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Document information

Author(s) and contributing partner(s) - if any

Name	Organisation	Contribution
Fariya Sharmeen	KTH	Section 1 Overall writing and coordination
Giangiuseppe Tateo	Nextome	Section 2
Matt Davoudizavareh	KTH	Section 3
Sylvia Crum	KTH	Section 4 and 5
Maria Konstantinidou	CERTH	Review and section 5
Annarita	Pin Bike	Review and section 2

List of abbreviations (if any)

ODP	Open Data Platform

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1. Executive Summary

This document corresponding to deliverable DEL05 “Guidebook for cites and practitioners’’ is produced in the context of Task A2205, by KTH in collaboration with CERTH, Nextome and PinBike. Its main goal is to document a roadmap for local authorities and practitioners about how to integrate the bicycles trajectories data in their strategies toward the promotion of a more active a greener mobility.

The guidebook contains all the necessary information for using and modifying the parameters of the Municipality dashboard. It also informs decision makers about the importance of utilizing bicycle trajectories data in planning and policy decision making.

It serves as a guide on using bicycle trajectories data to understand the performance of policy measures to increase bicycling modal share. It contains practical examples using data from the three pilot cities on the various elements of planning features appreciated and encouraged everyday cycling. The guidebook also identifes the role of incentives, includes a discussion on the success and failure factors and where it needs improvements to achieve a more efficient and sustainable modal shift.

2. Developing Open Access Dashboard

Pin Bike has patented a system to certify, monitor, and gamify urban bike rides. This anti-fraud system combines tracking via hardware (sensors) and software (app), validates, and stores it in Pin Bike’s dashboard. At the same time, Pin Bike’s diffused sensors collect useful data to inform data-driven decisions, policies, and investments. Pin Bike’s dashboard shows constantly updated KPIs (no. of users and local shop, average km cycled, CO_2 emissions saved, peak times and days, etc.) and cycling traffic heatmaps for the city managers to always have an overview of the pilot performance.

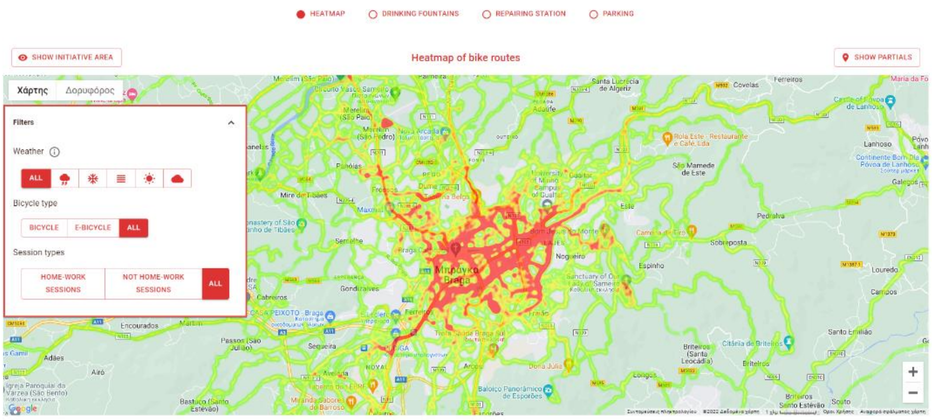
City managers are able to introduce tailored temporary measures such as multipliers that can increase the km reimbursement to citizens per each km cycled during peak hours to further decrease traffic. They can also engage citizens with extra prizes rewarding users taking part in local events and/or surveys. Furthermore, local governance will be more cooperative and participatory, since city managers will be able to send in-app notifications and (rewarding) questionnaires to their citizens while conversely receiving their reports about architectural barriers and infrastructural status. Citizens can also cooperate on the creation of local maps to pin cycling-relevant infrastructure and services.

A more limited, public version of the dashboard is the “Open Data Platform”, one of the main results of BICIFICATION. It is publicly available online to make the general public able to monitor the performance of the pilot and to inform data-driven research, policies, and investments. The ODP of each city is available in the following related link:

- Braga
- Tallin
- Istanbul

The ODP of each city shows:

- Heatmaps
- Cooperative maps of cycling-related infrastructure (drinking fountains, bike parkings, bike repairing stations) created by users
- Meaningful KPIs
- Shops participating in the project, I.e redeeming vouchers earned by cyclists (the ODP of Istanbul does not contain this information as the shops participated in the project are the ones in which the Istanbulkart can be used).



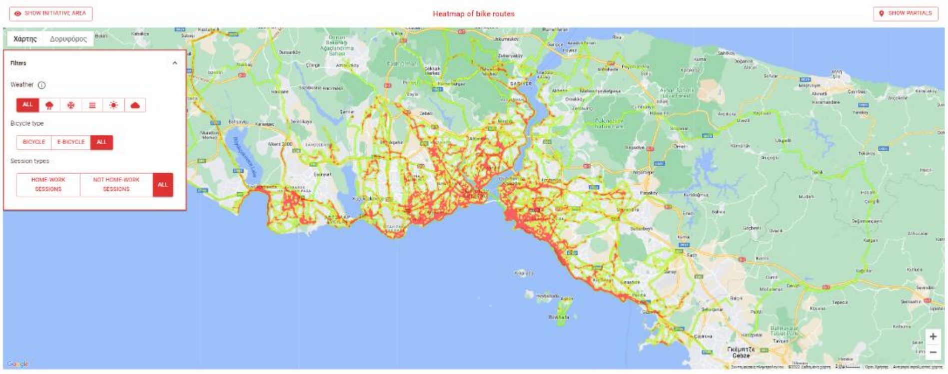


Figure 1: Heatmaps of cycling trajectories in the ODP of Braga, Istanbul and Tallinn

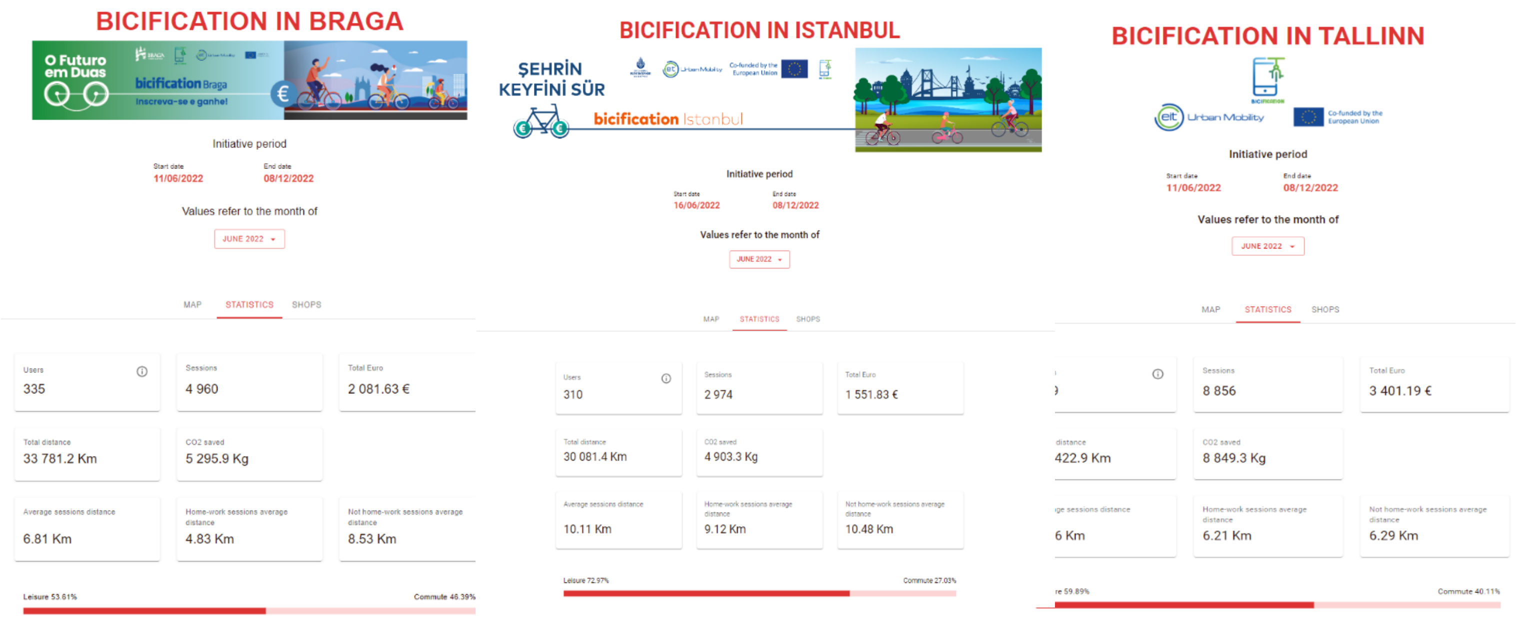


Figure 2: KPIs of Braga, Istanbul and Tallinn in their ODP

Figure 3: Shops feature as appeared in ODP of Braga and Tallinn

2.1. Data Sources

The sources for the Open Data Platform are mainly three:

