i-CHANGE: A platform for managing dockless bike sharing systems

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Abstract. The new generation of bike-sharing services without docking stations is spreading around large cities of the world. The paper provides a technical specification of a platform, for managing a dockless bike sharing system. The bicycles of the platform are equipped with GPS devices and GPRS cards that can transmit, over the Internet, their exact location at any time. We collect and store all events derived from a user's interaction with the system and in addition the trajectory points of a route during a rent order. The platform aims to fulfill the requirements of bikers, administrators and the research community through the collection, analysis and exploitation of bike sharing data.
In the context of the platform, an app for smart devices is implemented for citizens to access the system. A dashboard is offered to the administrator as a valuable tool to inspect, promote the system and evaluate its usage. Last, all stored anonymised data can be accessible for further analysis by the research community through a REST API. The i-CHANGE platform is currently pilot tested in the city of Thessaloniki, Greece.

Keywords: Micromobility, bike sharing, dockless systems, API, IT system

1 Introduction

The rapid population growth combined with the increase of urbanization makes the need for mobility in existing transportation networks increasingly challenging. Residents of large cities are facing the problem of traffic congestion in daily commuting. Thus, micromobility is gradually becoming popular worldwide due to a series of benefits that it offers for everyday commuting compared to the traditional transportation modes, like cars, buses and trains. Micromobility is a term which refers to light-weight means of transportation, such as bicycles and scooters, designed for individual use. It is a cost effective alternative, especially for last-mile trips. Besides cost, citizens save time, avoid traffic congestion and emissions are reduced. Bike-sharing has been gaining ground lately as a sustainable and environmentally friendly urban transportation mode. Bicycles available for hiring are distributed within cities by companies which offer micromobility sharing services.

Recently, technological platforms have been developed to enhance urban mobility. The authors in [10] propose a methodological approach with respect to a real-time traffic monitoring and supervising system, which also offers *"info-mobility"* services. The tools which are incorporated include traffic and environmental monitoring and management, vehicle routing, real-time minimum path calculation, etc. Several smart mobility sharing platforms have also been developed since the emergence of micromobility services. In this paper we present i-CHANGE, an integrated platform for managing a dockless bike sharing system, which attempts to serve both the users' and administrator needs in a large variety of aspects, but also to fulfill research needs by offering valuable insights with respect to transportation patterns.

Bicycles of the system have a lock integrated in their frame for securing the bicycle anywhere (inside a defined geo-fenced area) without the need of a docking station. The platform is designed for better system inspection (e.g. information around completed orders) and for providing critical information (e.g. possibly damaged or stolen bicycles) to the administrator. It is built to promote sustainable transportation by replacing the main traditional option of private car with bicycle and change the ownership approach and philosophy with the approach of sharing.

The study of established relevant platforms for good practices was the first step in the design process of the platform. The next step was the analysis of user requirements, both for riders and the administrator of the system, as well as the consideration of hardware and software needs and limitations. The platform also serves the research community by making its data available, always in compliance with the GDPR regulation[4] for protecting personal information.

2 Related Work

Micromobility is a rapidly growing field of urban transportation research. There has been a plethora of work related to various bike-sharing research problems. Early work refers to the generations of bike-sharing and its growth, bike-share usage and user preferences in various cities, barriers with respect to safety concerns and helmet legislation. Other works evaluate the impacts of bike-sharing on car use reduction and health and investigate the rebalancing problem [2]. Recently, dockless bike-sharing services have emerged as the last generation of these services. The lack of stations provides more flexibility to users and overcomes other barriers like limited budget and space for infrastructure. A considerable body of literature has studied various aspects of such services [1, 3, 5, 6, 9, 11].

Numerous studies have examined the implications of dockless bike-sharing services. Mobike, which is one of the largest dockless bike-sharing companies,

[4] https://gdpr.eu/

has written a white paper [3] with the support of the China New Urbanization Research Institute and Tsinghua University, based on analysis conducted on the trip data and user questionnaires in 36 cities in China. It presents the effects of bike-sharing on people's travel behavior, urban environment, pollution decrease and energy saving. This report provides statistics about user profiles and their trip purposes, bike and car usage as a result of bike-sharing expansion, integration of a dockless system with public transportation and its effect on carbon footprint reduction and energy saving.

