BIKE2WORK: A Shift Towards Sustainable Mobility

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Keywords: Sustainable Mobility, Active Mobility, Smart City, Motivational Systems, Engagement, Behavior Change.

Abstract: Encouraging a shift towards sustainable mobility habits based on active mobility is a key challenge for many cities, since they are increasingly facing problems of traffic congestion, road safety, energy dependency and air pollution. Active modes, as cycling, which are also the least polluting, should be particularly encouraged, especially for local recurrent journeys (i.e., home–to–school, home–to–work). In this context, addressing and mitigating commuter-generated traffic requires engaging public and private stakeholders through new innovative and collaborative approaches that focus not only on supply (e.g., roads and vehicles), but also on transportation demand management. In this paper we propose an approach to home–to–work mobility able to support the company Mobility Manager (MM) acting on the promotion of sustainable mobility and transport demand management by analysing the problems, needs and habits of employees, and trying to orient them towards new sustainable transport habits.

1 INTRODUCTION

Mobility plays a fundamental role within modern cities(Lyons, 2018): the way in which citizens experience the city, access its core services, and participate in the city life strongly depends on its mobility organization and efficiency (Vesco and Ferrero, 2015; Torrisi et al., 2020). In this context, the challenge that cities are facing is very ambitious: on the one hand, administrators must guarantee to their citizens the right to mobility and to easily access local services, on the other hand they need to minimize the economic, social, and environmental cost of the mobility system (Cruz and Paulino, 2021; Haarstad, 2017).

Dealing with this challenge requires a holistic approach that allows to efficiently harness existing mobility resources while integrating and promoting new or emerging mobility services to enable an integrated, efficient, and sustainable mobility ecosystem (Gallo and Marinelli, 2020; Klecha and Gianni, 2018). To this end, cities are planning and implementing interventions at the level of infrastructures, services, and mobility policies. These are certainly key ingredients towards a more sustainable and integrated mobility(Lam and Head, 2011), but another very important aspect to be considered, as a socio-technical phenomenon, is users' acceptance and adoption (Giesecke et al., 2016; König et al., 2016). Innovative policies, infrastructures, and services are liable to fail if they are not combined with actions aimed at making citizens aware and involved in this process and to influence their mobility habits in a gradual but profound way (Vesco and Ferrero, 2015).

In most cases, citizens' daily mobility choices are driven by habits and are based on wrong or outdated beliefs (Gartner et al., 2021; Anagnostopoulou et al., 2020). Citizens need to be aware of the mobility services offered by their city and of their actual value (in terms of time, cost, and environmental impact). They need to be conscious of the impact of their individual daily choices (in terms of traffic, greenhouse gas emissions and social cost). Most importantly, they need to feel part of a community that, through daily individual choices, can play a key role towards the fulfillment of city-level mobility strategic objectives (Giffinger, 2019; Kazhamiakin et al., 2021). In other words, individuals and communities must learn to take responsible actions and this can only be achieved through the development of a new culture for urban mobility. In recent years, a significant effort has been undertaken to understand how interactive technologies can be leveraged to raise citizens' awareness, encourage their active participation, break bad habits

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Bucchiarone, A., Marconi, A., Cipriano, P. and Giovannini, L.
BIKE2WORK: A Shift Towards Sustainable Mobility.
DOI: 10.5220/0011087000003203
In *Proceedings of the 11th International Conference on Smart Cities and Green ICT Systems (SMARTGREENS 2022)*, pages 147-156
ISBN: 978-989-758-572-2; ISSN: 2184-4968

and promote behavior change towards a more sustainable lifestyle (Hiselius and Rosqvist, 2016; Al-Thawadi et al., 2021; Marconi et al., 2021; Badii et al., 2017).

Our aim, within the AIR-BREAK project[1], is to implement sustainable mobility campaigns that involve the whole community raising its awareness on the possibilities and advantages offered by the available sustainable mobility services and to encourage the adoption of different, more sustainable, mobility habits.

In this paper we present BIKE2WORK: a home–to–work sustainable mobility campaign targeting employees of public or private companies that has the goals to promote the use of bicycles for home-to-work trips by providing economic incentives. Starting from the motivations that led to the definition of this campaign (see Section 2), we present the BIKE2WORK objectives and the various steps that have been performed to engage both companies and employees (see Section 3). We continue giving details on its technical implementation supporting its management and operation (see Section 4). We conclude the paper with some initial experimental results (see Section 5) and with some conclusions and future work (see Section 6).