- Session data
- Weather data
- Initiative data

Session data

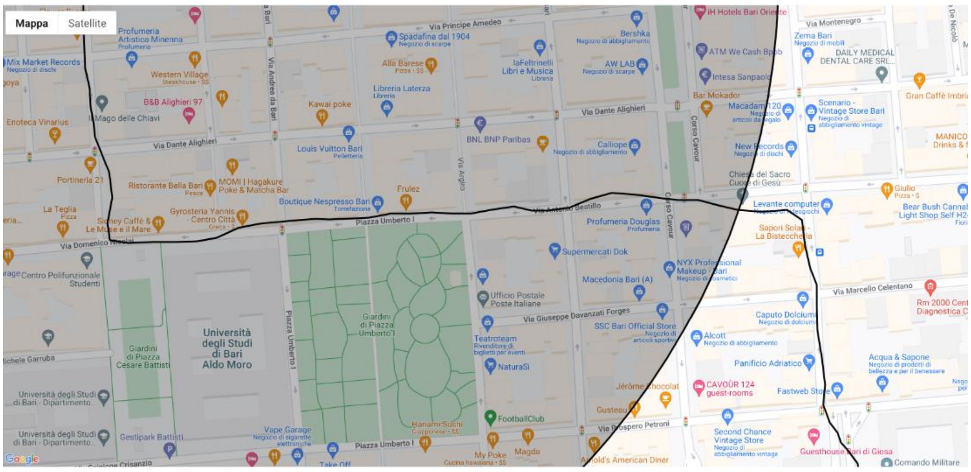
For each cycling session, Pin Bike collects a list of partials at a predefined interval. Each partial is compound by latitude, longitude, distance (certified by sensor) and time. The partials are used to:

- calculate the distance of the session, its duration, its co2 esteemed saving
- assign points and euro for kilometric rewarding
- plot bike trajectories

These data are accessible for the user himself or for the organization manager, to check the evolution of the initiative and are processed in batch the be shown, aggregated in the platform.

The first step of the pre-process phase consists in match the GPS trace into roads. The GPS positions saved in the session partials are matched onto the most likely driven route on the map.

Before the match:



After the match:

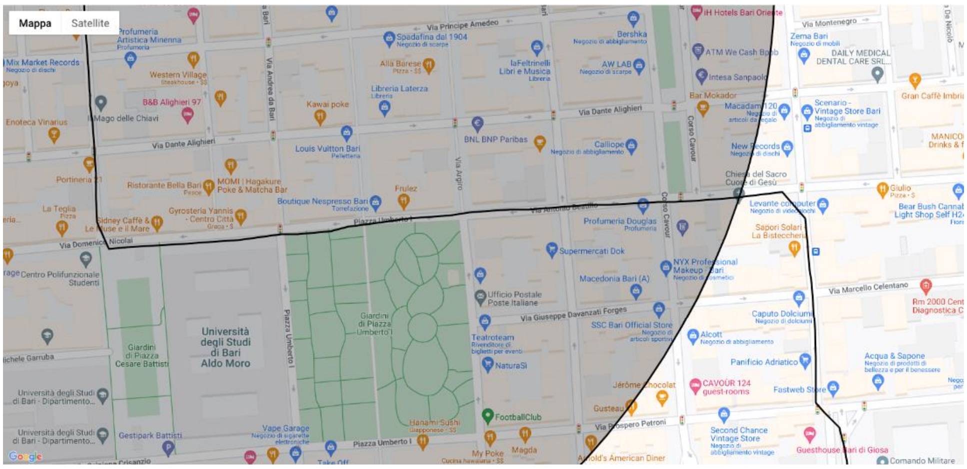


Figure 4: GPS trace before and after the match into roads

The second step is aggregate the sessions removing unused features and keeping the one used to filter the data. The result is a table having only the day of the end of the session (not the whole timestamp), the path, the bike type (muscular or e-bike), saved Co2 and if the session is a homework session or not.

A session is considered a home-work session if starts from the home address and ends to the work address (or vice-versa). Round trip sessions are not considered (e.g., if a user starts and ends a session to his home and the workplace is a stop-over). Users are encouraged to share home and work addresses because usually home-work sessions have higher amount of kilometric rewarding.

Weather data

Weather data are collected using open weather API (https://openweathermap.org). The data are collected hourly and are associated to the closest session in time. The collected data are temperature, pressure, humidity, wind speed, rain in the last hour, rain the last three hours, snow in the last hour, snow in the last three hours and cloudiness. For sake of simplicity, not all these data are shown in the open data platform filters.

Initiative data

During the initiative, both managers and user can report the position of drinking fountains, repairing stations and parking area. If the initiative allows it, shops can register to be eligible as points where consume vouchers. When a shop registers, it creates a profile and a list of products. All these data are collected and shown by the open data platform.

3. Utilizing bicycle trajectory data

The benefits of active modes are well established for several decades. Direct and indirect health benefits are indisputable facts of active travel modes such as cycling (Morris J. et al. 1958, Nazelle A. et. al. 2011, Green J. et al 2013, Götschi T. et al. 2016). Inducing 'active travel' via different strategies is beneficial for both mobility within our cities and our quality of life (Wanless D. et al. 2004, Mueller N. et al. 2015). Given the benefits, numerous governments across the world are gearing cities toward a bikeable built environment. An important strategy to increase active travel is the construction of new bicycle-friendly infrastructures (Pucher J. et al. 2011, Litman T. 2015, Chengxi L. et al. 2021). A study was conducted in Paris and Lyon, France from 2014 to 2020 (Xiao S. et al. 2022). They identified 15 locations across the city considering levels of cycling 6 months before the intervention compared to 6 months after and they observed an increase of at least 14.7% in Paris and 8.2% in Lyon in mean daily cycling counts. Another study in Glasgow Scotland observed that in the short-term introducing new cycling infrastructure, especially inside the city area will effectively induce cycling mode share (Hong J. et al. 2019). However, other studies have highlighted that constructing new cycle lanes may be necessary for cities to get more people on board when it comes to active travel mode share, but it is not sufficient to see significant changes in cycling levels (Tortosa . et al. 2021, Rachel A. et al. 2013). This lack of consistency across different studies could be because of relying on measures that are prone to be biased. Therefore, we need more in-depth analyses to get insights into contributing factors regarding cycling-induced policies and technologies, and infrastructure. This will pave the way for decision-making authorities and policymakers when planning a sustainable and bikeable urban area. One useful source of data to shed light on cycling behavior and route preferences is GPS-based bicycle data (Menghini J. et al. 2010, Hood J. et al. 2011, Hudson J. et al. 2012, Broach J. et al. 2012, Casello J. et al. 2014, Gustavo R. et al. 2015, Kristiann C. et al. 2016, Nikola M. et al. 2019, Chengming L. et al. 2019). Many GPS-based studies are conducted with a small number of candidates wearing a GPS device or via smartphones for a certain period of time. Therefore, they were not capable of recording for longer periods or with a large sample of users (Shen L. et al. 2014). What makes BICIFICATION unique is the amount of data being collected on a very large geographical and user scale (almost 1500) thanks to the available financial and human resources.

3.1. Sources: Which data, from where?

Data was collected via GPS kits provided by Pinbike. Data collection and storage were conducted by Nextome. In the end, three types of data were collected,

1. Trip traces:

Session Id: Randomly generated UUID (e.g 7447595a-fd51-4b1d-9223-cab1bc64a3a8) User Id: Randomly generated id (e.g NqaoElhbjDbreq9cxxHl2NBl56r2)
Type: 0 for session with muscular bike, 1 for session with electric bike
Start time stamp: start time stamp (UNIX time)
End time stamp: end time stamp in (UNIX time)
Trip duration: duration in seconds. Considers pause time, so it could be lesser than the difference between end timestamp and start timestamp
Trip distance In km
Euro: Euros earned by the user in this session
CO2: Estimated CO2 saving for this session. Calculated only if the user has selected a car in the app
Homework: Boolean, true if the session is a home/work session
Polyline: the route of the user in G-Maps' Encoded Polyline Algorithm Format.

2. Socio-demographic:

Collected via registration forms prior to the pilot. It provides: age, gender, employment status,

3. Weather data:

Collected and stored from an API (https://openweathermap.org/). This includes, weather category (clear, rain, cloudy, thunderstorm, etc.), wind speed and direction, amount of rain and other weather phenomena, at the time of which a trip was happening.

