Mapping cyclists' routes: involving citizens in collecting open cycling data

Diego Pajarito	Suzanne Maas	Maria Attard	Michael Gould
Universitat Jaume I	University of Malta	University of Malta	Universitat Jaume I
Geotec Research Group	Institute for Climate Change and Sustainable Development	Institute for Climate Change and Sustainable Development	Geotec Research Group
Avda. Sos Baynat S/N	MSD 2080	MSD 2080	Avda. Sos Baynat S/N
Castelló, Spain	Msida, Malta	Msida, Malta	Castelló, Spain
pajarito@uji.es	suzanne.maas@um.edu.mt	maria.attard@um.edu.mt	gould@uji.es

Abstract

Urban cycling is not only a sustainable mode of transport but also a suitable alternative for cities to reduce pollution, congestion and increase physical activity of their population. However, limited access to information about the use of bicycles in cities poses difficulties for effective promotion and development of adequate infrastructure for cyclists. While mobile technologies and location-based services can effectively improve data collection and analysis of cycling mobility, most of the available applications do not allow for users to access the data collected and are not targeting urban cycling. The "*Cyclist GEO-C*" mobile application was developed to address this lacuna and crowdsource open geo-spatial data to support visualization of cyclists' routes. It was tested by volunteer cyclists' in an experiment conducted in three European cities (Münster, Germany; Castelló, Spain; and the urban area of Malta). Analysing the open dataset created by volunteers, researchers not only identified the streets preferred for cycling but also reviewed volunteers' feedback on the application and their experience. This paper reports on the potential of citizen science and mobile technologies to analyse urban cycling, the results from the use of the application for cycling data collection, and the lessons learned from the experiment in the three cities.

Keywords: urban cycling, mobile, application, citizen science, VGI, open source data

1 Introduction

Urban cycling is an alternative mode of transportation promoted by cities worldwide to reduce congestion, pollution and increase citizens' physical activity (Oldenziel, 2015). However, due to the limited access to urban cycling information (Gössling, 2017), cities have difficulties to effectively develop new infrastructure and promote cycling. The past decade has seen an impressive increase in the capacity and willingness of citizens to contribute information captured through their five senses and freedom to move, powered by technology through their smartphones. This Volunteered Geographic Information (VGI) is valuable for understanding people's mobility choices and for decision making and support thereof (Goodchild, 2007; Attard, Haklay & Capineri, 2016).

For this citizen science pilot experiment, cyclists used their smartphones and acted as human sensors to document their cycling routes, movements and experiences, which later were aggregated to create an open dataset and analysed to identify spatial and temporal patterns. Groups of 20 volunteers in each of the three European cities (Münster, Germany; Castelló, Spain; and the urban area of Malta) used *Cyclist GEO-C*, an Android location-based application, to crowdsource geo-spatial data of their bicycle trips. The researchers aggregated the collected data points to define and map the cycling routes in the three cities.

This paper describes the interaction with the Cyclist GEO-C mobile application offering two kinds of virtual rewards, the exploratory analysis of the crowdsourced geospatial data, and its potential use in urban cycling analysis. Finally, there is a discussion of the lessons learned during the experiment, including volunteers' feedback and suggestions, and possible future applications for citizen science strategies combined with location-based services (LBS) for urban cycling.

2 Mobile technology to collect cycling data

Data about cycling is not always accessible, as it usually comes from general transport surveys and with a high level of aggregation (Gössling, 2017). Since high quality information can improve promotion of cycling and planning its infrastructure (Braun et al., 2016), different actors try to provide alternatives to collect data. With the development of mobile devices and LBS, different tools and methods are being used for the collection of mobility data in cities.

Traditionally, cycling data has been collected primarily by public agencies through either place-based (e.g. bike counts) or person-based (e.g. surveys, travel diaries) data collection methods (Handy, van Wee & Kroesen, 2014). More recently, data collection of cycling routes and movements has utilized smartphones and their built-in GPS technology. Nonetheless, there are also examples of researchers that collect data through other (mobile) technology: through voluntary online mapping platforms (e.g. OpenStreetMap/OpenCycleMap: Yeboah and Alvanides, 2015; Sultan et al., 2015; and BikeMaps: Nelson et al., 2015), and by utilizing handheld GPS devices to collect travel data with a higher quality (Montini et al., 2015; Chen, Shen & Childress, 2017) or to better fit the research design and target group (e.g. school children, Mavoa et al., 2011).