2 BACKGROUND AND MOTIVATIONS

The transport sector is the largest contributor to greenhouse gas (GHG) emissions (SUS, 2020). In 2017, 27% of total EU-28 GHG emissions came from this sector. Within this sector, cities are the main sources of global mobility demand due to citizens' transportation activities within and between urban areas. Traffic and commuting inefficiencies negatively impact urban infrastructure, increase pollution, and harm the environment and people's health.

Addressing and mitigating commuter-generated traffic requires engaging public and private stakeholders through a new innovative and collaborative approach that can focus not only on supply (e.g., roads and vehicles), but also on transportation demand management. In recent years, public authorities have broadened their focus from demand management policies that target individuals and households (which are a largely heterogeneous and disaggregated policy target) to demand management policies that target large traffic generators - including the public and private sectors.

[1]https://airbreakferrara.net/

Mobility is likely to be a valuable application area as the impacts on environment, climate, and land use are beyond the current generation, as it requires paradigm shifting decisions at the level of individuals (i.e., behavioural change) and decision-makers (i.e., policies and the use of resources).

According to (Hiselius and Rosqvist, 2016) changes in attitudes and social norms are required to promote new methods of applying technological solutions and new behaviors and lifestyles in the transition to a low-carbon society. Mobility Management initiatives have been proved to help people change their minds, but they have yet to be acknowledged as crucial components of a comprehensive transportation policy strategy.

Now, Covid-19 is generating a rapid change in the way people work, act, and move, which could pave the way for more change in transportation behavior (TEI, 2021; Bergantino et al., 2021; Scorrano and Danielis, 2021). This means that hard work will be needed to shape the new behaviors that will form in the future.

Positively transforming the way people travel for the benefit of society requires a profound transformation of habits and behaviors, which must be based on comprehensive impact assessments and simulations that consider social, health, environmental and climate impacts, as well as economic impacts.

Within the AIR-BREAK project, behaviour change and awareness raising campaigns have the aim to inform citizens' and raise their awareness on the possibilities and advantages offered by the available sustainable mobility services and to encourage the adoption of different, more sustainable, mobility habits.

BIKE2WORK is one of the initiatives in this direction with the goal to promote an approach to mobility oriented to workers able to support the company Mobility Manager in the promotion of sustainable mobility and transport demand management by analyzing the problems, needs and habits of workers, Covid-19 measures adopted by companies, trying to orient them towards new habits of sustainable transport.

BIKE2WORK, leveraging on behavioral change, technologies, and business model, intends to act on the decisive factors that hinder modal shift by providing services, information, recommendations, and incentives:

- To **support companies** in adopting policies and initiatives to plan and implement actions and measures to identify the most sustainable mobility solution.
- To **encourage workers** to significantly change their mobility habits, making them active partic-

ipants in the solution.

In the rest of the paper, we describe the BIKE2WORK objectives, how it has been realized, and the major findings after the first set of experiments.

3 BIKE2WORK OBJECTIVES, FEATURES, AND MANAGEMENT

The overall objective of BIKE2WORK is to promote a more sustainable home–work mobility, contributing to the reduction of CO2 emissions. Considering the emergency related to COVID-19 this aspect becomes even more important as new habits will have to be re–invented to adapt to the new constraints and limitations imposed by the government for the safety of citizens to improve, at the same time, the quality of life of employees.

The adoption of technological solutions alone cannot make transport more sustainable; to do so it is necessary to involve people and guide them towards a behavioural change. To achieve these goals, BIKE2WORK intends to engage companies with its employees to build new innovative, sustainable, and targeted solutions that can improve quality of life more effectively.

The specific objectives of this initiative are:

- To support workers in switching to sustainable mobility habits resulting in reduced CO2 emissions.
- To support public/private companies in the adoption of policies, initiatives, and the development of urban mobility plans.
- To increase the perception of corporate (ecological) Social Responsibility and improve Total Quality Management (TQM) within companies.
- To increase cooperation between different modes of transport and promote interconnection and interoperability between existing transport networks.
- To increase the attractiveness of sustainable transport modes through the implementation of different measures such as proposing new private mobility policies, promoting public transport, and pooling and sharing services.

