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A holistic approach to optimize and promote Bike-Sharing Systems, through an integrated action plan

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***Abstract*— While Bike-Sharing Systems (BSS) are going through a period of rampant growth, users can be reluctant to use them, especially for specific activities, that diverge from entertainment. In this paper, we present a holistic action plan that consists both of actions that aim to optimize the functionality of a BSS and others that aim to promote its usage, through promotions and awareness campaigns. The action plan is part of the CHANGE project and it is achieved largely through the developed i-CHANGE platform, which offers an integrated tool to manage, analyze and optimize BSS operations in the city of Thessaloniki, Greece. The fleet, which is managed by the platform, is a fully dockless, electric fleet of 200 bikes. In this respective, new services are integrated into the system and introduced to its user. Pre-booking, that allows the user to reserve a bike and two gamification mechanics. One that introduces a system of levels, points, badges, and missions, that challenges the users to engage with the BSS and another that offers incentives to use the BSS and rewards as part of promotional actions. One of those actions offered incentives to commuters to know the BSS and regularly use it, and is carried out in collaboration with two of Thessaloniki's municipalities. Another provided visitors of select hotels in the city with coupons that allowed them to explore the city using the system at a much lower cost. Furthermore, the system was rendered inclusive to users with disabilities, as two "companion-bikes", that allowed for users on wheelchairs to ride with a partner, were designed, constructed, and utilized as a part of the project. The aforementioned actions are expected to expand the system's usage and shift it further from being exclusively leisure-based, leading to a more sustainable urban landscape.**

Keywords—Bike-Sharing System, Dockless Systems, System Optimization, Promotional Actions, Gamification, Mobility Disabilities

I. INTRODUCTION

The ongoing urbanization of recent years is becoming an increasingly urgent problem. More than 68% of the world's population is expected to be concentrated in cities by 2050 [1]. This trend along with the increasingly car-centric transportation habits, calls for the adoption of more sustainable environmental, social, and economic practices. The increasingly adopted shared economies and particularly shared mobility are promising solutions to this problem. Furthermore, increases in cycling and Bike Sharing System (BSS) modal share has been linked with many positive effects

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such as health benefits [2], reduction in congestion [3], and environmental benefits [4].

While BSSs are not a recent trend and their first applications can be traced all the way back to 1965, when the first generation of BSSs appeared in Amsterdam [5], their popularity has skyrocketed during the last few years. In 2015 dockless BSS emerged in China, went through incredible growth, and expanded to the rest of the world. Dockless BSSs make the flexible distribution of bikes throughout the urban landscape possible, without the need for stations. The users locate, rent, and ride the bicycles using mobile applications, thanks to the Global Positioning System (GPS) sensors that are installed on the bikes [6].

A lot of parameters can contribute towards the effectiveness of BSS, the position of the system stations in docked systems [7] and bike allocation in dockless ones can be a crucial determinant. The lack of dedicated infrastructure can be a major deterrent of BSS usage, while BSS users often are more environmentally and socially aware [8]. Potential users have been found to be more willing to use a BSS for shorter trip durations when the choice come with time or cost gains compared to their primary mode of transport [9]. While dockless BSSs throughout the world have known unprecedented growth, in some cases the combination of local pre-dispositions such as extensive car usage and the lack of a bicycle-friendly society, make developing action plans that promote the use of BSS necessary.

II. Materials And Methods

A. Case Study Area

Thessaloniki, located in Northern Greece, is the country's second-largest city and a major city in the greater Balkans and the Mediterranean. It has a population of more than 1,000,000 citizens in its metropolitan area and the only available mass transit option is the bus [10]–[12].

The bicycle modal share in the city is less than 5%, while the cycling infrastructure is limited, consisting of about 12km of cycleways. The station-based BSS of Thessaloniki began operating in 2013 and consists of 200 bikes and eight stations, largely located along the city's waterfront. In the last few years, there was a reduction both in the number of subscribers and the average journey time of bicycle trips [13], [14].

In 2018, a dockless BSS started operating with a pilot run. The system's fleet is composed of electric bikes, that can be rented and locked/unlocked without the need for a docking station and by using a smartphone application [15]. Promoting bike-sharing networks has been recognized as a priority action for the city of Thessaloniki, something that has also been highlighted in the action guide of the "100 Resilient Cities" network entitled "Resilient Thessaloniki: A strategy to 2030" [10].

B. The CHANGE Project

CHANGE (enhanCing tHe bicycle-shAre ecoNomy throuGh innovativE services & applications) is a project that develops a multiparametric approach that aims to change the attitude of urban trip makers towards alternative, shared modes of transport, such as BSSs, while enhancing the penetration of shared economies overall [16].

The project uses the dockless BSS of Thessaloniki, which consists of a fleet of 200 electric bikes as a case study. The most crucial tool it utilizes is the i-CHANGE management platform that was developed as part of the project. The platform monitors the system's activity and collects data, in a fully anonymized compliant with GDPR manner. Screenshots from the management dashboard are presented in **Fig. 1,2 & 3**.