3.2. Data pre-processing

After data collection the raw data was shared with KTH, to be cleaned and pre-processed. First the trip data was merged with weather data using start time of each trip with the corresponding weather data. This will help us know the exact weather condition at the time of the trip. Next, user data provided from registration forms was merged with new trip dataset, using user identifier (a code which is generated to keep user anonymized). The new merged data frame provides valuable knowledge on different dimensions, therefore for every trip trace we have the corresponding weather and sociodemographic. This process was repeated for all the three cities of Braga, Istanbul and Tallinn. At the end more than 10,000 trips were recorded for each city during the pilot.

3.3. Preliminary results

To begin with some preliminary findings, we studied the effects of hours during a day on the number of trips. Peak hour is clearly visible in different cities; in Braga (figure below), there is a small peak around noon which shows the tradition of closing stores for a daily nap, which is generating a trip back and forth from home perhaps. In Istanbul on the other hand number of trips in peak hours are much more than non-peak hours compared to other two cities. This is due to the double rewards offered when cycling in rush hours. Another interesting finding is the gender distribution in different cities; in Tallin a suspiciously even distribution was found in the observed data, and this was caused by the different approaches that cities followed to register users. In Istanbul and Braga, the approach was first come first serve, meanwhile in Tallinn they decided to start the pilot only when 45% of users were female, 45% male and 10% “other”. This explains the higher involvement of female users, compared to other cities.

It is also worth mentioning that in Istanbul, travellers are allowed to put bicycles on ferries as we have noticed by looking at the trip trajectories on the map. This could cause a higher average distance cycled. Although the system cannot detect intermodality, it can detect if a user is cycling or not (when the wheel is turning) and eventually put the session to pause. So, the trajectories data and the user rewards weren’t impacted. The main cases are:

1. The user is on a ferry, the wheel is stable and the app goes on pause (or the user puts the app in pause manually): the time on the ferry is not considered for calculating distances and reimburses.
2. The user is on a ferry, but the app is not on pause (the user did not put the app on pause manually or the sensor detects motions of the wheel): the app will register GPS position of the ferry and sensor distance. The GPS distance will be longer than sensor distance and that session will be not automatically certified, so the user will not receive the reward. The user can ask for a manual check that will likely detect the problem and assign the correct distance.