As datasets are becoming available, studies started investigating the spatial and temporal patterns of bike usage. A study conducted on real time data from a major dockless bike operator in Singapore analyzed the spatiotemporal patterns on the system usage [9]. The impacts of built environment, access to public transportation and weather conditions on the spatiotemporal distribution of trip demand have been examined. The results reveal that diverse land use, easy access to public transport and supportive cycling facilities positively affect bike usage. A recent work [6] focused on identifying spatiotemporal similarities and differences in the activity patterns of six micromobility sharing services, including five operators of dockless electric scooters and one of dockless electric bikes, operating within Washington D.C. The bicycle service offers a far smaller vehicle fleet than the scooter services (the proportion is less than 35%) but it is used for longer trips, as its average trip distance and duration are much longer. The bike-sharing service presents generally different spatiotemporal patterns from the scooter-sharing services, explained by the operating difference between the two modes. Moreover, the difference in travel time between micromobility and ride-hailing services was examined, revealing that the former are faster on average during weekday rush hours for conducting short trips in the city center.

A large body of studies has focused on the prediction of the travel demand of the dockless bike-sharing systems leveraging the existence of relevant datasets. This is a spatiotemporal data mining task, offering valuable information for the development of efficient rebalancing strategies. Statistical techniques have been applied [9], but they have recently been replaced by more advanced machine learning approaches due to their powerful feature learning capabilities, especially in the case of large amounts of available data [11]. Hybrid deep learning models have been applied on GPS data of bike sharing operators in cities of China to address both temporal and spatial dependencies of the bike-sharing systems. Two recent works leveraged GPS data of bike sharing operators in cities of China to predict the spatiotemporal distribution of dockless bike-sharing [5, 1].

A number of relevant software platforms for bike-sharing management have also been studied. These platforms are BLOOM[5], Joyride[6], HOPR[7] and LINKA[8]. Table 1 summarizes the features included in these platforms. It is evident from the table that none of the platforms has managed to support all of them.

[5] http://bloom.bike/
[6] https://joyride.city/
[7] https://gohopr.com/
[8] https://www.linkafleets.com/

Table 1. Features of bike-sharing management platforms.

Features/Platform	BLOOM	Joyride	HOPR	LINKA
Real-time tracking	✓	✓	✓	✓
Statistics for admin/rider	✓	✓	✓	✓
Live alerts from users	✓	✓	✓	✓
Geo-fencing	✓	✓	✓	✓
Bike reservations	✓		✓	
Location-based ads	✓	✓		
Incentives for good etiquette			✓	
Maintenance and technician App				✓

The established practices along with user requirements and the research community needs were taken into consideration in the design of the i-CHANGE platform. As a result, i-CHANGE is a complete smart mobility sharing platform, which incorporates most of the features mentioned in Table 1 and more than that, such as an interactive map with various useful features for the application users and a social media monitoring service for the system administrator. In addition, it includes features derived from traffic analysis on the area where the system operates and data mining techniques applied on the collected data of the system. In the following sections the architecture of i-CHANGE platform along with the system components and their services are thoroughly described.

3 i-CHANGE System Architecture

The i-CHANGE platform is designed to support the operation of a dockless bike sharing system. Bicycles are strategically placed at different locations, covering a large geo-fenced area. Riders can start and terminate a rent at any point inside that area. Each bicycle has a GPS device, a GPRS card and a controller for handling events (e.g. unlock the bicycle on demand) integrated in their frame. Figure 1 depicts a high-level view of the system architecture.

Every time a user interacts with a bicycle (e.g. unlock), the exact location (in terms of latitude and longitude) is calculated from the GPS device, the timestamp of the event is attached and the data are transmitted with the help of the GPRS card to the system servers where they are stored. While a bicycle is rented, its location is periodically recorded to get the trajectory points.

The stored data derived from the users' rents are enriched with data from external APIs (e.g. weather data). The combined data could lead to useful information through additional analysis. The system implements an API for publishing the stored data for research exploitation and a dashboard to serve the needs of the admin user for system monitoring.

From the analysis of stored data, personal information about the users of the system could be potentially extracted. Working hours or home location could for instance be revealed in a relatively straightforward way. In order to prevent private information leaks and protect users, the data is anonymised before being

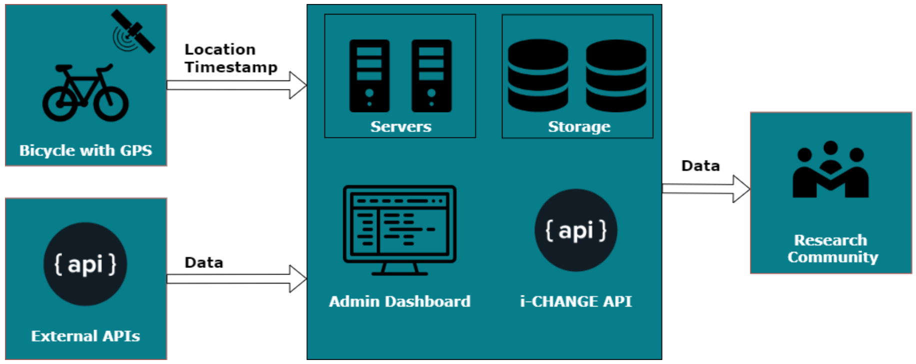

Fig. 1. System architecture of i-CHANGE.

exposed through the API. A unique identifier is assigned to each user of the system. All the identifiers are replaced with new ones on a daily basis. As a result, recurring routes cannot be attributed to specific users. Moreover, explicit personal information (e.g. email) is not accessible outside the system.