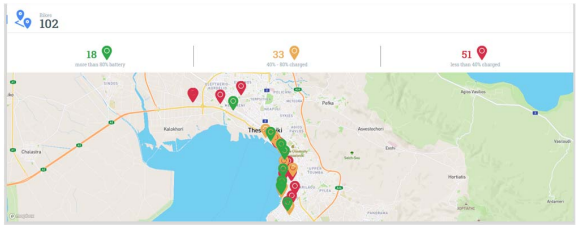


Fig. 1. Screenshot from the bicycle location service of i-CHANGE

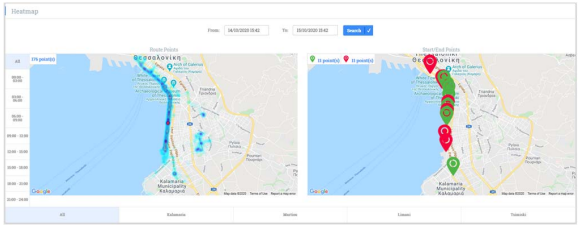
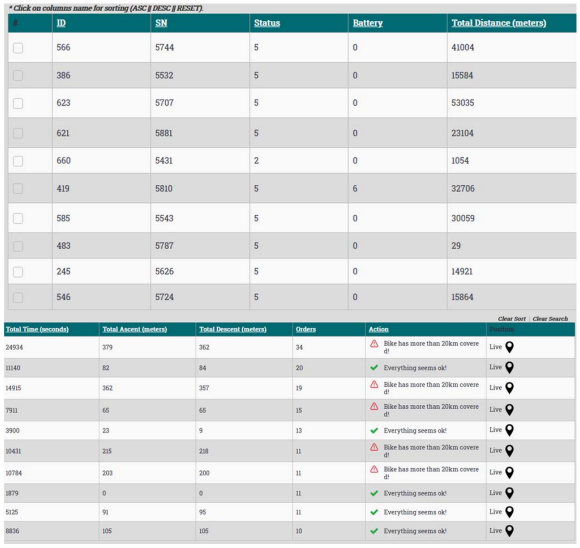


Fig. 2. Screenshot from the heatmap and trip start/end service of i-CHANGE



* Click on columns name for sorting (ASC || DESC || RESET).

#	ID	SN	Status	Battery	Total Distance (meters)
	566	5744	5	0	41004
	386	5532	5	0	15584
	623	5707	5	0	53035
	621	5881	5	0	23104
	660	5431	2	0	1054
	419	5810	5	6	32706
	585	5543	5	0	30059
	483	5787	5	0	29
	245	5626	5	0	14921
	546	5724	5	0	15864

Clear Sort | Clear Search

Total Time (seconds)	Total Ascent (meters)	Total Descent (meters)	Orders	Action	Trips
24934	379	362	34	Bike has more than 20km covere d!	Live
11140	82	84	20	Everything seems ok!	Live
14915	362	357	19	Bike has more than 20km covere d!	Live
7911	65	65	15	Bike has more than 20km covere d!	Live
3900	23	9	13	Everything seems ok!	Live
10431	215	218	11	Bike has more than 20km covere d!	Live
10784	203	200	11	Bike has more than 20km covere d!	Live
1879	0	0	11	Everything seems ok!	Live
5125	91	95	11	Everything seems ok!	Live
6836	105	105	10	Everything seems ok!	Live

Fig. 3. Screenshot from the bike status service of i-CHANGE (spread in two rows for improved readability)

In this paper, we present a holistic approach, that was designed as part of the project, to promote a BSS, through actions that aim to boost specific kinds of trips, using the system, and the system's attractiveness as a whole. In this way it highlights and promotes multiple facets of the ways a BSS can reshape the urban mobility landscape, by tackling practical issues, such as every-day commuting, recreational activities such as enhancing the city's touristic potential, and social contributions such as making another mode of transport available for users with disabilities. In the following sections, the four main pillars of that approach are presented and analyzed:

- Commuting by Bike-Sharing System
- Enhancing tourism with a Bike-Sharing System
- Pre-booking and Gamification
- Opening a Bike-Sharing System to users with disabilities

Each section offers a general overview of each of the BSS's aspects, that the action attempts to improve and goes through each action's implementation following that.

III. Commuting by Bike-Sharing System

A. Literature Review

Commuting trips are one of the major trip purposes BSSs are traditionally used for [17]. The mean frequency of a commuting BSS trip is four times greater compared to other trip purposes [18]. Commuters with increased commuting costs are more likely to start using a BSS for that purpose [19].

There is a wide variety of factors, found in pertinent literature, that affect how likely it is for someone to start using a BSS for commuting [20]–[22]:

- Their lifestyle, social upbringing, and bicycle usage for other types of trips. Those factors are found to majorly affect how likely someone is to start using a BSS for commuting, on a grander scale compared to immediately practical reasons listed below.
- Safety and comfort. The lack of either actual or perceived safety, while cycling, is a major deterrent to using a bicycle as a primary mode of transport. The behavior of other road users, mainly motorists, heavily impacts how safe cyclists feel. A BSS can contribute, to some extent, to its users feeling safe and protected while using it. One way towards that is by providing adequate instructions and good practices for the users to follow while riding. Another is by informing the users about local intricacies of the BSS's area of operation, such as the behavior of motorized users and challenges regarding the local cycling infrastructure.
- Cost, time, and effort. Those factors are highly significant, especially when a BSS is immediately compared to other competitive modes of transport. More specifically, increased trip cost or duration majorly affects the chances of choosing a BSS for commuting.
- A potential user's ability to ride a bicycle. Not feeling physically and mentally ready to withstand the physical strain and possible other challenges that come with using a bicycle can become a prohibitive factor towards using a Bike Sharing System.
- Health benefits. Many commuters prefer using a bicycle as a mode of transport, as they want to make the best of the time they would spend anyway commuting, by combing it with physical exercise.
- Adequate infrastructure. More bicycle infrastructure and higher density of the bicycle lane network have been linked with an increased likelihood to use a bicycle for commuting.
- Bicycle availability. Adequate bicycle availability in areas that are potential bicycle commuting trip generators, can be a crucial factor towards a BSS's successful operation. The increased flexibility of dockless BSSs can be an important factor towards more effectively meeting demand.