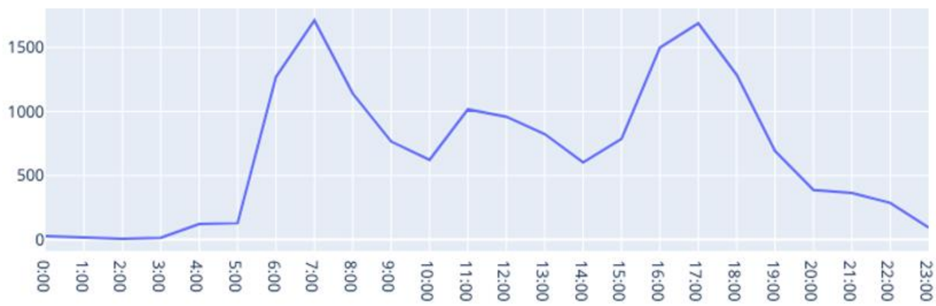


Figure 5: Hour effect on the number of trips in Braga

Figure 6: Hour effect on the number of trips per gender in Braga

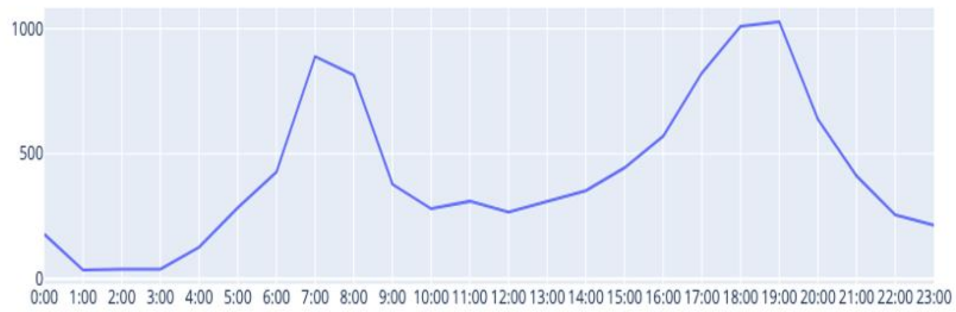


Figure 7: Hour effect on the number of trips in Istanbul

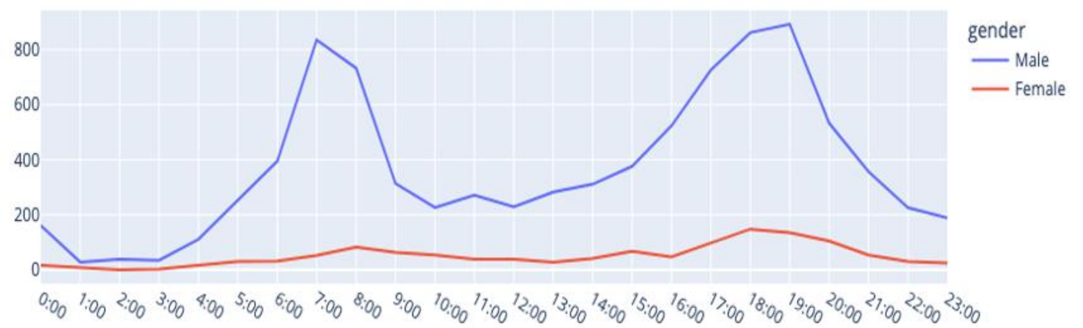


Figure 8: Hour effect on the number of trips per gender in Istanbul

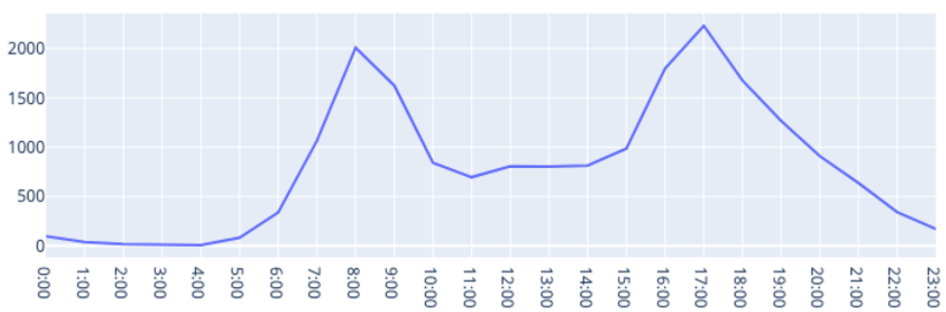


Figure 9: Hour effect on the number of trips in Tallinn

Figure 10: Hour effect on the number of trips per gender in Tallinn

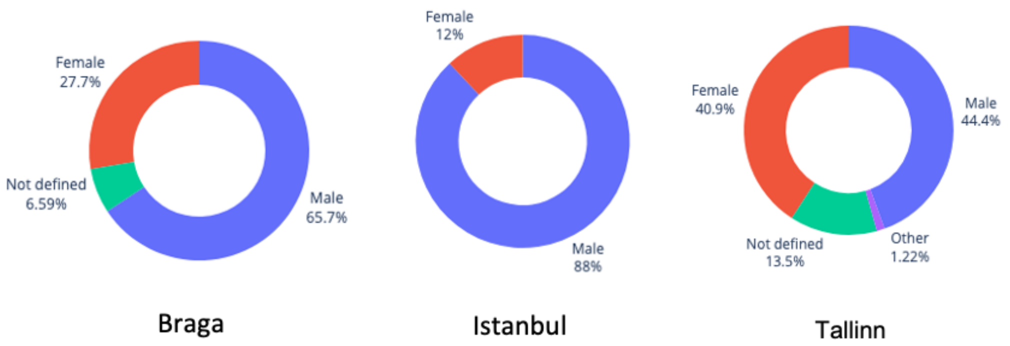


Figure 11: Gender distribution based on observed data

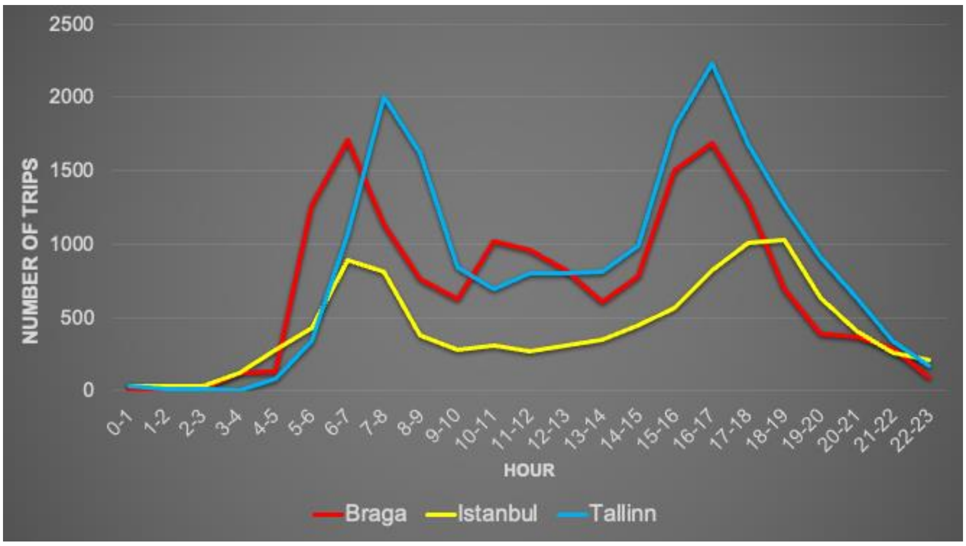


Figure 12: Comparative graph of hour effect on number of trips

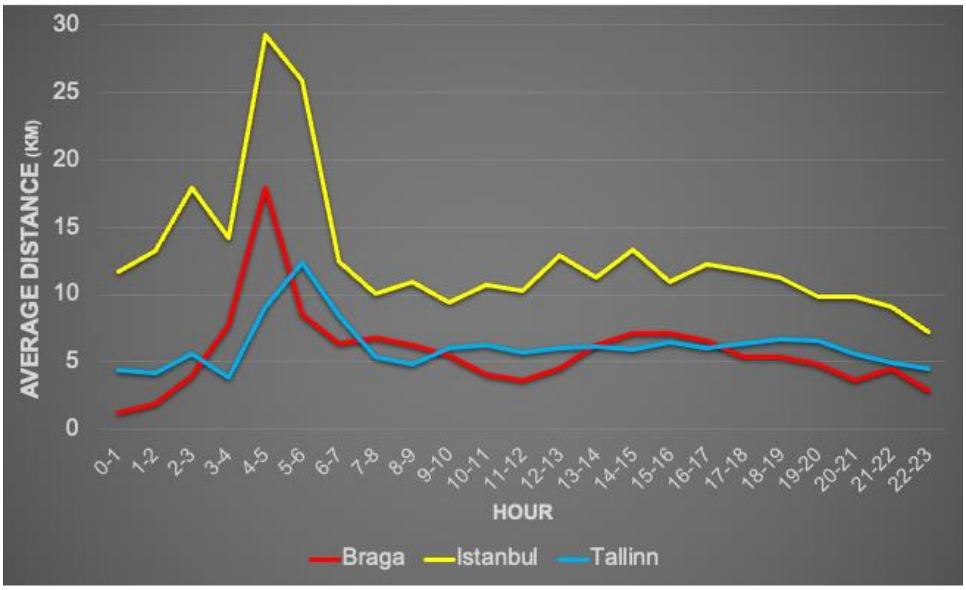


Figure 13: Comparative graph of hour effect on trip distance

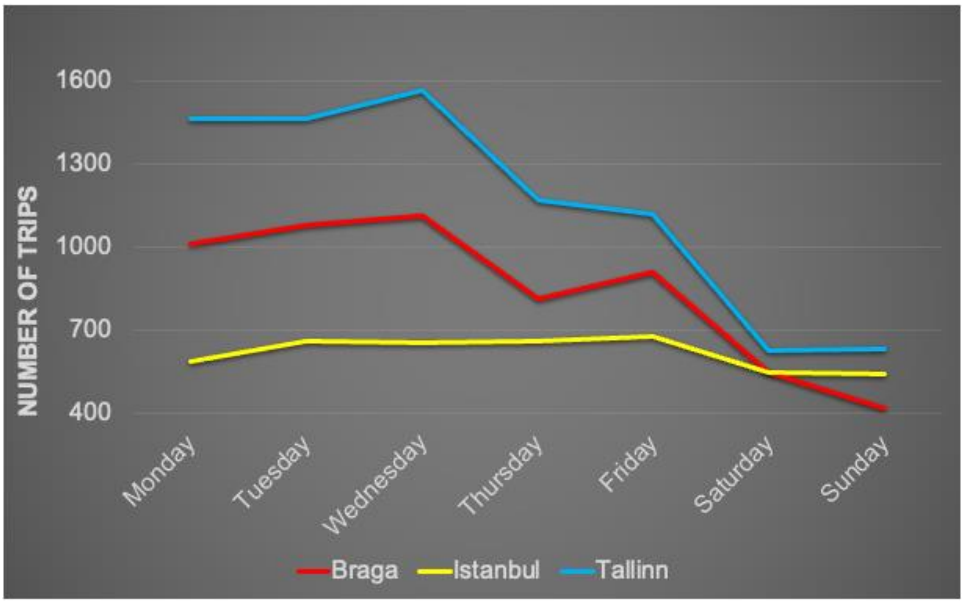


Figure 14: Comparative graph of day effect on number of trips

In the following graphs we compared historical weather during the pilot to weather during the trip occurrence to see the weather effect on trips (if any?). A slight effect of rain on trips was noticed. In the figure below for instance we observed only 9% of trips were taken place during the rainy condition even though 12% of times the weather was rainy in the period of the B raga's pilot. Same slight effect was observed in Istanbul but not in Tallinn. This is a rough estimate and a statistical analysis to detect significant correlations is suggested to be run for getting better insights.

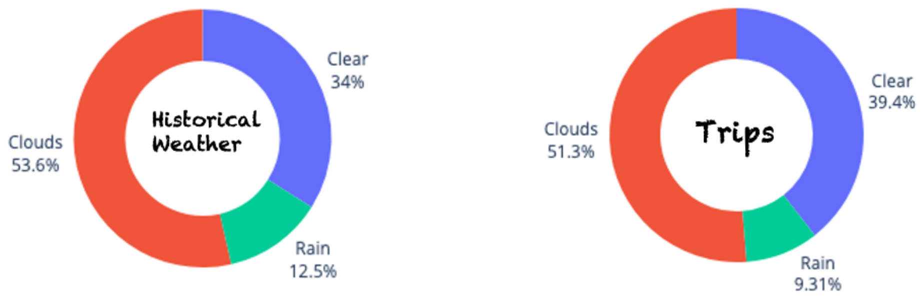


Figure 15: Weather effect on trips – Braga

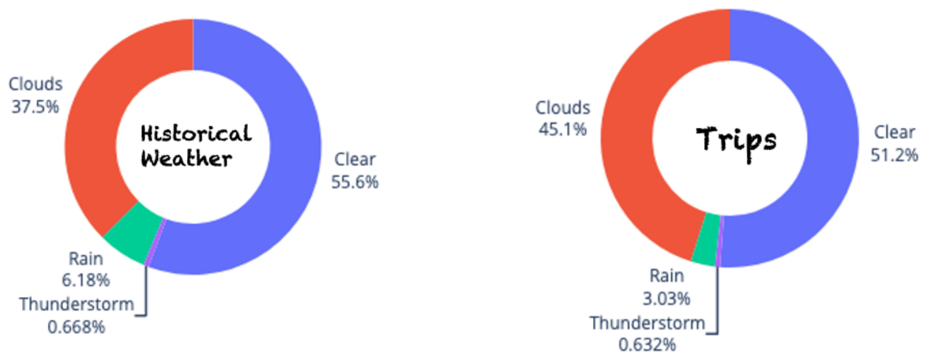


Figure 16: Weather effect on trips – Istanbul

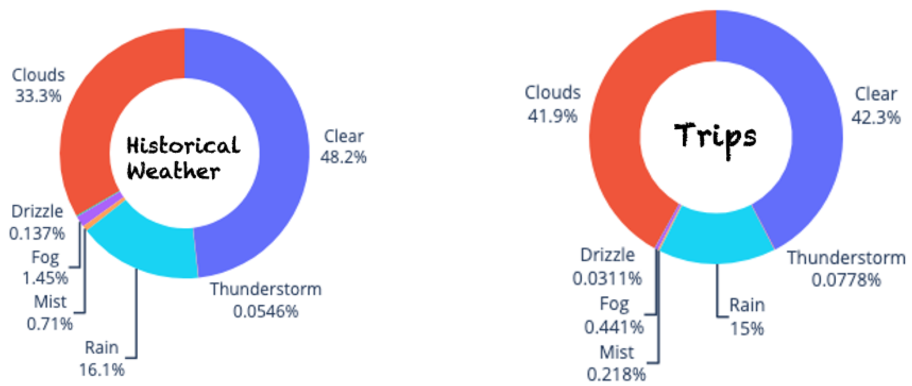


Figure 17: Weather effect on trips – Tallinn

In the following graphs we looked at the wind speed in the historical data and the wind speeds at time of the trips, to see if cyclists rather cycle in less windy conditions. However, based on the histogram this hypothesis is rejected. Therefore, we couldn't see any clear relation with wind speed and trip occurrence; this could be caused partly by peak hours occurring in times of the day with less wind. However, wind direction and speed in higher scales can affect cyclists' behaviour and even ability to cycle.