2.1 Mobile Applications for cycling data collection

To compare how urban cyclists interacted with competition-based and collaboration-based rewards, we developed *Cyclist Geo-C*, an application specifically targeting urban cyclists that integrates gamified tools to collect open source bicycle geospatial data to visualize cyclists' routes in their cities. There are a number of already existing smartphone applications which collect data on cyclist routes, movements and general health and fitness data. Table 1 shows an overview and comparison of popular applications for cyclists available in the Play Store and App Store (for Android and iOS operating systems respectively), their functionalities, features, and how they use location based services, health and fitness data, and gamification strategies.

The reviewed applications usually offer statistics of bicycle workout such as distance, duration and basic performance indicators, and some of them integrate sensors on wearable devices like the Apple watch. Certain applications combine gamified features such as interaction through social networks, and competition challenges, which are either personal (improving on past achievements, personal records) or within a group of friends or team (scoreboard of performance). It is not common to have challenges at the city level (distance or trip goals for cities). Currently, motivational gamification is limited to the individual or competitive performance, overlooking the potential of gamification strategies to reward the benefits of cycling for the wider community and city.

Most of the existing applications for cycling target sporting rather than commuting cyclists and use competition-based rewards and tools to improve personal performance and compare performance with peers (Pajarito and Gould, 2017). Among the reviewed applications, only Bike Citizen and Biko specifically target urban cyclists. In contrast to sports cyclists, urban cyclists appear more motivated by factors such as an efficient commute, generating less congestion and pollution, reducing stress on road and parking space and spending less on daily transportation (Pooley et al. 2008; Tabares, 2017). Four of the reviewed applications - Strava, Human, Bike Citizens and Biko - explicitly offer advisory and data services for mobility planning in cities as part of their business. However, none of them provide free access to the collected data.

Apart from OpenCycleMap, the OpenStreetMap initiative for cycling, it's very difficult to find open datasets to analyse urban cycling (Sultan, 2015). The *Cyclist GEO-C* application's ability to crowdsource geo-spatial data introduces the possibility to build an open source map of urban cycling as a novel feature to the landscape of cycling and fitness applications.

2.2 Gamification to promote citizen engagement

Strategies to motivate and engage citizens using applications include game elements (Schouten et al., 2017), as they reward volunteers according to their interaction and add an element of fun to the experience. Within the typology of citizen science proposed by Haklay (2013), the role of citizens relies on their motivation to join and contribute. The experiment considered gamified features to enrol volunteers as citizen scientists hovering between level 1, sensing and recording bicycle trips, and level 2, providing a basic interpretation of cycling conditions using tags to describe trips and commenting on the cycling activity of the city (Haklay, 2013). As Garrard (2015) noted, there is a lack of a good evidence base for cycling promotion, but innovative designs

Table 1: Mobile applications for Cyclists with more than 10.000 downloads

	Strava	Map My Ride	Runtastic	Endomondo	Human	Cycle Map	Velo Pal	Google fit	Apple Health	Bike Citizens	Biko
Downloads	10M	5M	50M	50M	50K	50K	50K	50M	-	500K	500K
Services for cities	X				X					X	X
Live Map Tracking	X	X	X	X		X	X	X		X	
Cycling Route						X				X	X
Stats - Distance	X	X	X	X			X	X	X	X	X
Stats - Duration	X	X	X	X	X		X	X	X	X	X
Stats - Speed	X	X	X				X	X	X		
Stats - Elevation	X		X				X	X	X		
Stats - Calories		X	X	X	X		X	X	X		X
Stats - Heart Rate									X		
Social Networks	X	X	X	X			X	X		X	X
Personal Challenges	X	X	X				X	X	X		
Friend Challenge	X	X		X							
Team Challenge	X				X		X				
City Challenge					X					X	X

Source: The Authors.

and data collection methods can address this. The design and use of the *Cyclist GEO-C* app aims to address this paucity in cycling data to provide evidence for promotional campaigns.