Furthermore, commuting by bicycle (and by extension using a BSS) has been linked with many potential benefits:

- Trip duration. While bicycles have relatively low maximum speeds compared to more widely used modes of transport, such as the private car, they can become a faster mode of transport during peak hours. This can be a potentially huge benefit when applied to commuting trips since a large number of them take place during peak hours. It is worth noting that extended usage of BSS has been linked with significant congestion reduction during peak hours in many US cities [23].
- Cost reduction. Bicycles have been linked with reduced operational costs compared to the private car. This cost refers both to the private cost each traveler needs to cover, as well as the grander social cost that comes from using each vehicle. More specifically, cost-benefit studies in Copenhagen have shown that private cars are approximately two times as expensive as a private bicycle regarding private costs, and six (6) times as expensive regarding total costs (both private and social) [24]. While BSSs are more expensive than private bicycles, they are accompanied by quality of life benefits that might be even more important regarding commuting trips. Such benefits are not having the risk of having your private bicycle stolen or vandalized, no maintenance costs, and having access to better quality vehicles and services (e-bikes, automated services that quantify the user's activity using the BSS, etc.). At the same time, BSS cost can be reduced when using long-term subscriptions, or when the cost is covered collectively by organizations (Business-to-Business BSS business plans).
- Health Benefits. Using a bicycle for commuting has been linked with reduced chances of heart disease, cancers, reduced body mass index, and reduced blood pressure and triglyceride levels [25]–[29]. At the same time, commuting by bicycle has been connected with a wider variety of benefits that contribute to the cyclists' well-being, such as spending more time in external spaces and cultivating a deeper connection with the urban landscape [30]. Improved health of the employees can in turn lead to increased productivity. Using a bicycle for commuting has been linked with a reduced number of sick days. The reduction is even larger for commuters that commute more frequently and for larger distances [31]. Commuting by bicycle has also been linked with increased work productivity [32].

B. Action Implementation

In order to maximize the expected benefits of the action, it was decided to organize it in a way that allowed to come in contact, in a centralized, structured manner, with a big number of commuters that would be potentially interested in using the BSS and had places of work that were inside or near or close to the BSS's area of operation. In order to achieve that we collaborated with two (2) of Thessaloniki's municipalities, the municipality of Thessaloniki and the municipality of

Kalamaria. As can be observed in the map of **Fig. 4**, both municipalities have worksites that are distributed close to the BSS's area of operations and headquarters (that have a much higher density of employees) that are inside or close to it. Furthermore, municipalities have already established communication channels, such as work e-mails and employee unions, that would allow us to come in contact with them in a more direct manner.

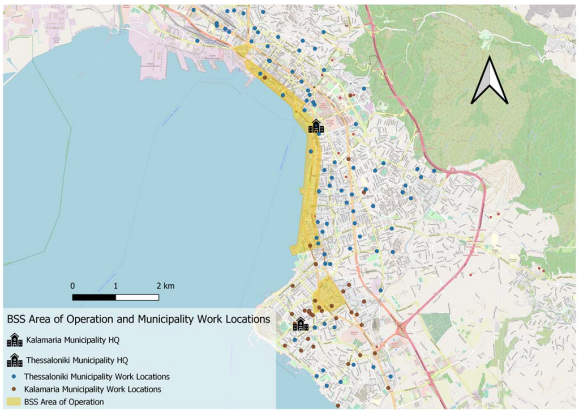


Fig. 4. Map with the Bike-Sharing System's area of operation and the municipalities' of Thessalonki and Kalamaria work locations

In order to motivate the municipalities' employees to partake in the action, a multi-tiered coupon plan was developed that would offer them incentives to use the BSS in a variety of ways:

- **Introductory Incentive:** A 20€ coupon is offered to all participating employees in order to enable them to get to know the BSS.
- **Commuter of the Month:** A 100€ coupon is offered to the participating employee that traveled the largest distance using the BSS each month.
- **Commuting Incentive:** A 10€ coupon is offered, each week, to every participating employee that used the BSS for commuting for at least three(3) out of five(5) workday that week.

The action's implementation consists of the following steps:

- Establishing a channel of operations with the municipalities' employees. An e-mail was sent to the employees' work e-mails that briefly described the project and explained the purpose of this specific action, mentioning that by participating in it they would have the opportunity of using the BSS for their commuting with some benefits. The e-mail also contained a link to an online form that the employees had to fill, in order to participate in the action. The form contained the following question sections:
    - Questions regarding the employees' approximate area of residence and the municipality's worksite at which they are employed.
    - Questions regarding their commuting habits (frequency, mode of transport, other activities they might take part in during commuting, such as dropping their children off at school or picking them up).
    - Questions regarding their cycling experience and the kind of trips they plan on making with the new BSS (all commuting trips, some commuting trips, other trips but not commuting trips, just planning to try out the BSS and decide if and how they are going to use it in the future)
    - Questions regarding their socio-economic characteristics (gender, age, education) and their contact information (e-mail).
- Re-adjusting the BSS's area of operation so that it includes the largest number of employees possible, without stretching the area and the associated maintenance costs too much.
- Contacting the employees that are eligible to take part in the action. At this point, they are eligible to receive the introductory incentive coupon.
- Monitoring the participating employees' use of the BSS, particularly for commuting. At this point, the "Commuter of the Month" and "Commuting Incentive" coupons are offered to the eligible participating employees. It should be noted, that the quantification of the participants' trips is done with full anonymization of their personal data and trips.
- Asking the participants for feedback. All participants are asked to fill in a survey that asks them for their feedback regarding the BSS and particularly its use for commuting. They are encouraged to share potential difficulties they encountered and suggestions for the future improvement of the BSS for commuting.

IV. Enhancing Tourism with a Bike Sharing System

A. Literature Review

Including a BSS in a city's touristic ecosystem has been shown to bring a lot of added value on the table, beyond benefits in the city's urban sustainable mobility. BSSs can become an effective mechanism of boosting and highlighting the city's pre-existing attractions. Their flexible nature and the outwardness that comes with using a bicycle offer visitors a more immediate experience while visiting the city's landmarks and areas of interest. The BSSs' effect on the uniqueness of a tourist's experience has been shown to be more important than the utility they offer, as it can increase the visitors' devotion to the specific tourist destination [33].