Ferrara[2] (IT) is a medium-sized city located between Bologna and Venice, along the Po river, with an overall number of inhabitants of 131,000 distributed in an area of 400 Km^2. The town has broad streets and numerous palaces dating from the Renaissance, when it hosted the court of the House of Este. Moreover, Ferrara is a pretty flat city where weather conditions that are never particularly impactful. For its beauty and cultural importance, it has been designated by UNESCO as a World Heritage Site. The municipal administration of Ferrara, through the signing of a Memorandum of Understanding with the Emilia–Romagna Region[3], promoter, and financier of the initiative, has launched in Ferrara the BIKE2WORK campaign for public or private companies based in the city of Ferrara.

The campaign is part of the sustainable mobility initiatives put in place to meet the new challenges of the Covid-19 emergency and wants to promote the use of bicycles for home–work trips by providing an economic incentive to employees of public or private companies in the Municipality of Ferrara. The needs related to social distancing have, in fact, imposed a drastic downsizing of public transport capacity, making it particularly relevant to encourage the use of bicycles and other modes of private transport with low environmental impact.

BIKE2WORK provides incentives for sustainable mobility through an economic contribution for workers who are committed to using bicycles for home–work trips. Public/private companies of the Municipality of Ferrara can join. Employees of participating companies are rewarded for their home–work trips by bike with economic incentives in their paychecks (0.20 € per Km, max 50 € per month, max 20 km per day). Mobility managers and employees are supported by a software platform and a mobile app, as described in Section 4, and the overall campaign participation is supported by a specific life–cycle depicted in Figure 1. Each interested company provides (in STEP 01) the following information: (a) all the company data, and (b) the list of MMs with their related information. After that, in STEP 02 each company specifies the details of the headquarters that will participate in the BIKE2WORK campaign with the declaration of closure days (e.g., holidays). STEP 03 is dedicated to the insertion of the employee's data that will be invited/engaged by the MM during STEP 04. In this phase the MM sends an email to each participating employee. In this email each employee receives:

- The presentation of the campaign with the relative regulations and information regarding data processing and privacy.
- The instructions to perform the registration to the campaign and to download the software applica-

[2]https://www.comune.fe.it/

[3]https://www.regione.emilia-romagna.it/

Figure 1: BIKE2WORK participation lifecycle.

tion needed to participate.

As soon as an employee accepts the invitation to participate to the BIKE2WORK campaign and the registration is done, he/she can start tracking the home–to–work and work–to–home bike journeys (STEP 05). Finally, STEP 06 is used to manage the employees' performance and reward them with the corresponding amount.

4 THE BIKE2WORK SUPPORTING TOOL

The life-cycle and all the features presented in the previous Section have been used to guide the implementation of the Play&Go Aziende Framework. It is an innovative ICT solution that provides a console of data, information, recommendations, and simulations for MM to assess, also through what-if analysis, the environmental impact of employee commuting, to evaluate changes because of specific measures and actions and to plan optimal and sustainable worker mobility strategies.

To achieve the identified objectives, Play&Go Aziende provides:

- A **web console**[4] - for the company MM to manage the necessary information (entity data, participating employees) and to visualize the information (trips/valid kilometers) of their employees. The web console allows each company to configure and manage all the information related to their company and employees participating in the BIKE2WORK campaign.
- The **Ferrara Play&Go Mobile App**[5,6] - for the employees, which allows them to track their home–to–work trips and to visualize the achieved results.

4.1 Web Console

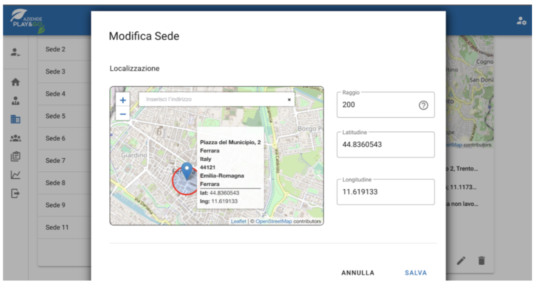
The web console allows each company to configure and manage all information related to their company and employees participating in the BIKE2WORK campaign. It is a tool addressed to the appointed company manager (Mobility Manager) who is in close contact with the campaign promoter (i.e., Municipality of Ferrara) before, during and after the execution of the initiative. Each MM can access a dedicated web console with the received credentials. Access can be done via the following console link https://admin.playngo.it. Once logged-in a MM can specify and modify the data useful for the validation of the journeys of their employees. In particular he/she can specify the data related to the company (address, latitude, longitude as depicted in Figure 2(a)), the non-working days and the days when the company is closed (e.g. holidays) as depicted in Figure 2(b).