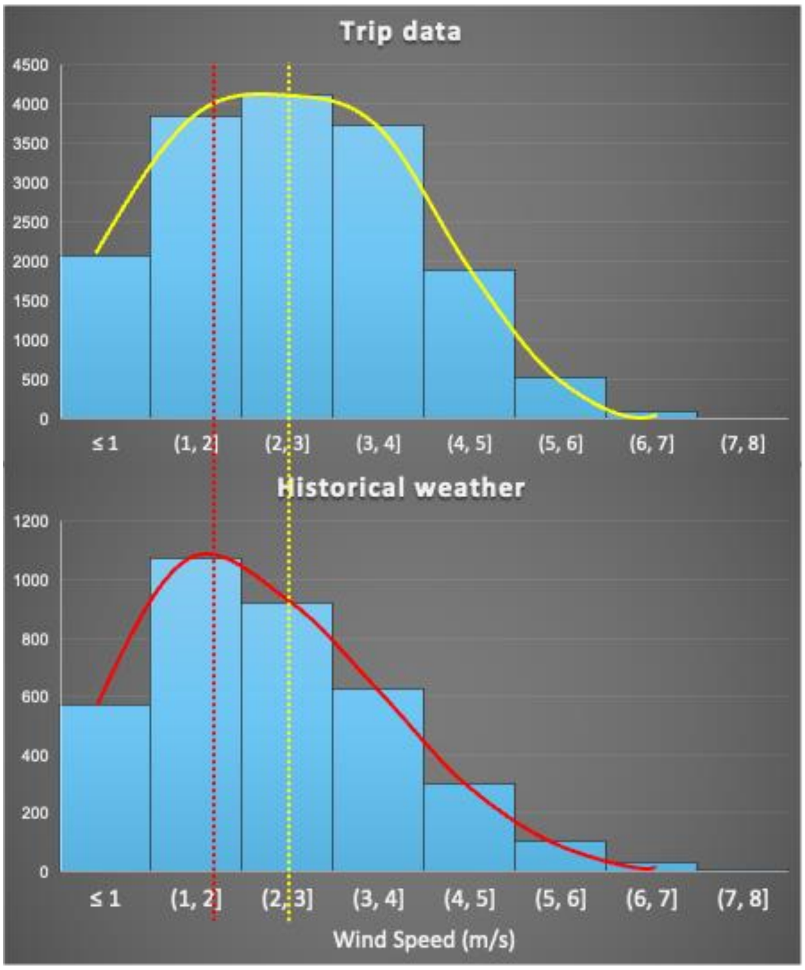


Figure 18: Wind effect on trips – Braga

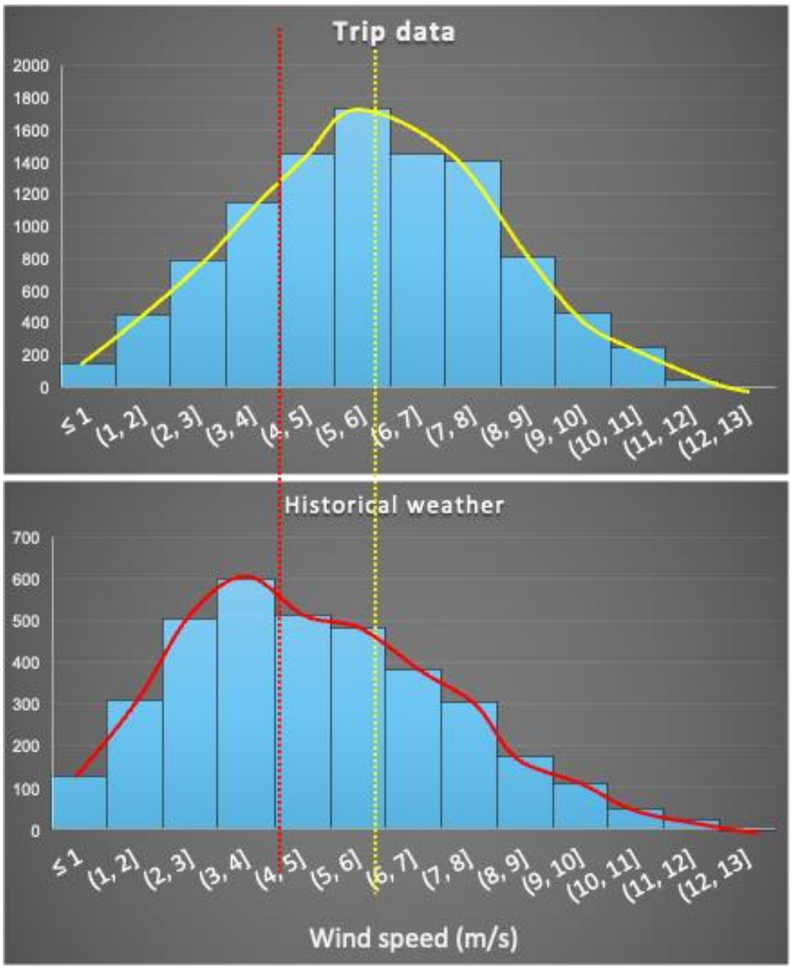


Figure 19: Wind effect on trips – Istanbul

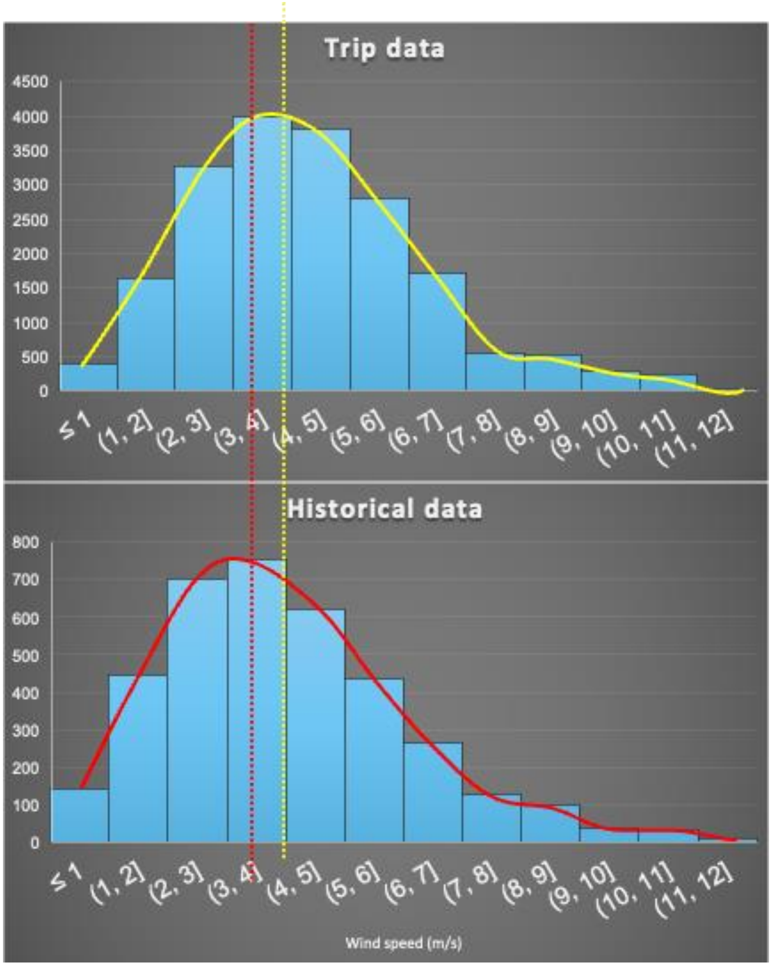


Figure 20: Wind effect on trips – Tallinn

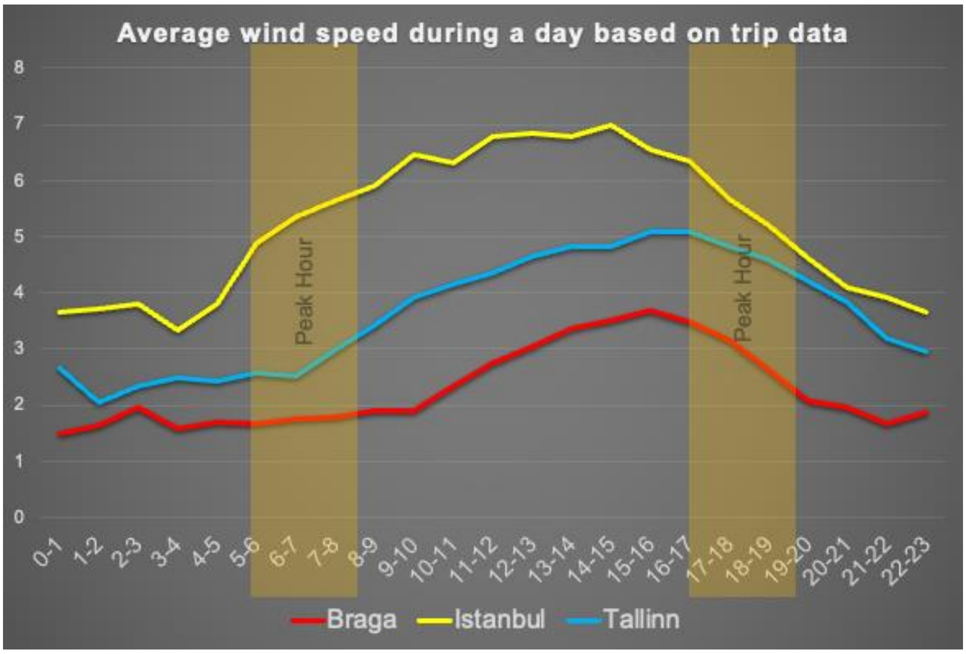


Figure 21: Comparative graph of wind speed effect on trips

In the following graphs we looked at temperature driver from the historical data and temperatures at time of the trips, to see if temperature could affect cyclists' behaviour. Despite wind speed we observed most of the trips are happening in milder temperatures between 17 to 25. However, it is not clear if this is caused by peak hour effect, or it there is truly a significant correlation. So, further study is needed, to see to what extend different weather conditions can affect cyclists' behaviour and frequency.