The following factors, explored in pertinent literature, have been found to significantly affect the touristic potential of a BSS [34]–[37]:

- Accessibility. Bicycle availability in locations with increased touristic activity are integral towards increasing their attractiveness to visitors.
- Developing synergies and collaborations with the city's pre-existing tourist facilities, such as hotels.
- The city's cycling infrastructure. The lack of dedicated cycling infrastructure, especially near the city's points

of interest can be a prohibitive factor that will severely limit the BSS's usage

- Advertising campaigns, that highlight the BSS's strengths and ease of use.
- Enough available information regarding the BSS for potential users. Lacking information on how to rent a bicycle and make proper use of a BSS can be very daunting to new users.
- Enough points of interest in the city that can be visited by bicycle
- Integration of the BSS in a pre-existing bicycle-friendly culture

B. Action Implementation

Taking into consideration the factors that were found to affect the touristic success of a BSS in the literature review, it was decided to work together with hotels to promote the touristic usage of the BSS. Four (4) hotels were chosen, three (3) of which are in the center of the city, within the BSS's area of operation, and in an area with established touristic activity. The fourth is close to the city center, but in an area that is considered easy to cycle from and to. The location of the four hotels in relation to the BSS's area of operation is displayed on the map in **Fig 5**.

Fig. 5. Map with the Bike-Sharing System's area of operation and locations of the partner hotels

The hotel staff was carefully trained regarding the CHANGE project overall, the way the BSS operates, and the specific promotional action they were taking part in. Promotional material in the form of information signs was posted at the hotel locations and more in the form of brochures was given to the hotels' staff, in order to distribute them to interested visitors. Both contained information about the BSS, a QR code that helped to download the BSS application, instructions on how to use it, and locations in the city that can be easily visited using the system's bicycles in both Greek and English. **Fig. 6** shows the posted signs and **Fig. 7&8** shows both sides of the brochure that was distributed. Every hotel visitor that expressed interest in using the system will be offered a 20€ coupon, to explore the city using the BSS.

Fig. 6. Signs that were posted in partner hotels' locations

Fig. 7. Front side of the brochure that is distributed in partner hotels

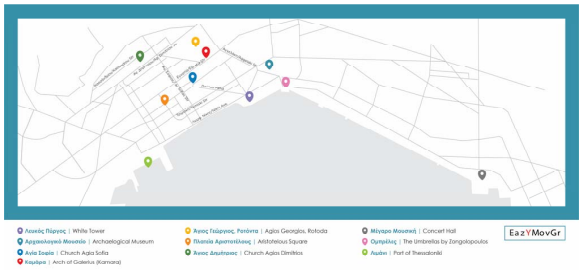


Fig. 8. Back side of the brochure that is distributed in partner hotels

V. Pre-Booking and Gamification

One of the most crucial factors of a BSS's success is having readily available bicycles when there is demand for them. Lack of available bicycles can become a major deterrent to use BSSs [38], [39].

One of the measures that were developed to counter this weakness was the integration of a pre-booking mechanic in the BSS management platform, as well as in the smartphone application. The pre-booking service allows users to reserve a system bicycle up to half an hour before their trip, in order to ensure it will be available at the time they desire or by the time they reach it, at no extra cost, provided they go on with renting

the bicycle. The reservation option is shown in **Fig. 9**, as it is displayed in the mobile application.

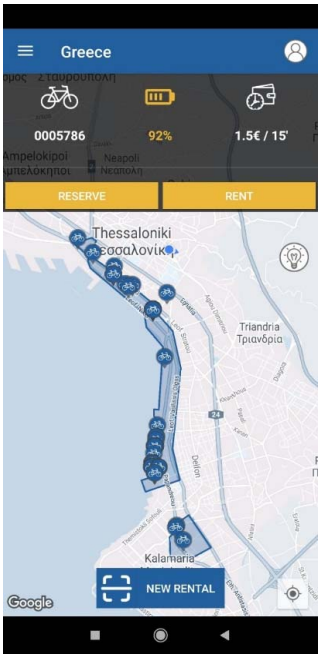


Fig. 9. Screenshot of the Bike-Sharing System's smartphone application that show the option to reserve a bike

Gamification is the practice of using game design elements in non-game applications [40]. While gamification does not have a clear definition yet, it often aims to shift the users' behavior towards the desired direction [41]. Many gamification applications make use of Information Technology and web or smartphone applications, but the practice itself does not have to utilize them. Furthermore, while gamification applications can offer incentives to the players to encourage certain behaviors, this is not a necessary component of gamification [41]. Gamification applications have often been utilized in a variety of transport-related contexts, such as to promote sustainable transport mode choice [42], to incentivize carpooling [43], to promote active mobility [44] and safer driving behavior [45]. Gamification has also been utilized towards promoting bike-sharing activities. Past applications have shown that it is effective towards increasing the users' engagement with the system and improving their loyalty to it [46]. Introducing a gamified, competitive environment between users leading to social dynamics was found to promote the use of bike-sharing for specific trip purposes such as commuting [47].

Gamification was introduced into the action in two ways. The first was designed to promote specific activities with the BSS and was integrated into it in the form of incentivizing coupons. Apart from the coupons that promoted commuting and tourist trips that were presented in previous sections, 100€ coupons were offered to the BSS users that made the largest total trip distance and largest total descent/ascent between their trips with the BSS each month. The second way was a virtual gamification system that was integrated into the BSS's management platform and mobile application. It allows the system administrator to adjust the manners in which the users can interact with the BSS, building a tailored experience that enhances the way they wish to operate and promote the system. The module of the platform that was created made use of a system of levels, points, badges, and missions that are fully configurable by the system administrator.

More specifically, badges can be earned by the BSS's users when they reach certain milestones while using the system. For example when completing a certain number of orders, when traveling a certain total distance with the BSS bicycles, when making long trips, using the system's bicycles, when using the BSS for consecutive days, etc. **Fig. 10** shows an example of the badge configuration interface.