Although gamification has seen successful applications in adapting game elements to transport analysis (Berri & Daziano, 2015), creating purpose-oriented campaigns (Wunsch et. al. 2016) or engaging specific groups of users (Schrammel et al., 2015), it can also have a shadow side, such as a negative impact on competitive users (Barratt, 2016) and issues related to privacy of users (Armoogum & Dill, 2015).

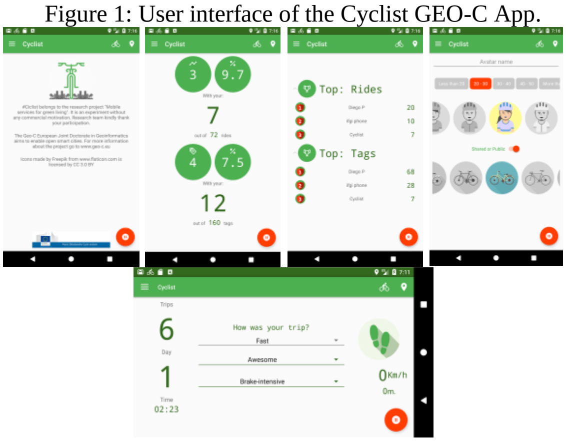
3 Methods

To (i) describe how citizens interact with cycling applications, (ii) identify the requirements to replicate or scale-up the use of such applications, and (iii) develop a proof of concept of understanding cyclists' movement using a pilot study in three different European cities (Münster, Germany; Castelló, Spain; and the urban area of Malta); the researchers recruited 20 volunteers per city to take part in the experiment. Despite its small size, each group could provide insights on the kind of rewards preferred by urban cyclists at each city and, at the same time, generate geospatial data for testing the analysis methods that can lead to understanding cyclists' movements. Feedback was collected from volunteers during the experiment, as well as through questionnaires distributed before and after using the application, which included questions about satisfaction and engagement with cycling and their perception of the virtual rewards offered by the app.

Volunteers were recruited through printed posters and flyers, as well as through messages on social media and email lists, targeting members of local cycling groups and organisations to participate. Volunteers needed to meet certain requirements: be over 18 years of age, cycle for their commute at least twice a week, have access to an Android phone to be able to run the mobile application, and attend to two sessions with the researchers. A total of 55 volunteers completed the full experiment. Each volunteer received a nominal €10 reward after finishing the tasks.

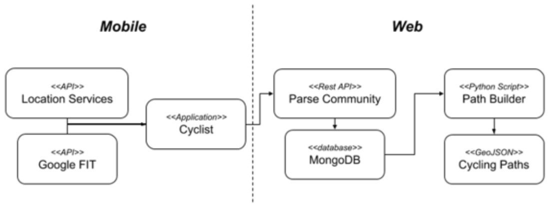
3.1 The Cyclist GEO-C Application

Figure 1: User interface of the Cyclist GEO-C App.



Source: The Authors.

Figure 2: Mobile application web components.



Source: The Authors.

The *Cyclist GEO-C* app is an Android location-based application for tracking cycling trips of volunteers and describing trips with up to 3 tags upon reaching their destination (see Figure 1), and one of the tools for enabling open cities offered by the GEO-C project's Open City Toolkit. The application aims to improve the analysis of cycling mobility by allowing users to choose up to 3 predefined tags, or add their own, to describe their trips, which could potentially reveal additional motivation or semantics relationship in the urban space used by cyclists. The app itself and the geospatial data collected will be open source and available to citizens, local councils or researcher groups. Consequently, any city or cyclist can track their trips, create route maps, analyse cyclists' movements and behaviour, as well as the description of each trip.

The application combines the "Location" and "Fit" Application Program Interfaces (API) provided by Google within an Android interface that starts and stops recording of location during cycling trips. It stores location information in a web server using the Parse Community REST API and MongoDB. A set of python scripts use the GeoJSON python library to produce GIS compatible geometries of the paths (see Figure 2).

A group of four researchers executed beta-tests in Münster and helped to identify security permissions, communication and data storage problems. The most important issue raised was the constraint for services running in the background, like the location tracking service, to notify the user when the service runs and provide a stop option at any time in the Android OS. This discovery resulted in a two week delay of the experiment launch in Germany, but at the same time made evident the importance of user's privacy in LBS for citizen science.