Once the company information has been defined, the MM can start to insert the data related to the various headquarters involved and the related employees that have expressed the interest to participate to the BIKE2WORK campaign. A MM can insert these info in a massive way through a file importing method (i.e. CSV) or can add new headquarters and the related employees manually through a dedicated form (as depicted in Figure 3).

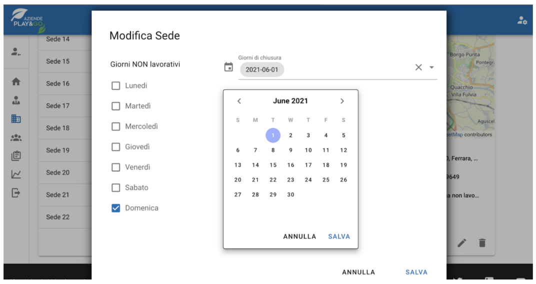
[4]http://admin.playngo.it

[5]https://play.google.com/store/apps/details?id=it.smartcommunitylab.playgoferrara,

[6]https://apps.apple.com/us/app/id1526145980

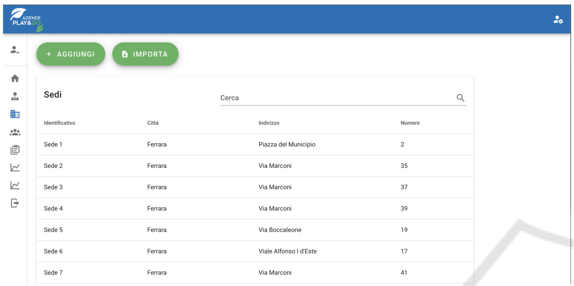


(a) Company Information.

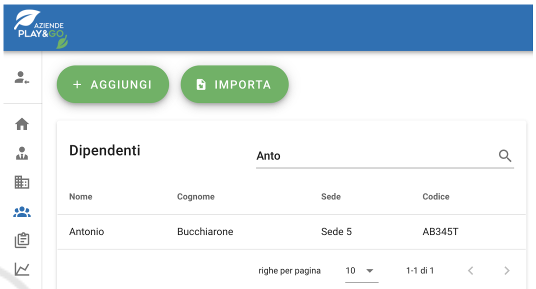


(b) Non-Working days declaration.

Figure 2: Web Console UI for Mobility Managers.



(a) Involved Headquarters.



(b) Involved Employees.

Figure 3: Headquarters and Employees Data Definition.

As soon as all the needed company information has been inserted in the console, each MM can declare the interest to start the BIKE2WORK campaign. It is from this moment that all the employees listed by the MM can start to track their bike journeys and accumulate valid trips and kilometers using the Ferrara Play&Go mobile app (see Section 4.2 for details).

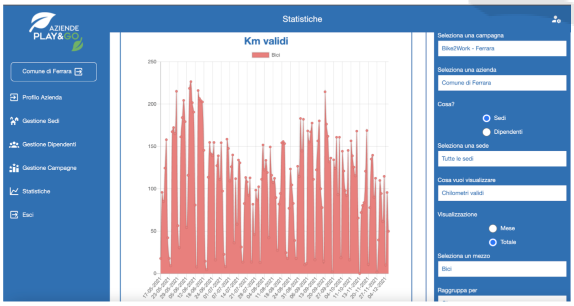


Figure 4: BIKE2WORK statistics.

The last feature that a MM can use in the console is related to the campaign "Statistics". The objective of this functionality is to filter and visualize the information necessary to understand the progress of the initiative and at the same time to export dedicated reports in CSV format for further analysis by the company. It is possible to visualize aggregated information about the trips and kilometers made by the different employees, of the different headquarters, etc.., eventually also choosing the interested period (monthly, global) using a filter component (see Figure 4).

Figure 5: Home Page.

4.2 Ferrara Play&Go Mobile App

The functionalities supported by the Ferrara Play&Go Mobile App concern the employee's registration and the management of the employee's profile, the tracking of sustainable trips, the inspection of employee's results (e.g., points earned, badges and badge collections, active challenges with completion status, weekly and global leader boards ranking, personal mobility diary), information on weekly and global prizes, as well as the access to game rules and regulation. The application provides a homepage (see Figure 5) , in which a summary of the employee's state is presented. The homepage also presents a set of frequent and immediate actions that the user can perform, e.g., trips tracking.