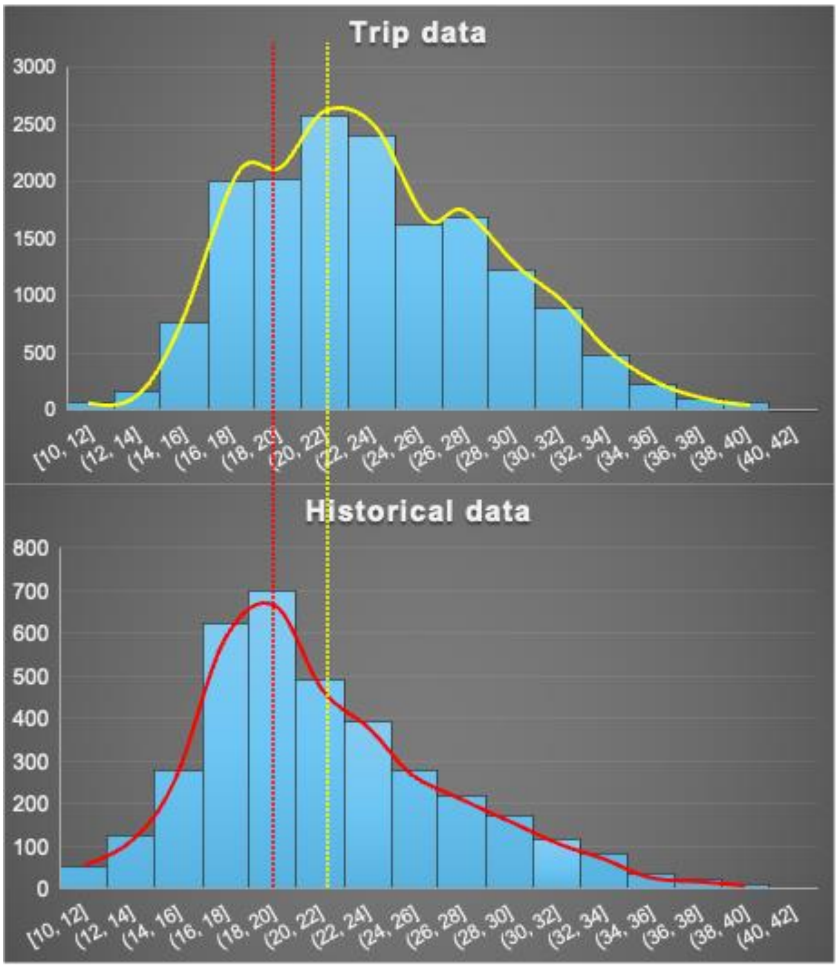


Figure 22: Temperature effect on trips Braga

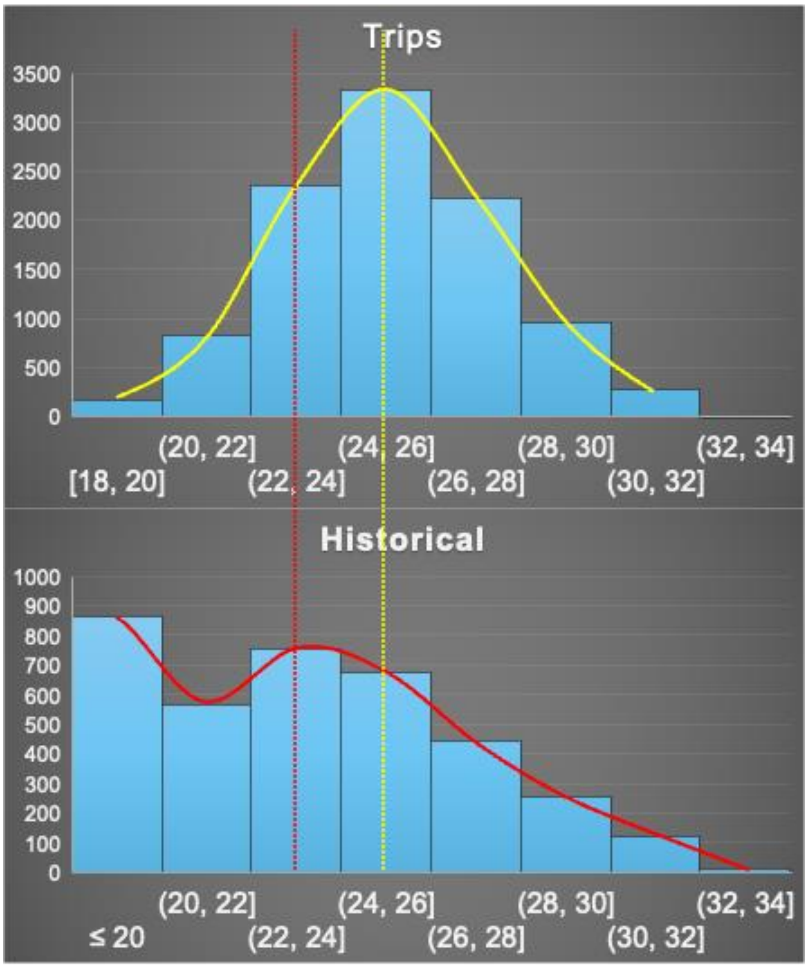


Figure 23: Temperature effect on trips Istanbul

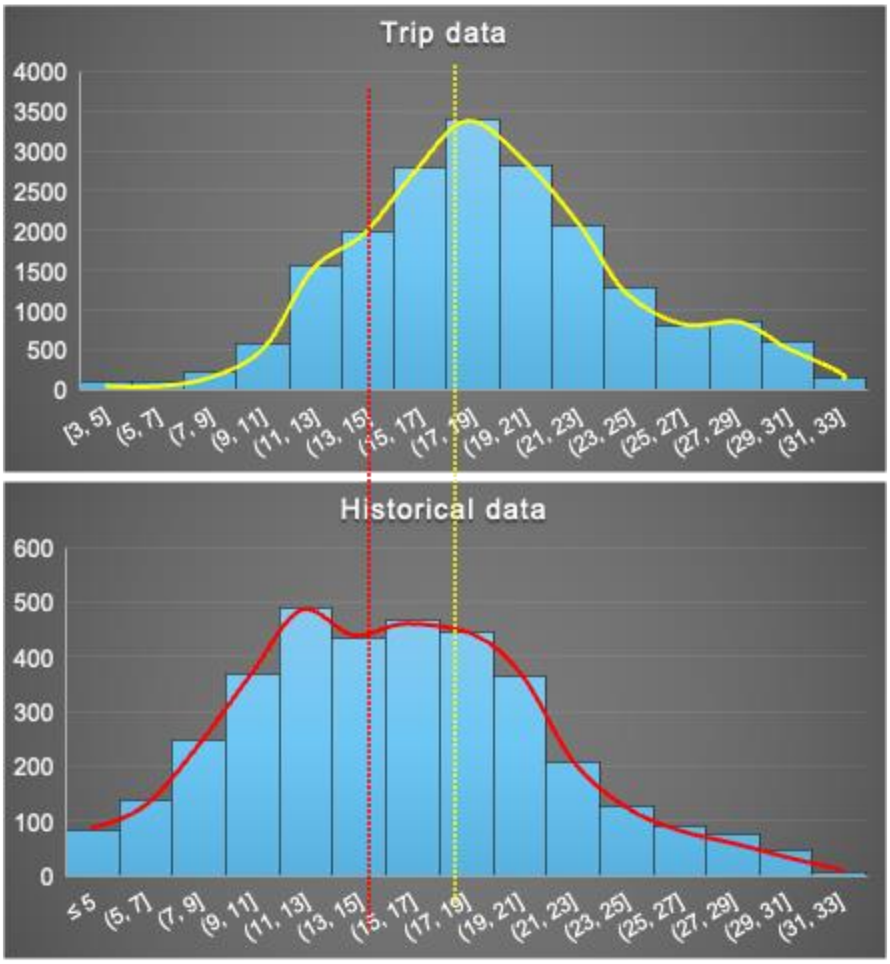


Figure 24: Temperature effect on trips Tallinn

In the following graphs, we estimated the emission reductions in terms of CO2, Nox and particulate maters (PM). This estimation has been done based on indicators published in CE report STREAM Personenvervoer 2014 [Passenger transport 2014] (CE 2015) which basically indicates that each 7 km by bicycle rather than by car will save an emission of 1 kg of CO2 and 1.5g of NOx and 7mg of particulate matter. Below you can find figures of reductions per cities.