4 i-CHANGE Platform

The i-CHANGE platform integrates all the components of the system. It provides an app for smart devices to users. Through this app bikers have access to a set of useful geospatial information and traffic insights. Furthermore, through the i-CHANGE dashboard, the admin users can evaluate the system status, check statistics, manage promotional campaigns (e.g. free vouchers), evaluate the effect of actions taken, get meaningful insights, understand user needs and reach social media content referring to relevant topics (e.g. bike sharing platforms). The research community may have access to bike mobility data through an API.

4.1 Application

To successfully interact with the bike sharing system, users have to install an app on their device. The data that a user has to fill in order to create an account, include the full name, the email, a selected password and a confirmation of it and a telephone number. Moreover, users have to explicitly declare that they accept the terms of use of the app. The app is named EazymovGR and can be found on the App Store[9] for iOS devices and on Google Play[10] for Android devices.

The app implements a menu (see Figure 2) through which a user can:

[9] https://apps.apple.com/us/app/eazymovgr/id1492459234?ls=1
[10] https://play.google.com/store/apps/details?id=gr.brainbox.eazymovandroid

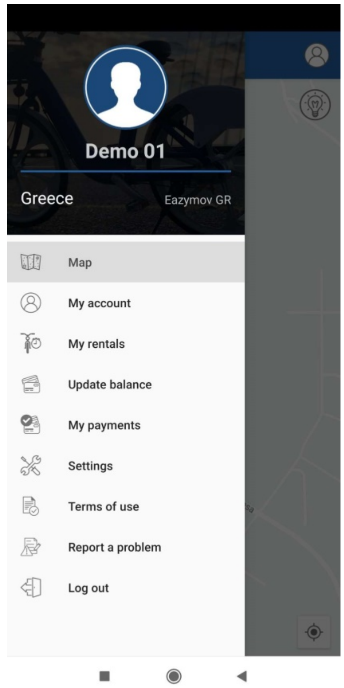

Fig. 2. Menu from app for smart devices.

- Create an account. The mandatory fields are a name, a valid email address[11], a password and a contact number. The user has to accept the terms of use, before registering into the system.
- Log in to account. With the email and password used in the registration, users can access their accounts. The app offers password reset functionality.
- See the exact locations of the bicycles in the map and the level of battery for each one. Moreover, users can get the unique identifier of each bicycle (it is also printed on the bicycle frame), to locate it among others when there are many stacked in a very short distance.
- Unlock a bicycle. By scanning a QR code that is located in the bicycle frame a user can initiate a rent. For reading the QR code, the camera of the smart device is used. In low light conditions the app can open the device flashlight.
- Terminate an order. By locking the bicycle manually, the app notifies the biker that the bicycle is locked and the order has successfully ended. Upon termination of an order, time and cost are displayed.
- See history of rentals. Information accompanying each rental includes the bicycle unique identifier, the timestamp that has started and ended, the duration and the cost.

[11] App checks for valid email formats name@domain and if no other registered user exists with the same address.

- Update their balance. Users can top up their accounts by selecting one of the predefined amounts[12]. Through a secure payment system users fill their credit card details and if the charge is successful the corresponding amount is added to the user's balance.
- See history of payments. For every payment, the app displays the timestamp and the amount charged.
- Modify account information. A user can change the information that has been provided in the step of registration, like setting a new password.
- Report problems in bicycles. Each bicycle is divided into 14 control points[13]. A user can select the number of the bicycle part that has failed, include a small description of the problem and submit the report. The app then notifies the administrator to take action and repair the bicycle, if necessary.
- Read the Terms of Use they have agreed to.
- Log out. Users can log out from their accounts at any time.

4.2 Traffic Macro-based Data

A novel part of the i-CHANGE approach is the combination of micro-based mobility data (e.g. trajectories of rides) with macro-based strategic traffic data. Within the context of the i-CHANGE platform, a strategic macroscopic traffic simulation model was developed for the city of Thessaloniki with the use of the software PTV Visum[14]. Based on the traditional four-step travel demand model and the study of human behavior, the area where the system is established was divided in 370 different traffic zones (see Figure 3). Based on the software and the analysis made, information about trips between each zone (and in-zone) was extracted. The implemented traffic model includes three transportation modes: private car, public transportation and walking. For each one of them, transportation time and cost are calculated from/to each traffic zone.