In the BIKE2WORK campaign, employees can track trips by bike and can visualize the trips on a real-world map (see Figure 6), both in real-time while they are recording them during their journey, and for past trips stored in their profile.

Figure 6: Trip tracking view.

Each employee who has joined the BIKE2WORK campaign can directly enter in a dedicated area (see Figure 7) where she/he can monitor her/his progress in the campaign. Access to this private area can take place directly through the Ferrara Play&Go App through a dedicated web link[7]. The main objective of this area is to show to each employee her/his behavior regarding home–to–work mobility. For this reason, it is possible to visualize dedicated information on the Km traveled, the CO2 saved and the number of valid trips. Moreover, each employee can consult the BIKE2WORK campaign regulations, the privacy information document, and any news dedicated to the campaign in execution.

To validate the bike journeys done to reach the work locations by the employees, the mobile app exploits a dedicated *trip Validation component*. The validation algorithm implemented by this component uses the trace coordinates, deriving the information about the user speed and using that for validation (e.g., max limits, average speed, etc.). Furthermore,

[7]https://aziende.playngo.it/

Figure 7: Employee Dedicated Area.

the algorithm can be configured, depending on the application setting, to also consider some additional information to "certify" the tracked data. For example, in the case of the BIKE2WORK campaign, the employees are assigned to a specific set of company headquarters that he/she could reach every working day. The trip validation component checks if each single journey starts or arrives from/to one of the declared locations in this set and if the trip is performed within a company working day. If the trip validation component considers the trip valid, the corresponding employee action is sent to the Gamification Engine component that updates the employee state correspondingly. Otherwise, the Trip Validation component provides a specific motivation for not considering the trip valid (e.g., too fast). The validity outcome, in case of a valid trip, or the motivation explanation, in case of an invalid trip, is presented to the employee in the mobile App. Finally, employees of participating companies to the BIKE2WORK campaign are rewarded for their home–to–work trips with economic incentives in their paychecks (0.20 € per Km, max 50 € per month, max 20 km per day).

5 EXPERIMENTAL RESULTS

In this Section we present the preliminary results of the BIKE2WORK sustainable mobility campaign which have been obtained through the data collected from the Ferrara Play&Go Mobile App and the MM Web console.

The campaign was launched on May 15, 2021 and it is still running. At the end of December 2021, **55 companies**, in the territory of the municipality of Ferrara, were registered to the campaign with **537 active employees**. In this first period **24.491 sustainable trips** have been tracked and considered valid. These trips have contributed to obtain **93.542 sustainable Kms** and **15 Tons of CO2 saved**.

Figure 8 shows the distributions of trip total distances (in Kilometers) while Figure 9 the dura-

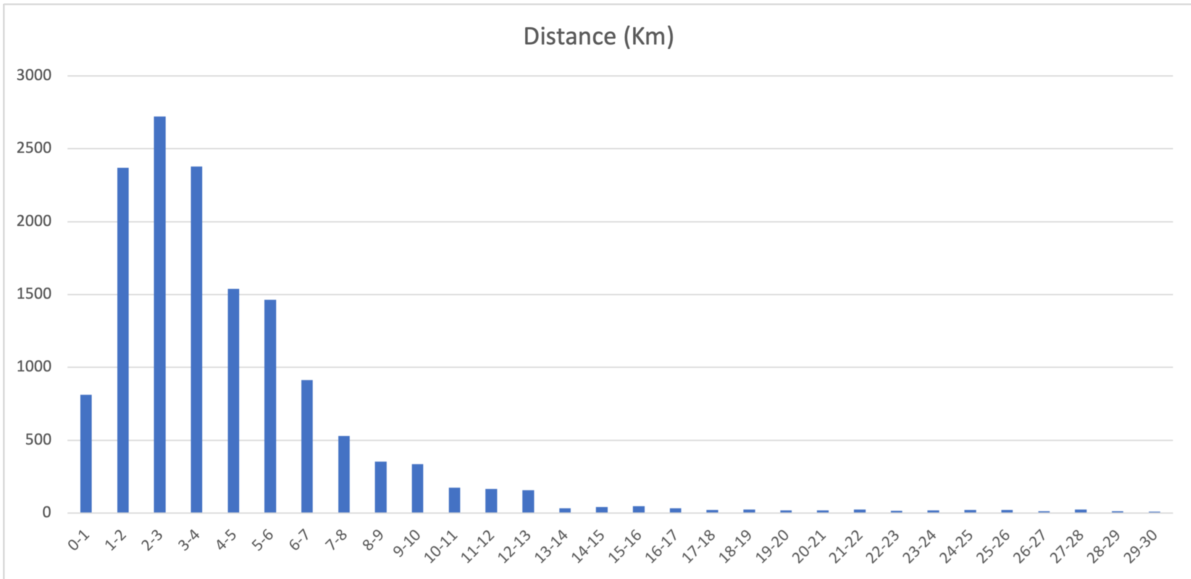


Figure 8: Distribution of the BIKE2WORK trip distances.