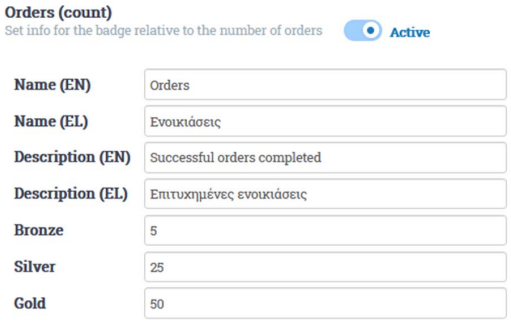


Fig. 10. The badges' configuration interface, it is seen by the Bike-Sharing System's administrator

Missions are objectives that can be set for the users to accomplish. There are three (3) types of missions integrated into the system. Parking missions, that ask the users to lock their bicycle, after using it, near a city landmark. Exploration missions, that ask the users to ride through certain historic or picturesque areas of the city. Both parking and exploration missions aim to encourage the users to explore the city while using the BSS. They are intended both for frequent users of the BSS and city visitors. Finally, commute missions, encourage the user to make a commuting trip using the BSS, which is defined by traveling to a destination with a bicycle remaining there for a pre-set amount of hours and making a return trip with a bicycle. **Fig. 11 & 12** show examples of the parking and commute missions' configuration interfaces.

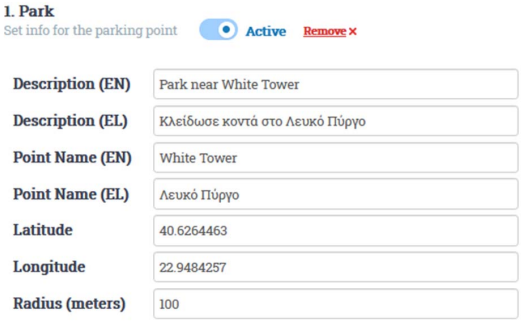


Fig. 11. A park mission's configuration interface, as it is seen by the Bike-Sharing System's administrator

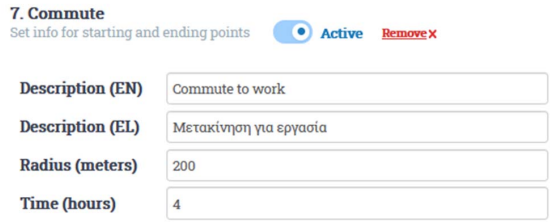


Fig. 12. A commute mission's configuration interface, as it is seen by the Bike-Sharing System's administrator

Points are earned by the users when they use the BSS or when they earn badges and complete missions. The users can earn points for each pre-set amount of orders completed, kilometers traveled, minutes traveled, meters of ascent or descent made, while using the system's bicycles. By gathering a pre-set amount of points, the users can level-up their BSS user profile. There are plans to implement certain advantages higher-level users can unlock. **Fig. 13 & 14** shows the point-earning and leveling systems.

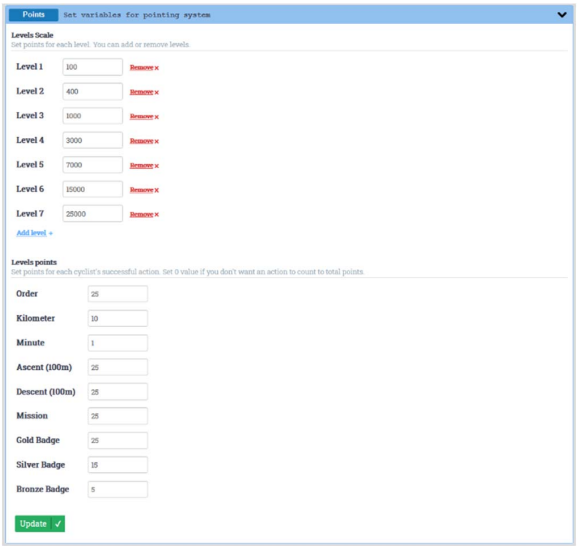


Fig. 13. The point-earning and leveling systems' configuration interface, as it is seen by the Bike-Sharing System's administrator

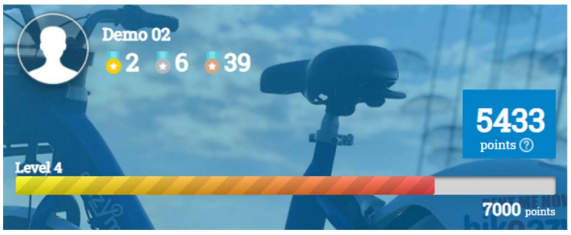


Fig. 14. The point-earning and leveling systems, as they are seen by the Bike-Sharing System's user

VI. Opening a Bike-Sharing System to Users with Disabilities

This action's aim is to make a new mode of transport available to a social group that was previously largely barred from using it. Including users with disabilities in the use of pedaled micromobility vehicles is about more than the practical benefits of offering them one more mode of transport. It is, mainly, a step towards allowing a whole social group to take part in a wide variety of activities that involve those vehicles and offering them another window of socializing with their loved ones the wider society.

Integrating pedaled vehicles, designed to cater to the needs of users with disabilities, in an existing mobility ecosystem involves a lot of potential challenges. Those vehicles are often accompanied by increased construction and maintenance costs. Furthermore, potential malfunctions during a ride could leave the rider with disabilities stranded and unable to continue his journey with other means, especially when the vehicle does not allow for mobility aids to be carried along [48]. It is also worth mentioning that disabled users of pedaled vehicles are often undermentioned or not mentioned at all in strategic planning guides and relevant documents [49].

The first major issue that needed to be tackled was deciding on the type of pedal cycle that would be used for the needs of this action. Pedal cycles for disabled users could be divided into two major categories; one-seat and two-seat vehicles. Types of vehicles from both categories are presented in **Table 1**. One-seat vehicles use varying types of movement transmission, depending on the user's disability, many of which are hand-powered and they are presented in the first column of **Table 1**. Two-seat vehicles usually require the presence of a riding partner, that contributes to the vehicle's movement and are presented in the second column of **Table 1**. [48]:

- It was decided that the type of pedal cycle that best fitted the project's aims and scope is a tricycle that allows for a wheelchair to be transferred with it.
- A one-person vehicle would be limited to users able to operate the vehicle. A handcycle could be operated by many paraplegic users but would be prohibitive for tetraplegic users. A vehicle that allows for a wheelchair to be transferred along with the disabled user is not only compatible with most types of wheelchairs but also allows the user to continue moving after the part of the trip that was made with the pedal cycle is over.