Six skim matrices were constructed with dimensions 370 x 370 (all the pairs of traffic zones). For example, the value in cell $< 200, 302 >$ in the matrix of transportation cost with private car declares the cost in Euro needed for moving from zone 200 to zone 302. Values in the diagonal represent metrics for intrazonal trips. Table 2 contains the components of the six matrices.

The i-CHANGE platform uses these arrays for comparing time and cost metrics of renting one of the system bicycles, with the corresponding values of other transportation mode choices. When an order is completed, a visualization (Figure 4) is presented that summarizes how much time and money is saved or lost compared to the case the user had conducted the same trip from one zone to another making a different choice (private car, bus, walking). Users can inspect the exact deviation in minutes and Euros.

[12] Choice among 2, 5, 10, 20 and 50 Euro.

[13] Mudguard, Large Basket, Exposure Area, Bicycle Frame, Electrical Assistance, Brakes, Lights, Seat Height Adjustment Lever, Saddle, Kickstand, Front Wheel, Rear Wheel, Lock.

[14] https://www.ptvgroup.com/en/solutions/products/ptv-visum/

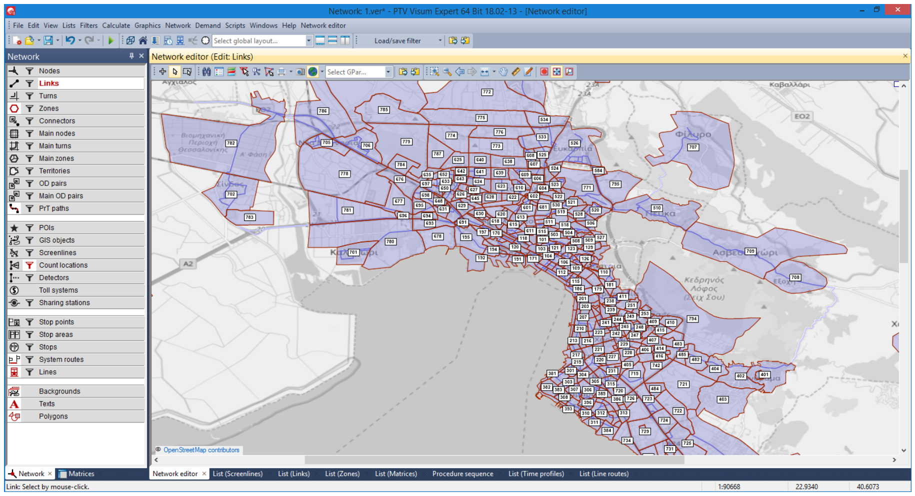

Fig. 3. Calculated traffic zones extracted from VISUM software.

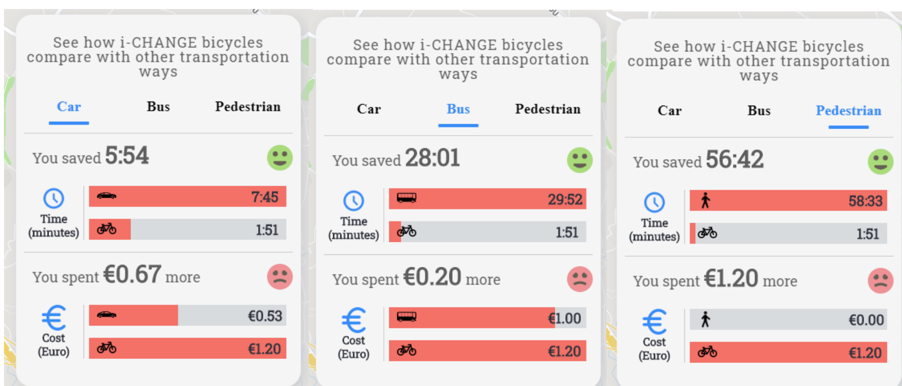

Fig. 4. Time and cost comparison of i-CHANGE bikes with other modes of transport.

4.3 Interactive Map

Through an interactive map that is integrated in the app for smart devices, users can access a series of helpful information that are relative to their exact location (extracted from the device GPS). Figure 5 depicts an instance of the map that contains all the information. For easier interpretation, different icons and colors have been assigned to each type of information. The users can select to show only specific information on the map, by ticking the corresponding entry from the menu on the left. Moreover, they can close the menu to view the map in full screen. Zoom and pan functionalities are implemented for easier map navigation.

Table 2. The components of traffic simulation matrices.

Component	Comments
Driving time in minutes	–
Driving cost in Euros	The cost is calculated based on an equation that models distance and fuel consumption
Bus riding duration	The diagonal of this array is always zero because in-zone trips are not conducted by bus due to the small coverage of the calculated traffic zones. Negative cell value (-1) indicates no bus connection between the two zones.
Bus riding cost in Euros	Costs are summed if more than one bus is required to complete the trip. The diagonal of this array is always zero. Negative value (-1) in a cell means that a bus connection between the zones does not exist.
Walking duration in minutes	–
Walking cost in Euros	All values of this table have zero values, as walking does not have any measured cost.