tion (in minutes) for the whole set of trips of the BIKE2WORK campaign. The most frequent trips are shown to be the ones lasting between 10 to 20 minutes and the ones covering a distance of 2-3 Km, while the average ride duration is 35 minutes for an average distance of 5 Km.

Taking 20 Km/h as a reference for standard urban cycling speed we could therefore say that BIKE2WORK commuters on average do not rush to work, but rather enjoy their ride.

To analyse the BIKE2WORK impact, different mobility data analytics have been implemented. In particular, an ingestion procedure has been developed to get anonymixed raw GPS data from Ferrara Play&Go (depicted in Figure 10), followed by a map-matching algorithm that reconstructs each trip from the raw GPS logs using the OpenStreetMap[8] road network.

Generally speaking, a map-matching algorithm (Quddus et al., 2007) is an automatized procedure that combines measures from one or more positioning devices with data from a road network map to provide an enhanced positioning output. This task is usually not straightforward because of the combined effect of measurement errors in positioning data and accuracy errors in road network data. The map-matching procedure exploited (Giovannini, 2011), in the context of the BIKE2WORK campaign, handles the positioning uncertainties adopting a bayesian approach of maximum likelihood; the data are projected on the road segments that have the higher probabilities of having generated them.

The overall procedure can be divided in different phases. Before the actual map-matching of GPS trajectories takes place, some initialization operations are performed to speed up the following elaborations: road network data for the area are loaded in memory and a road proximity map is created. This proximity map allows for a fast identification of the road arcs that are close to every given spatial position inside the area.

Once the initialization step is completed, the map-matching can start. First of all, the data from each bike trip goes through a trajectory aggregation stage, that serves the purpose of removing useless data and aggregating useful GPS data into trajectories. Then, GPS trajectories are processed in sequence through the two last steps of the procedure: the projection of GPS data onto the surrounding road elements and the identification of the optimal path between projected data. A typical map-matching case is presented Figure 11: the red triangles identify single GPS data records (in this case very distant from each other); the blue line, connecting the GPS data into a sequence, represents a GPS trajectory; the yellow line describes a possible reconstruction of the path followed.

Another set of automatic procedures calculates different indicators at single road segment, by timestamp. These procedures are though to provide practical and easy answer to typical use cases:

- What are the most used routes within the city?
- Do they match infrastructures for bikers and pedestrians?
- What are the critical points for cyclist/pedestrian