TABLE I. Types of Pedaled Vehicles for Disabled Users [50]–[59]

	One-Seat	***Two-Seat***
Handcycle (Vehicle that is powered by the user's hands)		

Recumbent Tricycle (Vehicle that allows the user to cycle while partially lying on his back)		
Recumbent Handcycle (Vehicle that allows the user to partially lie on his back while cycling with his hands)		
Pedaled Quadricycle (Vehicle with four wheels for greater stability)		
Tricycles with removable wheelchair (The wheelchair is part of the vehicle but can be removed and used on its own)		
Wheelchair carrying Tricycle (Vehicle that allows for a wheelchair to be secured on the vehicle and get carried with it)	-	

The vehicle was designed bottom-up and construction was assigned to the company Elektronio, which specializes in creating custom micromobility vehicles with certain characteristics and specifications [60].

A wide variety of challenges were faced and solved during the vehicle's design process. The wheelchair carrier was placed in the front of the vehicle, in order to give the disabled rider the best possible view of the journey, and in order for the vehicle to have the minimum possible width, in order to be able to fit in the pre-existing cycling infrastructure. The wheelchair needed to be able to board the vehicle safely and fast, since the process will be frequently repeated. A rotating ramp was designed, that also acted as a safety front wall/rail for the vehicle. The rail also helped the perceived safety of the rider. The wheelchair is secured on the vehicle using a combination of safety belts and non-slip flooring. Due to the increased vehicle size and weight, the vehicle is a pedal-assisted electric bike. The battery can be removed from the vehicle and charged separately. Feedback on the bicycle was taken from the Panhellenic Association of Paraplegics and certain design aspects were tackled in tandem with the Association [61]. **Fig. 15** shows the final version of the vehicle. Two of those vehicles will be made available to the Thessaloniki's users with disabilities and they will be able to use them free of charge after booking them.

Fig. 15. The final version of the vehicle that was designed

VII. Conclusions

In this paper, a holistic approach towards promoting the usage of a BSS in a city with overall low bicycle usage is presented. It aims to enhance the BSS's attractiveness and its integration in the urban mobility ecosystem, by allowing potential users to know its strengths and trying to mend its weaknesses.

Commuters are offered incentives to compare the BSS's potential, to their previously preferred mode of transport for commuting. By experiencing the BSS for a longer period they are given the chance to acknowledge extended benefits, beyond the immediately perceived, commuting by bike can have on their lives, such as extra exercise or replacing time they could have spent stuck in a traffic jam with recreational activity. Furthermore, collaborating with big organizations

such as the municipalities that were approached for this action, creates a window of opportunity for alternative BSS business plans, such as business-to-business operations. Organizations can see firsthand potential benefits that can be derived by offering to their employees zero or low-cost options for using a BSS for their commuting, such as increased productivity and health of their employees and contributing to a more sustainable urban mobility.

By integrating a BSS to existing tourist operations and making sure landmarks and attractions of the city are visited with it and new users don't feel daunted by using the system, it can potentially become more than an extra mode of transport that is made available for visitors. It is turned into an extra attraction for the city that also promotes and highlights its pre-existing assets. Exploring a new city with a bicycle and visiting noteworthy locations with it makes the experience more immediate and rewarding. Offering coupons that allow visitors to try out the system free of charge, can highlight those benefits to future visitors (both through current visitors' positive reviews and through the hotels suggesting it to them or even integrating the BSS in their operations).

Beyond attracting users to use a BSS, it is important to offer them a positive experience using it, that will urge them to keep using it and make it part of their mobility habits. Towards this, the pre-booking and gamification modules were included in the BSS. Making users feel safer about having a readily available bike waiting for them, giving them an interactive experience that urges them to use the system for more activities, and offering them incentives to keep using it, can substantially contribute to building user loyalty and increasing satisfaction by its use.

Finally, societal equity is more than giving all members of society equal opportunities; it extends into giving them the means of partaking in an extensive facet of activities in which they can interact with the rest of society. In this manner making the BSS available to disabled users is more than giving them an extra mode of transport or solving a practical transportation problem. It's a small step towards equity for a social group that is so often left out.

While the presented methodology tackles the issue of promoting a BSS with a holistic approach that improves a wide variety of its operations, there are still factors, that heavily affect BSS usage, that were not easily improved as part of this action plan. Those factors include improving and extending dedicated bicycle infrastructure, that will make cycling and BSS safer and more competitive, compared to alternative transport modes, streamlining the interoperability between the BSS and other transport modes, and making BSS operations, such as bicycle redistribution, more efficient.

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REFERENCES

[1] Departement of Economic and Social Affairs United Nation, *World Urbanization Prospects 2018*. 2018.

[2] N. Cavill, C. Foster, P. Oja, and B. W. Martin, "An evidence-based approach to physical activity promotion and policy development in Europe: contrasting case studies.," *Promot. Educ.*, vol. 13, no. 2, pp. 104–111, 2006.

[3] T. L. Hamilton and C. J. Wichman, "Bicycle infrastructure and traffic congestion: Evidence from DC's Capital Bikeshare," *J. Environ. Econ. Manage.*, vol. 87, pp. 72–93, 2018.

[4] P. DeMaio, "Bike-sharing: History, Impacts, Models of Provision, and Future," *J. Public Transp.*, vol. 12, no. 4, pp. 41–56, Dec. 2009.

[5] S. A. Shaheen, H. Zhang, E. Martin, and S. Guzman, "China's Hangzhou Public Bicycle: Understanding Early Adoption and Behavioral Response to Bikesharing," *Transp. Res. Rec. J. Transp. Res. Board*, vol. 2247, no. January, pp. 33–41, 2011.

[6] Institute for Transportation & Development Policy, "The Bikeshare Planning Guide," *Inst. Transp. Dev. Policy*, 2018.

