+15	5092787788	6908989217	01/07/2020 21:25	01/07/2020 21:34	90	11880	31847145	31856891	1460	BIKE 22933
5092787788	6908989217	5092878017	6914152867	01/07/2020 22:11	01/07/2020 22:15	40	3760	31856891	31858979	370	BIKE 22933
5092878017	6914152867	5092869633	6913970383	02/07/2020 19:14	02/07/2020 19:16	20	160	31858979	31901420	12590	BIKE 22933

Figure 5.1.: Preview of the collected Nextbike data

However, not all the data can be used for the project, the ride_time_minutes, the ride_begin and ride_end are not measuring the ride itself, but the length the bicycle was reserved, meaning if a user rents the bike but doesn't immediately start riding, the ride_timeminutes still increases. As well as that, the distance is measured in a straight, direct line and not the route length.

Afterwards, the data got preprocessed, to remove unnecessary data, combine multiple files and add additional information, this was done in seven Steps. The collected, and pre-processed data can be found in this GitHub Repo. [2]

1. removing unnecessary data to reduce the total amount of rows in the csv
2. adding the daily csv files together in monthly periods, and removing redundant data
3. creating a new feature, "parked time"

[1] https://github.com/nextbike/api-doc (last accessed 19.09.2022)
[2] https://github.com/WanjaSchaible/mobility$_p reprocessing_N extBike$ – $Data(lastaccessed$20.09.2022)

4. removing of false data, commonly created by GPS tracking malfunction
5. change of structure, in order to highlight the rides and not just the stationary bikes (e.g. add lat/lng begin and lat/lng end)
6. crating a new feature, "distance"
7. verification, meaning checks for duplicates, invalid data (negative data, outliers etc.)

5.2. Bike route planner NRW

In order to calculate the routes, both bike friendly and bike usable, it is planned to use the API provided by the bike route planner NRW [3]. The result of an API request is a list of coordinates which mark the resulting route depending on the parameters given. Those parameters include, start and finish coordinates, as well as up to 19 additional points in-between. Additionally, one can add optional parameters like, "AvoidSteepGrades", "ThematicRoutes" or the more interesting options in this context "EntireBicycleNetwork" (preferring bike lanes) and "No" (shortest route using all streets). A full documentation of the usage and implementation of the API was requested through the NRW ministry of traffic. Because it is not a public documentation, one can request access through the official channels or Moritz Langer or Prof. Dr. Schaible.

[3] https://www.radroutenplaner.nrw.de (last accessed 20.09.2022)

6. Conclusion

Creating a visualization, that compares two different routes taken with the same start and finish, one bike friendly and one bike usable, is the goal of this project. With the present work, the fundamentals for creating that visualization has been compiled. The stakeholder have been identified and categorized and were then used to create the requirements for the project, which create a good overview of the project needs. The Data, API and suggestions for the frameworks is also given, so that the project should be able to be created without doing further research. some functionalities and specifications are still to be decided, however this was done deliberately and in conjunction with the supervising Professor, as it allows more flexibility and freedom for the next part of the project.

6.1. Future work

The next steps include the creation of prototypes, implementing data and API. Future features that could be included in the project are interactivity for the map visualization and or the additional comparisons. As well as the options to filter the visualization, for different parts of the city as an example. In addition, technical questions like whether a bulk loading or lazy loading should be used is another part of the future work.

6.2. Reflection

The project was hindered in the beginning due to a late start because of complications in the organization, which resulted in a shorter than usual timespan. Because of this, no Prototype was created, which can be a time-consuming task in the next phase. Nonetheless, a good project base was created in this semester, finding the idea for the work, specifying, analysing and working out requirements was a success. Finding and requesting a functional API for the Project was a crucial step, that was successful. All in all, one could say that a solid ground was created on which a further development can be built.

List of Figures

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A. Framwork

	d3.js	Observable	Jupyter	GeoPandas	Folium
Licence	ISC-licence (Open Source)	Free for up to 5 users per notebook	Modified BSD-license (Open Source)	BSD-licence (Open Source)	MIT-licence
Language	JavaScript	JavaScript	Python	Python	Python
Documentation	-Large official documentation -Official example library	-Great official documentation -Official video tutorials	-Great official documentation	-Decent official documentation (still being worked on)	-official documentation (still being worked on)
Community/ Support	-Large community ⇒ huge support, forum, etc.	-Decent sized community -Official forums	-Big community ⇒ support, forum, etc.	- smaller Community	-small Community -still in the early stages
Environment/ Testing	SVG/HTML	Notebook ⇒ direct visualization of code	Notebook ⇒ direct visualization of code	Plotting through matplotlib	
Expandability	Greatly flexible and customizable	Limited flexibility and customizability	Good flexibility and customizability	Greatly flexible and customizable	Greatly flexible and customizable