The i-CHANGE platform communicates with various external APIs in order to collect the information that is included in the map. This consists of the following:

- The exact locations of the i-CHANGE bicycles that are closest to the user's location. For each one of them, the distance from his/her location, the level of battery and the serial number are displayed.
- Alternative transportation. The closest to the user's location bus stations and bus lines are shown on the map. For each station the corresponding distance and its name are shown, and for each bus line the name, number, route length and direction are displayed. In the area where i-CHANGE is established, another bike sharing system (with docking stations) is in operation. For this system the map shows the location of the closest to the user's location stations and for each one of them it shows the corresponding distance, the available bikes and the name.
- Weather forecast. Temperature and weather description (e.g. partly cloudy) for the user's current location and for a time window of 3 hours ahead, are displayed.
- Infrastructure. The established bike lane network is projected on the map.
- Points of interest. Exploiting public data offered by Foursquare[15], users get the locations of the closest points of interest (e.g. restaurants). For each one of them, the distance from the user's location, the name and the address are displayed.

[15] https://foursquare.com/

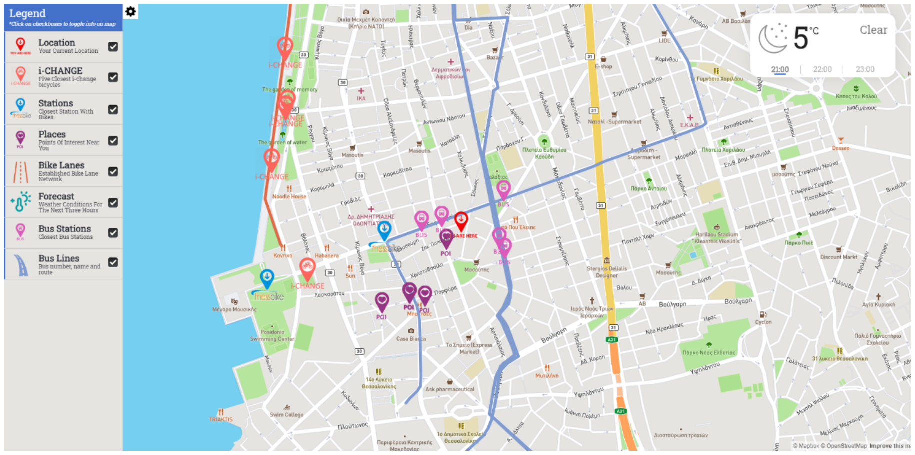

Fig. 5. Interactive map with geographical information.

4.4 Data Processing and Mining

The i-CHANGE platform collects and stores a large amount of data that derives from users' interaction with the system. With the use of data mining algorithms, useful insights can be extracted like transportation patterns. Two visualizations are implemented into the admin dashboard, with the first one analyzing the timestamps of orders and the second one their locations.

Figure 6 depicts the visualization for the time analysis. Orders are aggregated by hour of the day (00:00 – 23:00) and day of week (Monday - Sunday). Admin users can easily understand rush hours, prepare the system for periods with high demands or schedule the maintenance and rebalancing of the bicycles when the system needs are low. Selecting a time window is also possible, for monitoring specific periods of time (e.g. weekends) and seeing how rush hours are changing.

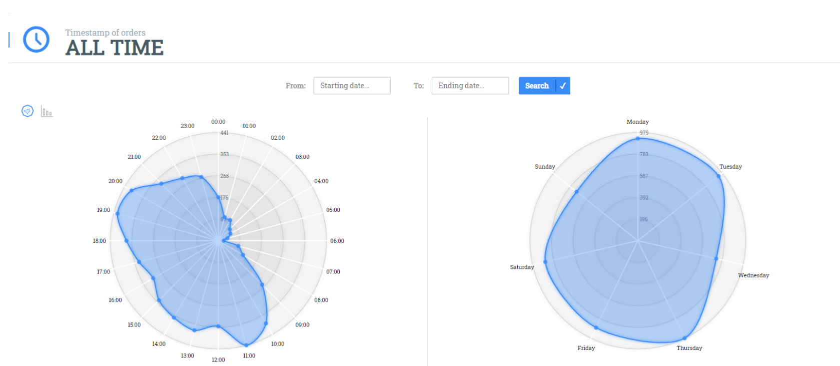

Fig. 6. Time analysis of orders.