[7] A. Nikiforiadis, G. Aifadopoulou, J. M. S. Grau, and N. Boufidis, "Determining the optimal locations for bike-sharing stations: Methodological approach and application in the city of Thessaloniki, Greece," *Transp. Res. Procedia*, vol. 52, no. 2020, pp. 557–564, 2021.

[8] V. Torrisi, M. Ignaccolo, G. Inturri, G. Tesoriere, and T. Campisi, "Exploring the factors affecting bike-sharing demand: Evidence from student perceptions, usage patterns and adoption barriers," *Transp. Res. Procedia*, vol. 52, no. 2020, pp. 573–580, 2021.

[9] I. Politis, I. Fyrogenis, E. Papadopoulos, A. Nikolaidou, and E. Verani, "Shifting to shared wheels: Factors affecting dockless bike-sharing choice for short and long trips," *Sustain.*, vol. 12, no. 19, pp. 1–25, 2020.

[10] Thessaloniki Public Transport Authority (THEPTA), "Resilient Thessaloniki: A strategy for 2030. THEPTA report (in Greek)," Thessaloniki, Greece.

[11] G. Pozoukidou, "Land use transport interaction models: Application perspectives for the city of Thessaloniki," *Spatium*, vol. 1, no. 32, pp. 7–14, 2014.

[12] "Socio-Economic Study in the Thessaloniki Metro extension to Kalamaria," Thessaloniki, 2011.

[13] Thessbike, "Thessbike. Website of Thessaloniki's bike sharing system." [Online]. Available: http://www.thessbike.gr/en/. [Accessed: 17-Feb-2021].

[14] R. Katkadikas, "No TitleManagement and analysis of massive data (big data) of the public bicycle users in the city of Thessaloniki by using the programming language R," Aristotle University of Thessaloniki, 2016.

[15] "Bikeazy. Website of bikeazy system." [Online]. Available: https://bikeazy.gr/. [Accessed: 20-Jul-2019].

[16] CHANGE, "CHANGE Project," 2021. [Online]. Available: change.iti.gr. [Accessed: 17-Mar-2021].

[17] S. Shaheen, E. Martin, and A. Cohen, "Public Bikesharing and Modal Shift Behavior: A Comparative Study of Early Bikesharing Systems in North America," *Int. J. Transp.*, vol. 1, no. 1, pp. 35–54, 2013.

[18] Z. Chen, D. van Lierop, and D. Ettema, "Exploring dockless bikeshare usage: A case study of beijing, China," *Sustain.*, vol. 12, no. 3, 2020.

[19] L. Yang, Q. Shen, and Z. Li, "Comparing travel mode and trip chain choices between holidays and weekdays," *Transp. Res. Part A Policy Pract.*, vol. 91, pp. 273–285, 2016.

[20] E. Heinen, B. van Wee, and K. Maat, "Commuting by bicycle: An overview of the literature," *Transp. Rev.*, vol. 30, no. 1, pp. 59–96, 2010.

[21] A. Kabra, E. Belavina, and K. Girotra, "Bike-share systems: Accessibility and availability," *Manage. Sci.*, vol. 66, no. 9, pp. 3803–3824, 2020.

[22] B. Muñoz, A. Monzon, and E. López, "Transition to a cyclable city: Latent variables affecting bicycle commuting," *Transp. Res. Part A Policy Pract.*, vol. 84, pp. 4–17, 2016.

[23] M. Wang and X. Zhou, "Bike-sharing systems and congestion: Evidence from US cities," *J. Transp. Geogr.*, vol. 65, no. May, pp. 147–154, 2017.

[24] S. Gössling and A. S. Choi, "Transport transitions in Copenhagen: Comparing the cost of cars and bicycles," *Ecol. Econ.*, vol. 113, pp. 106–113, 2015.

[25] L. B. Andersen, "Active commuting is beneficial for health," *BMJ*, vol. 357, p. j1740, 2017.

[26] C. A. Celis-Morales *et al.*, "Association between active commuting and incident cardiovascular disease, cancer, and mortality: prospective cohort study," *BMJ*, vol. 357, p. j1456, 2017.

[27] E. Flint, S. Cummins, and A. Sacker, "Associations between active commuting, body fat, and body mass index: Population based, cross sectional study in the United Kingdom," *BMJ*, vol. 349, no. August, 2014.

[28] P. Gordon-Larsen, J. Boone-Heinonen, S. Sidney, B. Sternfeld, D. R. Jacobs, and C. E. Lewis, "Active commuting and cardiovascular disease risk: The CARDIA study," *Arch. Intern. Med.*, vol. 169, no. 13, pp. 1216–1223, 2009.

[29] S. RJ, "Is active commuting the answer to population health?," *Sport. Med.*, vol. 38, no. 9, pp. 751–758, 2008.

[30] K. Wild and A. Woodward, "Why are cyclists the happiest commuters? Health, pleasure and the e-bike," *J. Transp. Heal.*, vol. 14, no. March, p. 100569, 2019.

[31] I. J. M. Hendriksen, M. Simons, F. G. Garre, and V. H. Hildebrandt, "The association between commuter cycling and sickness absence," *Prev. Med. (Baltim).*, vol. 51, no. 2, pp. 132–135, 2010.

[32] L. Ma and R. Ye, "Does daily commuting behavior matter to employee productivity?," *J. Transp. Geogr.*, vol. 76, no. October 2018, pp. 130–141, 2019.

[33] C.-F. Chen and C.-Y. Huang, "Investigating the effects of a shared bike for tourism use on the tourist experience and its consequences," *Curr. Issues Tour.*, vol. 0, no. 0, pp. 1–15, 2020.

[34] Austrian Institute of Technology, "Bike-sharing for touristic use Survey of Austrian bike-sharing systems for touristic use," 2018. [Online]. Available: https://www.ait.ac.at/en/research-topics/integrated-mobility-systems/projects/bike-sharing-for-touristic-use/. [Accessed: 08-Dec-2020].