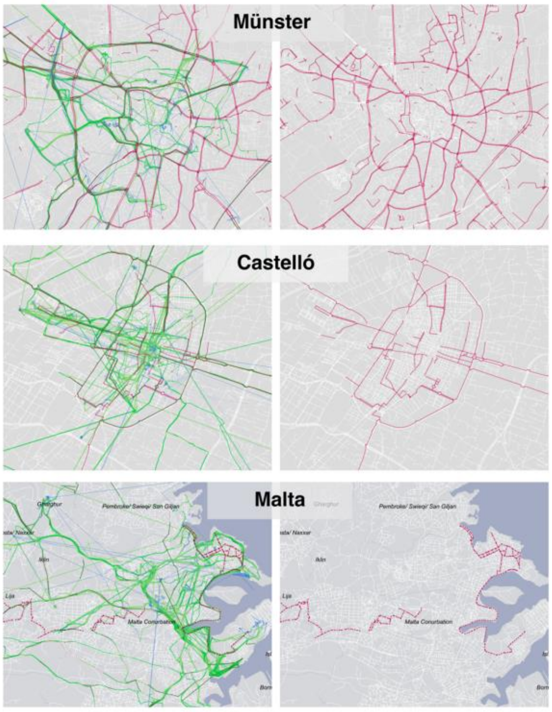
4 Results

Volunteers recorded 793 trips in the three cities, 343 trips (209 tracks) in Castelló, 335 trips (148 tracks) in Malta, and 115 trips (28 tracks) in Münster. Researchers identified streets that volunteers preferred for cycling as well as the way in which they used existing cycling infrastructure. Trips recorded in Germany were mostly urban and during workdays while in Malta and Spain volunteers also recorded their weekend's countryside trips. On average each volunteer recorded 13.4 trips, 6.6 trips per week, 5.6 kilometers long, and lasting 30.2 minutes. Volunteers recorded 791 tags that described trips, mostly related to the benefits of cycling in cities or environmental conditions during the trip.

Data collected during the experiment revealed differences between the cities such as the number of trips and tags recorded and their geographical distribution. Whereas in Münster the trips were predominantly within the city, in Malta and Castelló they were longer and connecting villages. While Münster has a pretty impressive 39% bicycle modal share (Münster Stadt, 2017), Castelló has a low 2% (Ayuntament de Castelló, 2012) and Malta has a modal share of less than 1% (Transport Malta., 2016). Volunteers' mobility was also different: in Münster 50% of volunteers reported bicycle as their only mode of commuting, whereas in Castelló and Malta almost all volunteers combine cycling with another transport mode.

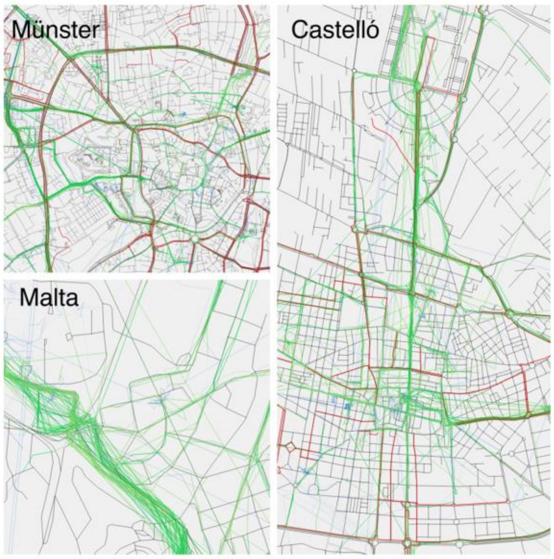
The recorded trips allowed to identify basic mobility patterns of cyclists mapped in Figure 3. The green lines visualise the data collected by the volunteers, with the thickness indicating the frequency of use of the route, whereas the red lines indicate the location of cycling infrastructure. Solid red lines indicate existing infrastructure, dotted red lines show the location of proposed infrastructure. For the purposes of these maps, cycling infrastructure includes all types of bicycle infrastructure, ranging from segregated bicycle lanes, to painted lanes on the road, to shared streets. Segregated unidirectional bicycle lanes are the most common form of cycling infrastructure in Münster, and most of the streets are two-way for bicycles. In Castelló there is a mix of painted lanes on sidewalks, shared streets with speed limits and segregated lanes. In Malta there are currently only a few lanes that are shared with public transport and taxis (shared bus lanes), but two cycling routes based on a shared street concept, including traffic calming measures, are being proposed.