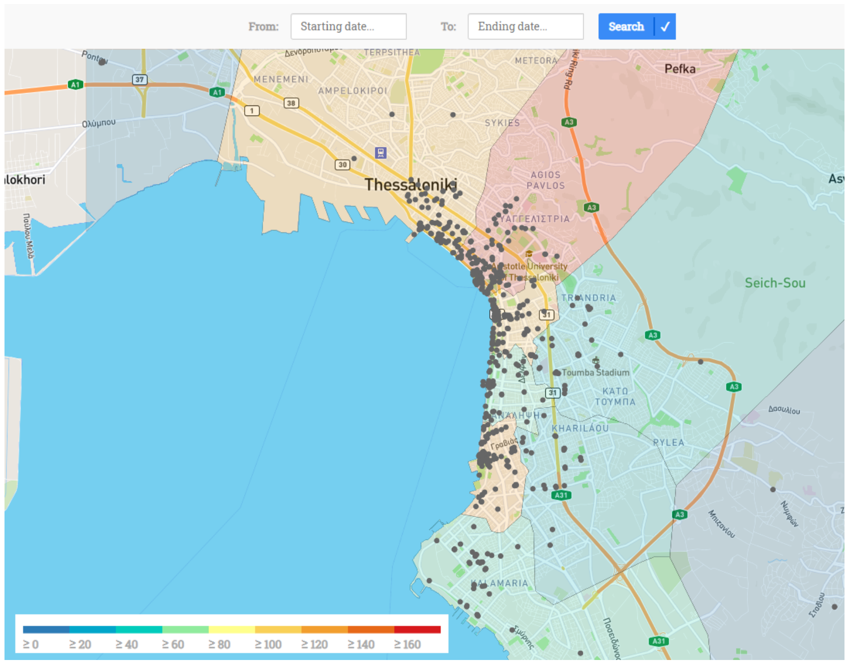

Fig. 7. Spatial analysis of orders.

Figure 7 depicts the spatial analysis of the rents' starting points locations. The area, in which the bike sharing system is established is divided into a set of clusters, so that the distance between points in the same cluster is minimized and the distance between points in different clusters is maximized [4, 12]. Cluster coloring is based on the number of starting points inside it. The administrator can inspect which areas need a larger volume of bicycles and which less, to plan a more efficient placement of bicycles according to users' needs. The administrator can also select a specific time window to see how clusters are modified.

4.5 API

The i-CHANGE platform provides controlled access to all the stored (anonymised) data that comes from users' rents. To this end, an API has been defined and implemented. To obtain access to the API and its data, it is mandatory to register an account with the system. The permission is given only to accredited personnel. The API only accepts requests that originate from users with verified accounts and respecting the defined rate limit (180 calls per 15 minute). Figure 8 depicts a user account with access to the API.

The API is built to handle two specific calls. One for retrieving orders and one for retrieving trajectory points for a specific order. All the results are structured in JSON format and have the necessary informative messages (e.g. when rate

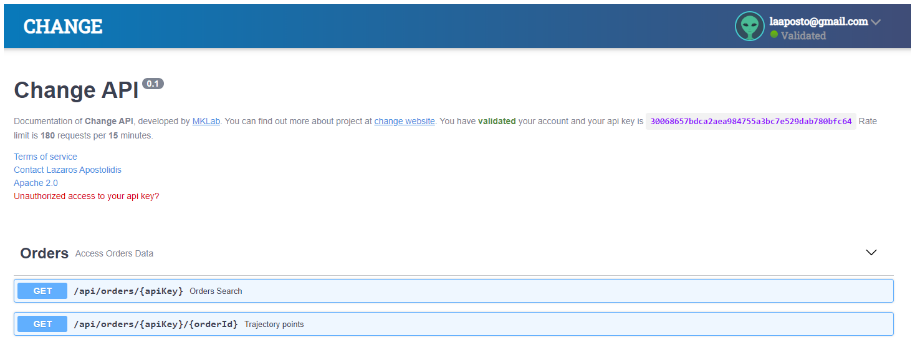

Fig. 8. User account with API access to orders data

limit exceeded). The API implements pagination to customize the size of the response based on caller needs.

Through the API a user can search for orders matching specific criteria. A series of input parameters are available to filter results. More specifically, the user can set:

- The number of returned orders in a page and the page number.
- The minimum and maximum timestamp of start and end event of an order.
- The minimum and maximum order time.
- The minimum and maximum order distance
- The minimum and maximum order cost.
- The status of the order.
- The unique bicycle and user identifiers.
- A bounding box for the start and the end point of the order.

The response consists of an array of orders that matches the input parameters. For each one of them, the API returns the distance, time and cost, the bicycle, user[16] and order unique identifier and the exact location and timestamp of start and end point.