[35] E. Bakogiannis, A. Vassi, G. Christodoulopoulou, and M. Siti, "Bike sharing systems as a tool to increase sustainable coastal and maritime tourism. the case of piraeus," *Reg. Sci. Inq.*, vol. 10, no. 3, pp. 57–71, 2018.

[36] J. Kalina, "Bike Sharing for Different Target Groups," Velocitta Project, 2016.

[37] B. Zhou, T. Liu, C. Ryan, L. en Wang, and D. Zhang, "The satisfaction of tourists using bicycle sharing: a structural equation model - the case of Hangzhou, China," *J. Sustain. Tour.*, vol. 28, no. 7, pp. 1063–1082, 2020.

[38] M. Lowalekar, P. Varakantham, S. Ghosh, S. D. Jena, and P. Jaillet, "Online repositioning in bike sharing systems," *Proc. Int. Conf. Autom. Plan. Sched. ICAPS*, pp. 200–208, 2017.

[39] M. H. Almannaa, M. Elhenawy, and H. A. Rakha, "Dynamic linear models to predict bike availability in a bike sharing system," *Int. J. Sustain. Transp.*, vol. 14, no. 3, pp. 232–242, 2020.

[40] S. Deterding, D. Dixon, R. Khaled, and L. Nacke, "From game design elements to gamefulness: Defining 'gamification,'" *Proc. 15th Int. Acad. MindTrek Conf. Envisioning Futur. Media Environ. MindTrek 2011*, no. 2014, pp. 9–15, 2011.

[41] B. T. H. Yen, C. Mulley, and M. Burke, "Gamification in transport interventions: Another way to improve travel behavioural change," *Cities*, vol. 85, pp. 140–149, 2019.

[42] S. Castellanos, "Delivering modal-shift incentives by using gamification and smartphones: A field study example in Bogota, Colombia," *Case Stud. Transp. Policy*, vol. 4, no. 4, pp. 269–278, 2016.

[43] R. Olszewski, P. Pałka, and A. Turek, "Solving 'smart city' transport problems by designing carpooling gamification schemes with multi-agent systems: The case of the so-called 'mordor of Warsaw,'" *Sensors (Switzerland)*, vol. 18, no. 1, 2018.

[44] PASTA Project, "PASTA (Physical Activity through Sustainable Transport Approaches)." [Online]. Available: https://pastaproject.eu/home/. [Accessed: 17-Mar-2021].

[45] F. Steinberger, R. Schroeter, M. Foth, and D. Johnson, "Designing gamified applications that make safe driving more engaging," *Conf. Hum. Factors Comput. Syst. - Proc.*, vol. 2017-May, pp. 2826–2839, 2017.

[46] M. G. Pasca, R. Guglielmetti Mugion, M. Toni, L. Di Pietro, and M. F. Renzi, "Gamification and service quality in bike sharing: an empirical study in Italy," *TQM J.*, 2020.

[47] A. Millonig *et al.*, "Gamification and Social Dynamics behind Corporate Cycling Campaigns," *Transp. Res. Procedia*, vol. 19, pp. 33–39, 2016.

[48] W. Clayton, J. Parkin, and C. Billington, "Cycling and disability: A call for further research," *J. Transp. Heal.*, vol. 6, pp. 452–462, 2017.

[49] N. Andrews, I. Clement, and R. Aldred, "Invisible cyclists? Disabled people and cycle planning – A case study of London," *J. Transp. Heal.*, vol. 8, pp. 146–156, 2018.

[50] Amazon.com, "Amazon; Top End Excelerator Handcycle," 2020. [Online]. Available: https://www.amazon.com/Invacare-1166564-Stock-Hand-cycle/dp/B078HCG2H7. [Accessed: 14-Dec-2020].

[51] Ashfield Special Needs Ltd, "Rider Plus Cycle," 2020. [Online]. Available: http://www.ashfieldspecialneeds.co.uk/tandem-wheelchair-bike.html. [Accessed: 14-Dec-2020].

[52] B. Friday, "One-of-a-Kind," 2020. [Online]. Available: https://www.bikefriday.com/folding-bikes/advert/custom-handcycle-tandem. [Accessed: 14-Dec-2020].

[53] Industrial Bicycles, "Greenspeed Magnum Handcycle Recumbent," 2020. [Online]. Available: https://www.industrialbicycles.com/GreenspeedMagnumHandCycle.htm. [Accessed: 14-Dec-2020].

[54] Kinetics, "Recumbents - Kinetics," 2020. [Online]. Available: https://www.kinetics-online.co.uk/recumbents/. [Accessed: 14-Dec-2020].

[55] Tadpole Rider, "Tadpole Tandem Trikes," 2020. [Online]. Available: https://tadpolerider2.wordpress.com/2014/06/04/tadpole-tandem-trikes/. [Accessed: 14-Dec-2020].

[56] Team Hubrid, “Add-On Viper Power Cycle,” 2020. [Online]. Available: https://www.teamhybrid.co.uk/product/viper-sport-power-cycle/. [Accessed: 14-Dec-2020].

[57] Utah Trikes, “Racing Hand-cycle Tandem,” 2020. [Online]. Available: https://www.utahtrikes.com/RECENTTRIKE-4308165_UTCustomTrike.html. [Accessed: 14-Dec-2020].

[58] VierBike, “VierBike Sport Standard,” 2020. [Online]. Available: https://www.vierbike.com/bikes/sport/sport-standard. [Accessed: 14-Dec-2020].

[59] VierBike, “VierBike Sprint,” 2020. [Online]. Available: https://www.vierbike.com/bikes/sprint. [Accessed: 14-Dec-2020].

[60] Elektronio, “Elektronio - Handcrafted Vehicles,” 2020. [Online]. Available: https://elektroniowheels.gr/el/. [Accessed: 14-Dec-2020].

[61] PASPA, “Panhellenic Association of Paraplegics, Macedonia and Thrace Chapter.” [Online]. Available: https://www.thesspaspa.gr/. [Accessed: 17-Mar-2021].