Figure 3: Maps of the bicycle trips recorded with the application and Cycling Infrastructure. Scale 1:250.000.



Source: The Authors.

Figure 4: General patterns of bicycle trips in the three cities. Multiple scales.



Source: The Authors.

In Münster, volunteers use the high-quality cycling infrastructure that connects the concentric urban design from the promenade around the city center to the surrounding neighborhoods. In contrast, although Castelló is developing a network of bicycle lanes, volunteers only intensively use the ones connecting the university, city center and the port area, and additionally, use secondary roads and pedestrianized streets in downtown to complement the official bicycle infrastructure. Furthermore, routes branching out of the city can be identified, owing to the popularity of leisure and sports cycling in the surrounding countryside and mountains.

The urban area of Malta, and to a lesser extent Castelló, show much more dispersed routes than Münster; mobility patterns are not easy to identify beyond the intense use of flat streets along the waterfront. The urbanized east coast of Malta is characterized by dry valley systems, sloping down towards sea level, creating a variety in elevation levels. This hilliness presents a barrier for cycling, and cyclists' propensity for choosing low-lying or level cycling routes can be observed from their prevalence to follow the coast roads and promenades, main roads with gentle slopes, and even contraflow shortcuts. However, as can be seen from the proposed cycling infrastructure, the planned network is aimed at diverting cyclists away from the main roads in certain places, segregating cycling from car traffic. Future research could look into collecting data on cycling movements after the introduction of the planned network to see if routes have shifted towards the new cycling infrastructure, or if cyclists continue using the existing road network.

After looking into trips in each city in more detail, further patterns became clear. In Münster the configuration of the city with concentric rings and cycling trips along the bicycle lanes on and connecting the rings form the majority of trips. To access or pass around downtown, there is a promenade exclusive to bicycles in a ring around the city center. Figure 4 shows how the majority of trips connect with this ring and very few of them go through neighborhoods or the pedestrianised city center.

In Castelló, the main routes used are those connecting the city center with the university, as well as to the north, outside of the city towards the mountains (Figure 4). Closer to the city center, there is a more dispersed pattern, as volunteers either avoid the pedestrianized center, or navigate the small streets to pass through. The existing cycling infrastructure connecting the aforementioned locations are used by the volunteers of the experiment, but there are also bicycle lanes that were never used during the volunteers' collected trips. Further analysis and a larger sample size of volunteers would help with a better estimation of the use of cycling infrastructure.

The lack of bicycle infrastructure in Malta combined with its hilly topography, busy roads and a strong prevalence of one-way streets make cycling difficult and unsafe. Trips show a combination of defined corridors following cyclable slopes (see Figure 4) and a network of different secondary roads and shortcuts chosen by cyclists trying to avoid hills, sometimes going against the traffic flow. The dataset is a valuable input to identify and prioritise the need for contraflows, as well as to show main priority areas for cycling infrastructure.

5 Discussion

In all three cities, most of the envisaged number of 20 volunteers successfully participated in the experiment within the foreseen timeframe. The general response of volunteers was very positive: they saw the potential for their personal use and/or for the cycling organisation they form part of, and were willing to share their location data and movements for this purpose. Volunteers commented that they see the value of using the app as a motivational tool, especially for beginners, to collect data for tracking their personal goals, or for use in campaigning or lobbying.

Volunteers suggested two sets of improvements. Firstly, related to improvements in the app functionalities, such as reminders for using the app, better control of trip recording, and an easier interface for adding tags. Secondly, related to extensions to the app, such as adding a map feature, using the mobile phone as a sensor for mapping the quality of infrastructure by combining location and vibration detected with the accelerometer and extended gamified features based on topography (e.g. points for 'climbing hills').