The second call provides information for a specific order. More specifically, it returns all the trajectory points of the route of an order. The only input parameter that is required is the unique identifier of the order the user is interested in. The response consists of an array with all the trajectory points. For each one of them the exact location (latitude and longitude) and the corresponding timestamp are returned.

Both calls include in the response informative messages for the (developer) user: Messages that describe the status of the call (e.g. successful), all the input parameters, the remaining calls before hitting the rate limit and the time left to refresh the number of calls back to zero.

[16] It refers to the identifier after the process of anonymisation.

4.6 Admin Dashboard

For the administrator of the system, the i-CHANGE platform provides a dashboard that summarizes and presents via various visualizations all the stored data. The dashboard includes notifications, aggregate statistics, maps, information for registered users, completed rents, bicycles and users of the i-CHANGE API. Figure 9 depicts an instance of the dashboard and menu.

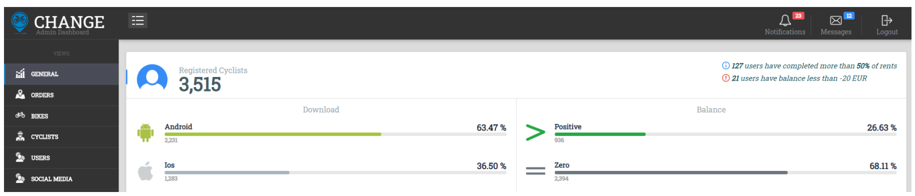

Fig. 9. Admin dashboard of i-CHANGE and its menu.

From the menu the administrator is able to access data for:

- General statistics. The number of registered users, the percentage of them that has positive, negative and zero balance in their accounts and the percentage of the platform they are using (iOS, Android, Web) are displayed. The number of orders and how many of them were completed or cancelled is presented along with the average ride time, distance and cost. The location of the available bicycles is shown in a map and for each one of them the status of their battery.
- Completed orders. Two maps with zoom and pan functionalities are offered. The first one is a heatmap that shows all the intermediate points of the routes during rents and the second one all the start and end points of rents. Orders can be filtered by time so that the two maps include data from a specific time window only. Moreover, a timeline shows the number of completed rents and data can be aggregated for 6 hours, one day and one week. The admin user can focus on a specific time window and zoom the timeline at convenience.
- Bicycles. A table is presented containing one record for every bicycle of the system. The table columns include bicycle unique identifier, serial number, status, level of battery, total distance covered, total time used, number of orders completed, if any action needs to be taken (e.g. maintenance) and its exact location in the map. By selecting a bicycle, all orders that have been completed with this bike are shown in another table. For each order the administrator gets its unique identifier, serial number, status, the unique identifier of user that made the order, the start and end timestamp, the distance covered, the total time and cost. In addition, a map showing the exact route followed is revealed by clicking a specific order. The table implements searching and sorting functionalities.
- Registered users. For each user that has created an account in the system, the administrator can inspect the unique identifier, the platform used for

registration, the timestamp of registration, the balance and the numbers of orders completed. Like bicycles, by selecting one user's record the system returns all the orders that are completed by the specific user combined with a heatmap showing the areas that he/she is mostly active in when renting a bicycle. Searching and sorting functionalities are also implemented for the table holding registered users.
- API users. For each user using the API of the i-CHANGE platform, the system logs the unique identifier, timestamp of registration, private key, if the account is verified, the email and how many times the rate limit has been exceed.
- Social media content. The i-CHANGE platform implements a service for monitoring and searching over the social media platforms of Twitter and YouTube. The administrator can set a list of keywords around a topic (e.g. bike sharing systems) and relevant content posted on Twitter and YouTube will be gathered and indexed minutes after it is published. The administrator can modify the list at any time, by adding or removing keywords. Based on the active list of keywords, all relevant posts related are presented, including metadata (time of publication, author, etc.).

Through the dashboard, the administrator can also receive notifications and messages. Notifications include actions that need immediate attention, like when an unusually long order is noticed and probably the user forgot to lock the bicycle and terminate the rent. Messages include information for the system, like when a new user creates an account for using the API.

4.7 Social Media Monitoring

The i-CHANGE platform integrates an open source solution [8] for monitoring relevant content from popular social media networks (e.g. Twitter). The collection of posts takes place in real time. With the formation of appropriate API calls, the framework continuously tracks the social media platforms, while at the same time it respects the set API usage rate limits. As soon as a relevant post is uploaded, it is collected (seconds to minutes after its publication). In addition to the text of the publication, the framework collects information about the users that published them, the embedded media items and the linked URLs.

The i-CHANGE administrator provides as input a list of keywords/hashtags to track, and the social media monitoring framework fetches relevant content from social media platforms by querying the respective platform API. The list can be edited at any time, by adding or removing keywords. All gathered posts are stored inside a common pool of content that is indexed and is then easy to query using the open-source Solr library[17]. A simple "feed" interface enables the administrator to browse through the collected posts and filter based on keyword/phrase, as well as on other criteria.