[8]https://www.openstreetmap.org/

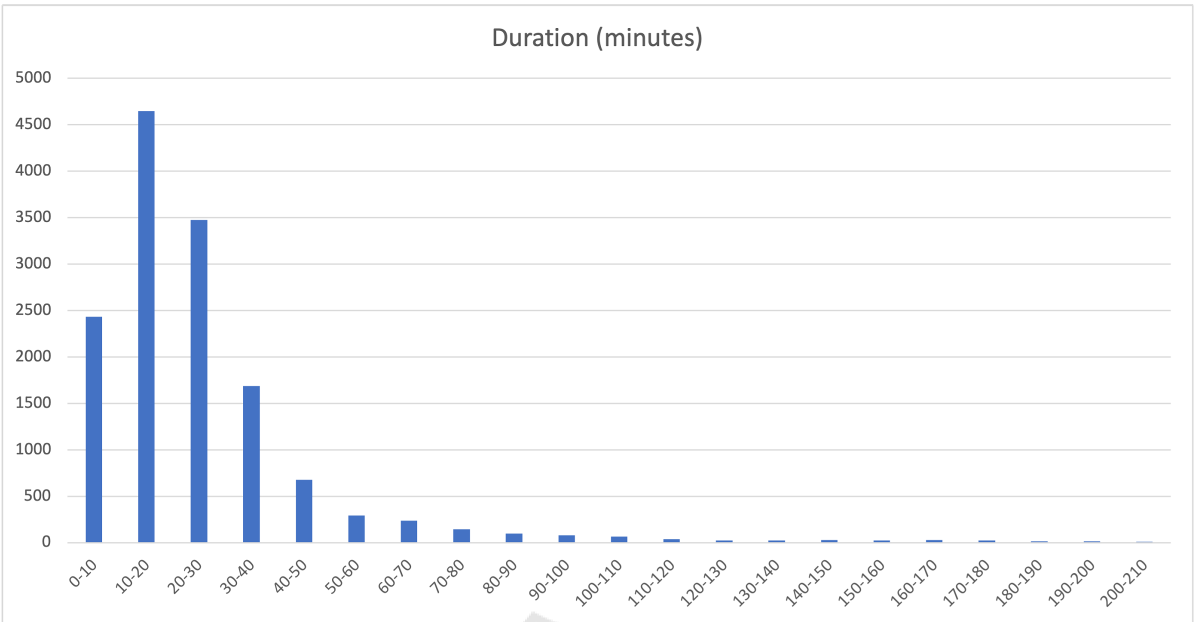


Figure 9: Distribution of the BIKE2WORK trips durations.

safety?

- Where are cyclists riding the wrong way?

To showcase the results, different map applications have been deployed for sharing data. Interactive web maps are based on a set of open-source Javascript library (OpenLayers[9])) for displaying spatial data in web browsers as slippy maps, similar to Google Maps and OpenStreetMap.

Based on GPS logs, different spatio–temporal indicators have been developed. The map in Figure 12 shows where are the streets mostly used by the BIKE2WORK participants in Ferrara, from May 2021 until end of December 2021. In the map, the two major findings are highlighted in blue colour:

- Corso Giovecca, which cuts the city centre from east to west and which in the western part is lacking dedicated cycle lanes despite being very popular (see the the blue ellipse with label A in Figure 12).
- The new cycle lane, opened in early 2021, that leads from the center to the hospital of Ferrara in Cona village (located to the east) and which appears to be widely used by commuters working at AUSL and University ((see the the blue ellipse with label B in Figure 12).

To make the results of this initiative continuously available, an interactive map has also been made available online[10]. The map can be browsed (zoom/pan) and queried: by clicking on a street segment, user gets information about number of transits in the specific street segment, divided by weekday and weekend (total number of transits and daily average).

6 CONCLUSIONS AND FUTURE WORK

With this work, we present a home-to-work sustainable mobility campaign (BIKE2WORK) defined and executed in the context of the AIR–BREAK project. It targets employees of public and private companies and has the goal to promote the use of bicycles to move in a sustainable way by providing economic incentives. We present the software platform, the mobile app, and the interactive web maps, that have been implemented to support the Mobility Managers and the employees throughout the campaign and to understand the progress and the impact of the running initiative. After the first 8 Months of campaign's execution, some initial results have been obtained and reported. We will continue running the campaign for the next two years (till December 2023). Future works will be focused on a thorough and systematic analysis of the quantitative and qualitative data we collected, both in terms of the achieved environmental impact and in terms of user experience.