6 Conclusion

From the largely successful execution of the experiment in three cities across Europe, and the feedback of 55 volunteers who have used the *Cyclist GEO-C* app, the following lessons were learned:

- The proof of concept of the application in three different cities, each with their own user base and geography, culture and cycling facilities, demonstrates that such technology has the potential to help cities and citizens to understand and promote urban cycling. There is a need to create guidelines to ensure the use of the application in other cities and contexts, so that individuals, cycling activists, advocacy groups, researchers, or local authorities can use or modify it for their particular purposes.
- Further analysis could provide insights in specific mobility patterns of cyclists, such as average speed and times of the day preferred by cyclists, as well as an understanding of why or where they usually make stops, where they have to divert from the straightforward path, or why certain infrastructure is underused.
- Involvement of citizens in validating results, framing further research questions and doing analysis together could increase the engagement of citizens.
- The application can support data collection and replication of the procedure in other cities. Its open design can be improved to support additional features to collect more data as well as personalised versions with adapted geo-visualization and analysis techniques for better adoption within different cultural environments. The application can also be adapted to collect data on additional modes of transport such as walking, be used for mobility management at specific events such as conferences or festivals.
- The application can support a wider audience, even though it started as a research experiment deployed using university (UJI) infrastructure. Doing so would require a manager (group) that maintains the platform and manages the data storage and processing tasks. Effort in streamlining and automating the process of using the app will contribute to wider usability and sustainability.
- Data collected with mobile phones, and in general within untrained volunteers, requires cleaning and validation. Although researchers can perform visual representations of the trips and descriptive analysis, the dataset needs further depuration to support stronger analysis. Collecting complementary information and field validation could also help to provide stronger conclusions.

Acknowledgment

Authors of this document gratefully acknowledge funding from the European Union through the GEO-C project (H2020-MSCA-ITN-2014, Grant Agreement Number 642332, http://www.geo-c.eu/); from the Citizen Science COST Action CA15212 www.cs-eu.net; and from the AGILE bursaries for ESRs. The experiment has been satisfactorily granted by the Committee of Ethics at Universitat Jaume I with the reference number 04/2018 and the Committee of Ethics at the Institute for Geoinformatics, University of Münster.

References

Armoogum, J. & Dill, J., 2015. Workshop Synthesis: Sampling Issues, Data Quality & Data Protection. Transportation Research Procedia, 11, pp.60–65.

Attard, M., Haklay, M. & Capineri, C., 2016. The Potential of Volunteered Geographic Information (VGI) in Future Transport Systems. Urban Planning, 1(4), p.6. Available at: http://www.cogitatiopress.com/ojs/index.php/urbanplanning/article/view/612 [Accessed January 18, 2017].

Barratt, P., 2016. Healthy competition: A qualitative study investigating persuasive technologies and the gamification of cycling. Health & Place. Available at: http://linkinghub.elsevier.com/retrieve/pii/S1353829216301903 [Accessed January 12, 2017].

Berger, M. & Platzer, M., 2015. Field Evaluation of the Smartphone-based Travel Behaviour Data Collection App SmartMo. Transportation Research Procedia, 11, pp.263–279.

Berri, A. & Daziano, R., 2015. Workshop Synthesis: Caring for the Environment. Transportation Research Procedia, 11, pp.413–421.

Braun, L.M. et al., 2016. Short-term planning and policy interventions to promote cycling in urban centers: Findings from a commute mode choice analysis in Barcelona, Spain. Transportation Research Part A: Policy and Practice, 89, pp.164–183. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0965856416303901.

Broach, J., Dill, J. & Gliebe, J., 2012. Where do cyclists ride? A route choice model developed with revealed preference GPS data. Transportation Research Part A: Policy and Practice, 46(10), pp.1730–1740. Available at: http://dx.doi.org/10.1016/j.tra.2012.07.005.

Ayuntament de Castelló, 2012. PLAN INTEGRAL DE MOVILIDAD URBANA SOSTENIBLE, Castellón de la Plana. Available at: http://www.castello.es/archivos/12/Plan2012/Textos/Catalogo_Plan_Acustico_Movilidad/Plan_de_Movilidad_Urbana.pdf [Accessed November 30, 2016].

Chen, P., Shen, Q. & Childress, S., 2018. A GPS data-based analysis of built environment influences on bicyclist route preferences. International Journal of Sustainable Transportation, 12(3), pp.218–231. Available at: article: http://dx.doi.org/10.1080/15568318.2017.1349222.