Based on the above-mentioned indicators, it is estimated that in total during the pilots 60 tons of CO2, 90 kg Nox, and 500 g of PM was saved in Braga, Istanbul and Tallinn.

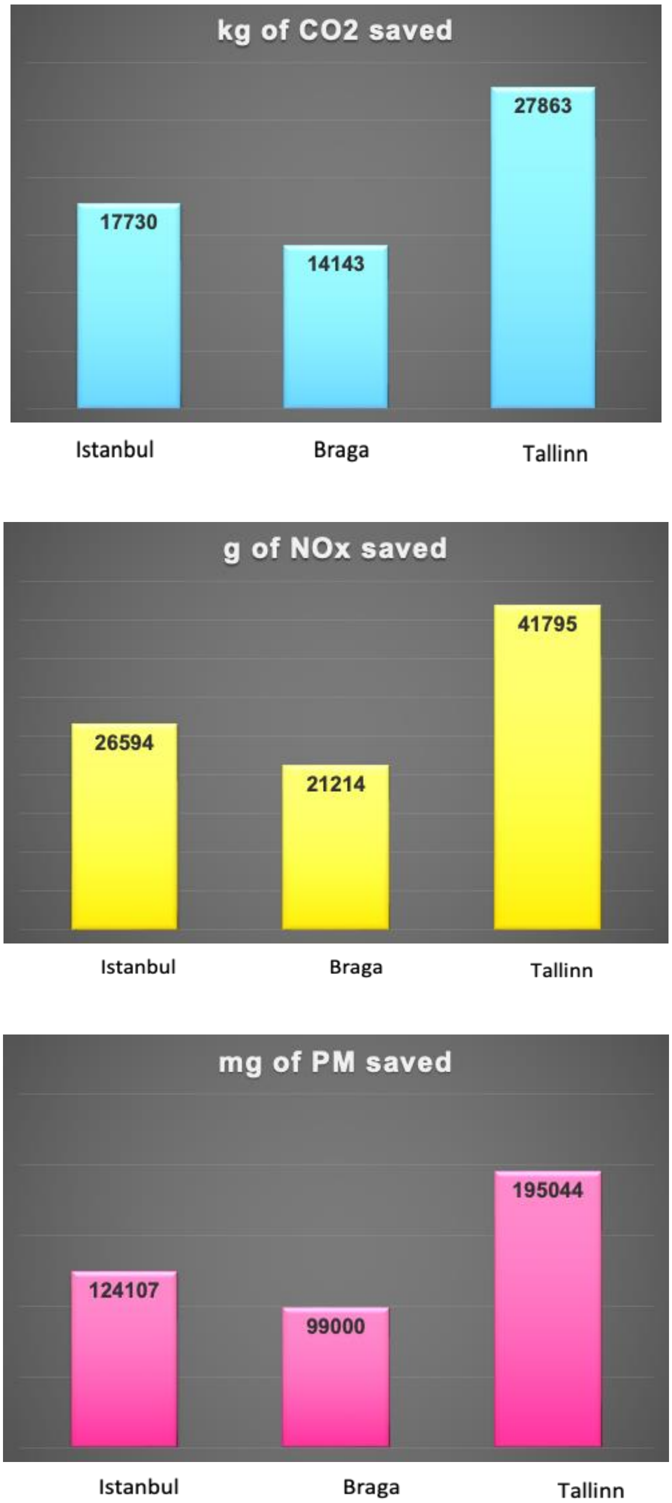


Figure 25: Comparative graphs of emission reductions in terms of CO2, Nox and particulate maters (PM) savings

In the figure below, we observed an increase of bicycle use frequency on average per category between what has been filled by the users in the registration form vs the use during the pilot. Each bar shows the increase as such, therefore, how much the number of times that participants in Istanbul and Braga used their bikes increases (in average) in a week. Tallinn's categories were different (6 categories) at the time of analysis; therefore, it is not included in this figure for comparison purposes.

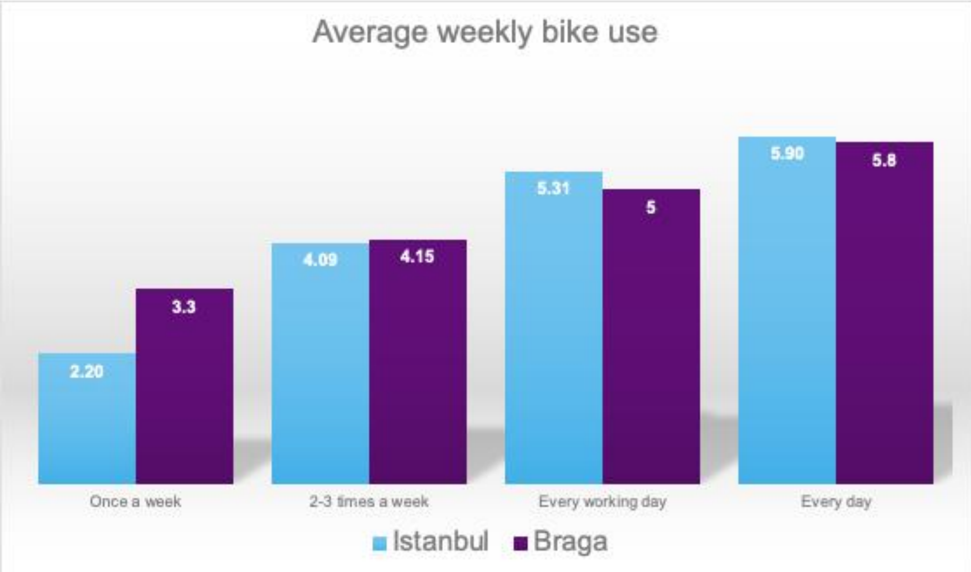


Figure 26: Increase of bicycle use frequency on average per category

For future study, we have matched the trip trajectories using QGIS and Open Street map, to further analyse the behaviour of cyclists. This will give us valuable insights on built environment effects on cycling behaviour. For instance, the presence of greenery, stores, bicycle infrastructure and their effects on trip frequency. There are outliers and errors collected by GPS which should be cleaned in a separate process before the analysis.

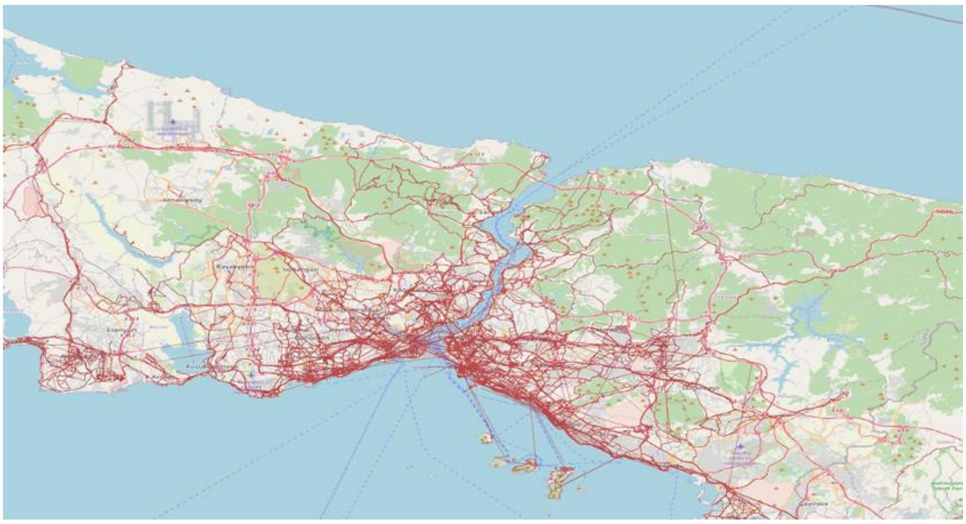


Figure 27: Trip Trajectories – Istanbul

Figure 28: Trip Trajectories – Braga

4. Role of incentives

The guidebook also identifies the role of incentives, the success and failure factors and where it needs improvements to do better.