[9] https://openlayers.org/

[10] http://metropolidipaesaggio.it/progetti-pilota/mappa-tragitti-cittadini/

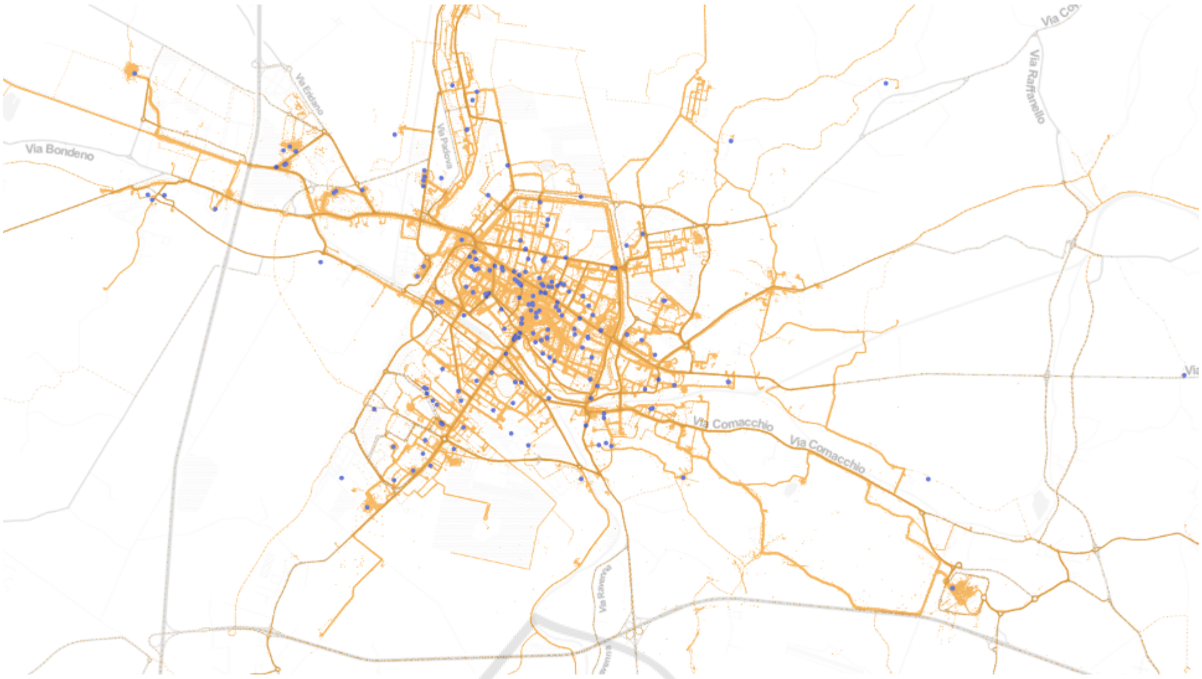


Figure 10: GPS logs (in orange) and companies locations (in blue) from Ferrara Play&Go.

Figure 11: A typical map-matching case.

ACKNOWLEDGEMENTS

This work is supported by the AIR-BREAK project funded through the ERDF Urban Innovation Actions 2020 UIA 05-177.

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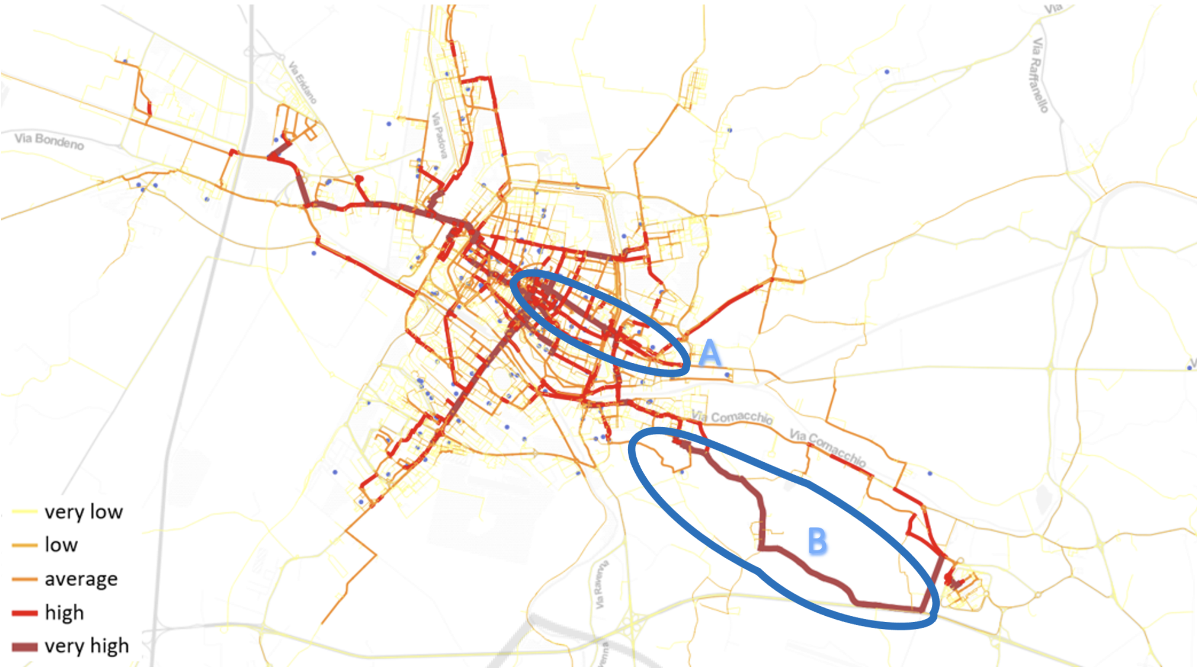

Figure 12: Map of BIKE2WORK commuters in Ferrara (at December 2021).

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