Using the social media monitoring framework, the administrator can track online conversations about the system of bicycles in order to gain insights from

[17] https://lucene.apache.org/solr/

influencers, identify bikers' and citizens' concerns and more. Users of the bike sharing system that had a bad experience and report it in social media can be identified, so that the administrator can contact them to get feedback on their experience and, if appropriate, try to compensate them (e.g. provide a free ride). The feedback can also be used to avoid having disappointed users in the future. Besides posts with negative experiences, the administrator can learn about the operation of the system and even discover new ways of promoting it to new users. Another use of the framework is market research and intelligence. For instance, the administrator could monitor competitors' social media campaigns and take appropriate actions (e.g. promotional vouchers).

5 Future Work

In the future, we plan to examine a wider variety of algorithms for data mining and apply them to the collected data of the system. The algorithms will be rated based on outcomes and how they can help the administrator make the operation of the system optimal, fulfil users' needs and maximize gains. New visualizations will be added to the dashboard, providing new ways of exploring the stored data. Bike-sharing demand will be spatially and temporally modeled in order to make short-term predictions. Outlier detection will be applied for identifying rare data deviating significantly from the "average" behaviour [7].

Future steps also include activities to promote the system to new users and engage even more the already registered ones. The tasks cover the following:

- Bicycle pre-booking. Users will be able to reserve a bicycle for a short time. In this period the bicycle cannot be rented by anyone else. Pre-booking ensures that the bicycle will remain available while this user is directed to it.
- Gamification. Integrate game mechanics into the platform to motivate participation, engagement, and loyalty of users.
- Increase use for commuting trips. Provide motivation for citizens to use bicycle for their daily commutes to and from work.
- Recreational transportation. Attract citizens to use bicycles for recreation.
- Approaching high altitude inaccessible areas with the supply of electric bicycles.
- Provide access to disabled citizens with the supply of bicycles produced for people with disabilities or limitations.
- Rebalancing of bicycles. As the platform is based on a dockless system, the problem of bicycle imbalance is critical and results to significant impact on service quality and company revenue. A model for bicycle rebalancing that reduces cost and maximizes administrator gain will be developed.
- Maintenance plan. Based on historic data, a model that predicts when a bicycle might need maintenance will be developed.

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References

1. Ai, Y., Li, Z., Gan, M., Zhang, Y., Yu, D., Chen, W., Ju, Y.: A deep learning approach on short-term spatiotemporal distribution forecasting of dockless bike-sharing system. Neural Computing and Applications **31**(5), 1665–1677 (2019)
2. Fishman, E.: Bikeshare: A review of recent literature. Transport Reviews **36**(1), 92–113 (2016)
3. Global, M.: Beijing tsinghua tongheng planning and design institute, & china new urbanization research institute.(2017, may 19). the mobike white paper: Bike-share in the city
4. Han, J., Kamber, M., Tung, A.K.: Spatial clustering methods in data mining. Geographic Data Mining and Knowledge Discovery pp. 188–217 (2001)
5. Li, Y., Shuai, B.: Origin and destination forecasting on dockless shared bicycle in a hybrid deep-learning algorithms. Multimedia Tools and Applications pp. 1–12 (2018)
6. McKenzie, G.: Urban mobility in the sharing economy: A spatiotemporal comparison of shared mobility services. Computers, Environment and Urban Systems **79**, 101418 (2020)
7. Roy, P.R., Bilodeau, G.A.: Road user abnormal trajectory detection using a deep autoencoder. In: International Symposium on Visual Computing. pp. 748–757. Springer (2018)
8. Schinas, M., Papadopoulos, S., Apostolidis, L., Kompatsiaris, Y., Mitkas, P.A.: Open-source monitoring, search and analytics over social media. In: International Conference on Internet Science. pp. 361–369. Springer (2017)
9. Shen, Y., Zhang, X., Zhao, J.: Understanding the usage of dockless bike sharing in singapore. International Journal of Sustainable Transportation **12**(9), 686–700 (2018)
10. Torrisi, V., Ignaccolo, M., Inturri, G.: Innovative transport systems to promote sustainable mobility: Developing the model architecture of a traffic control and supervisor system. In: International Conference on Computational Science and Its Applications. pp. 622–638. Springer (2018)
11. Xu, C., Ji, J., Liu, P.: The station-free sharing bike demand forecasting with a deep learning approach and large-scale datasets. Transportation Research Part C: Emerging Technologies **95**, 47–60 (2018)
12. Xu, R., Wunsch, D.: Survey of clustering algorithms. IEEE Transactions on Neural Networks **16**(3), 645–678 (2005)