4.1. Behavioural Nudging

There is an opportunity for behavioral nudging the potential day-to-day cyclist. Those that use cycling as a utilitarian mode (to travel from point A to B), often undervalue the health aspects of cycling. Here is where a media campaign would do well to educate on the health benefits of bicycling (Götschi et al., 2016). It could highlight the benefits experienced by those who are already riding. And it could motivate, with a light-touch behavioral nudge, those who are interested in trying to ride. This social media should be designed by a "choice architect", someone with the responsibility for organizing the context in which we make our decisions. The behavioral nudges to encourage higher ridership levels would aim to alter behavior in a predictable way without forbidding any options, or significantly changing a citizen's economic incentives. (Thaler & Sunstein, 2021). And this is exactly how the BICIFICATION campaign was designed. Certainly, the economic incentives per kilometer do not sound like much money. However, a monetary reward of this type fits in with the definition that a behavioral nudge does not significantly alter one's economic incentives, but it does give immediate feedback on making the desired choice.

What motivates communities to make a change? Is it an issue like poor air quality's negative impact on the health of our citizens? Or maybe cities are concerned about equity and whether all families, regardless of income or social status have access to work and school opportunities? Maybe it is the high cost of car ownership? Whatever the motivation, how can we influence behavior to change to a more desired transportation option?

Many European countries have tried campaigns to promote active mobility. But the cycling mode share remains very low. How people choose to travel to work, school and even the grocery store is a behavior and a habit. And as we know, behavior can be difficult to change, even as there are new modes available to choose from. The BICIFICATION project aims to achieve a mode shift to bicycling by nudging participants to ride bicycles, by giving them tangible awards (both monetary and non-monetary) and widely communicating the message "you ride - you earn".

4.2. Findings of reward based intervention projects

Interviews were conducted with three BICIFICATION cities: Tallinn, Estonia; Istanbul, Turkey and Braga, Portugal, as well as with 4 other cities who previously offered incentive-based projects: Santa Cruz, California; Cuneo, Italy; Cesena, Italy and Nijmegen, Netherlands. To gain a better understanding of the impacts of these rewards programs, city officials, transportation consultancy firms, local advocates and gamification app companies who collected the rider data were interviewed.

All of these cities offered a monetary incentive of some kind. Some focused on Bike to Work programs, either for all citizens or by working with specific companies. Some focused on one neighborhood. And still others opened their campaigns to everyone in a given city or region. One city, the city of Nijmegen, gave riders an opportunity to collectively earn points for money towards a community goal like: money for a local food bank's soup kitchen or for a bicycle that a community group could use to take coffee and conversations around their neighborhood.

Some campaigns focused specifically on moving car drivers out of cars and on to bikes. Others recognized that some people are already riding, and it is okay for them to join the incentive campaign. This was seen by Ring Ring's campaigns in Njimegen. These campaign organizers believed rewarding already active cyclists was good because others would want to copy their behavior. This type of positive social pressure is a choice architecture strategy that plays on the concept of following the herd. Peer pressure works because humans like to conform. And by observing the actions of the already successful bicyclists, while simultaneously linking their actions to an opportunity for a social good, a greater number of people were willing to join their bicycling campaign. (Thaler & Sunstein, 2021).

Among the BICIFICATION cities, the motivations varied. Istanbul's population was excited to get to have a Bicycling project like other European cities. Braga hoped to convince participants that cycling is worth it. They also noted that they hoped to demonstrate that "the city and community are ready to invest in [this type of] behavioral change." Braga was a city that prioritized commute trips by offering a higher incentive payment, if participants bicycled to work. And Tallinn city officials noted a lack of mobility data about people who use bicycles in their city. BICIFICATION provided an opportunity to gather that data. City officials also wanted to build a better relationship between the City and the Bicycle Community.

When asked directly about motivation, both opinions were shared! Some cities say that cash motivates an initial engagement with bicycle riding, but does not keep people riding. Others contend that the cultural aspect is the stronger motivator, even if they offered a monetary incentive or if they offered a chance to collectively earn towards a community benefit, like Nijmegen. Cities also had climate change goals as a motivation, and of course all European countries now have these goals.

4.3. Key learning elements

These collective climate change goals now provide an opportunity to change the public's travel behavior because "a norm or practice that is understood to be emerging, or to be increasingly supported, can operate as a powerful nudge, even if it is not yet supported by the majority" (Thaler & Sunstein, 2021). Local governments are searching for ways to reduce their Greenhouse Gas emissions. And now they are supported by the motivation to attain their country-wide climate change goals. So, the decision makers are now in a place to support cleaner travel modes. And citizens are also motivated. Perhaps they feel a nudge based on their identity: we as Europeans, or citizens of a particular country, are the kind of people who are committed to acting against climate change. Or perhaps, on the issue of climate change, we have collectively moved past pluralistic ignorance, where individuals did not know that their neighbors were also interested in making a change (Thaler & Sunstein, 2021). Climate Change is now an eminent enough threat that people in all levels of society are discussing the consequences and possible solutions.

An additional motivation could be an increase in obesity rates and decrease in activity among citizens, worldwide. Citizen inactivity is a greater health risk than the increased short-term air pollution exposure a cyclist might experience (de Hartog et al., 2010; de Nazelle et al., 2011; Giles-Corti et al., 2016; Rojas-Rueda et al., 2011). Inactivity and its consequences are now global concerns. Even in The Netherlands, a place known for high rates of bicycling, has a 62% sedentary rate for its population (de Hartog et al., 2010). The negative effects of this widespread lack of activity results in high rates of cardiovascular disease, as well as other negative health outcomes like diabetes, obesity, cancer, osteoporosis and depression (de Hartog et al., 2010). As a group, these are known as Non-Communicable Diseases (NCDs).

Of course, a bicyclist's exposure air pollution carries a health risk. But the health problems occurring from inactivity and car culture have grown so enormous that we must find ways to encourage and promote active transportation even with what we know about risks from air pollution (Giles-Corti et al., 2016). An evaluation of the launch of a bike-share program in Barcelona concluded that "The health benefits of physical activity from cycling using the bicycle sharing scheme (Bicing) in Barcelona, Spain, were large compared with the risks from inhalation of air pollutants and road traffic incidents." (Rojas-Rueda et al., 2011)

5. Conclusions and Lessons learnt

This section summarises the main points of the current document, providing valuable insights to the cities on the use of bicycle trajectories data for understanding the performance of policy measures related to the increase of bicycle modal share. The identification of the role of incentives, the success and failure factors and the required improvements to achieve a sustainable modal shift complement the guidebook giving added value.

The main point are summarised as following:

- One of the most valuable datasets to extract information about cycling behavior and route preferences is GPS-based bicycle data. Although many GPS-based studies are conducted, the number of participants that wear a GPS device or share data from their smartphones for a short time period is small and therefore, no reliable results can be obtained. BICIFICATION data covered a very large geographical (3 cities) and user scale (almost 1500), enabling an evidence-based decision-making process to authorities and policymakers when planning a sustainable and bikeable urban area.
- The correlation between trip, weather and socio-demographic (age, gender, employment status) could provide valuable knowledge on different dimensions. This knowledge can be used from the cities to direct their policy measures towards the ''weaker'' target group (e.g if women cycle less, more incentives could be given to them) or to enhance the incentives for the ''bad for cycling'' weather days.
- Conventional planning decisions that make driving the easier choice removes opportunities for daily physically healthy movement. New transportation planning efforts, such as infrastructure to support an incentive campaign such as BICIFICATION, attempt to fold active travel opportunities into daily travel. Integrating cycling into a daily transportation routine offers the convenience of fitting in physical activity into busy modern schedules.
- Since bicycling is not a highly skilled activity, this active mobility option is available to a large swath of the population. Designing more compact communities, with comfortable places to bike and walk encourage daily active travel that leads to more positive health outcomes. People of any income level could fold physical activity into their daily routine and gain greater mobility as a co-benefit. (Götschi et al., 2016; Litman, 2013)
- There is a lack of evidence, though, as to the types of people who will increase their physical activity, during behavioral change campaigns and when the built environment is changed to support more walking and bicycling. Is it just previously active bicyclists who will ride more? Will sedentary people remain sedentary? Reducing the dependency on car commuting allows for benefits from physical activity (Andersen et al., 2000; de Nazelle et al., 2011; Grabow et al., 2012)

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