Diego, P. & Gould, M., 2017. Smart Mobility, the role of Mobile Games. In Lecture Notes in Computer Science. p. 13.

Garrard, J., 2005. Evaluating cycling promotion interventions. In R. Burton, ed. Cycling futures. Adelaide: University of Adelaide Press, pp. 429–452.

Goodchild, M.F., 2007. Citizens as sensors: the world of volunteered geography. GeoJournal, 69(4), pp.211–221. Available at: http://link.springer.com/10.1007/s10708-007-9111-y [Accessed February 7, 2018].

Haklay, M., 2013. Citizen Science and Volunteered Geographic Information: Overview and Typology of Participation. In Crowdsourcing Geographic Knowledge. Dordrecht: Springer Netherlands, pp. 105–122. Available at: http://www.springerlink.com/index/10.1007/978-94-007-4587-2_7 [Accessed February 7, 2018].

Handy, S., van Wee, B. & Kroesen, M., 2014. Promoting Cycling for Transport: Research Needs and Challenges. Transport Reviews, 34(1), pp.4–24. Available at: http://www.tandfonline.com/doi/abs/10.1080/01441647.2013.860204.

Johnson, M. (Transport researcher) & Bonham, J., 2015. Cycling futures, Adelaide University Press. Available at: http://dro.deakin.edu.au/view/DU:30080904 [Accessed February 5, 2018].

Mavoa, S. et al., 2011. Linking GPS and travel diary data using sequence alignment in a study of children’s independent mobility. International journal of health geographics, 10, p.64. Available at: http://www.ncbi.nlm.nih.gov/pubmed/22142322 [Accessed February 7, 2018].

Montini, L. et al., 2015. Comparison of Travel Diaries Generated from Smartphone Data and Dedicated GPS Devices. Transportation Research Procedia, 11, pp.227–241. Available at: https://www.sciencedirect.com/science/article/pii/S2352146515003117 [Accessed February 7, 2018].

Münster Stadt, 2017. Bicycles in Münster. Available at: http://www.stadt-muenster.de/english/transport/bicycles.html [Accessed February 12, 2018].

Nelson, T.A. et al., 2015. BikeMaps.org: A Global Tool for Collision and Near Miss Mapping. Frontiers in Public Health, 3, p.53. Available at: http://journal.frontiersin.org/Article/10.3389/fpubh.2015.00053/abstract [Accessed February 7, 2018].

Oldenziel, R. et al., 2015. Cycling Cities: The European Experience, Eindhoven : Foundation for the History of Technology and Rachel Carson Center for Environment and Society. Available at: http://www.cyclingcities.info/.

Opromolla, A. et al., 2015. Gamification in a Smart City Context. An Analysis and a Proposal for Its Application in Co-design Processes. In Games and Learning Alliance conference. pp. 73–82. Available at: http://link.springer.com/10.1007/978-3-319-22960-7.

Pooley, Colin (Lancaster Environment Centre, L.U. et al., 2008. Understanding Walking and Cycling, Summary of key findings and recommendations Project team, Available at: http://www.its.leeds.ac.uk/fileadmin/user_upload/UWCReportSept2011.pdf [Accessed August 11, 2017].

Schouten, B. et al., 2017. Games as Strong Concepts for City-Making. In Springer, Singapore, pp. 23–45. Available at: http://link.springer.com/10.1007/978-981-10-1962-3_2 [Accessed February 8, 2018].

Schrammel, J. et al., 2015. Using Individual and Collaborative Challenges in Behavior Change Support Systems: Findings from a Two-Month Field Trial of a Trip Planner Application. In Persuasive Technology. pp. 160–171. Available at: http://www.springerlink.com/index/10.1007/978-3-540-68504-3.

Sultan, J. et al., 2015. Using Crowdsourced Volunteered Geographic Information for Analyzing Bicycle Road Networks. Available at: http://www.fig.net/resources/monthly_articles/2015/december_2015/Sultan_etal_december_2015.pdf [Accessed February 7, 2018].

Tabares, C.M., 2017. Individual factors related to utilitarian urban cycling : representations, motivations and perceived aggression. Paris 8. Available at: http://www.theses.fr/2017PA080003 [Accessed September 14, 2017].

te Brömmelstroet, M., 2014. Sometimes you want people to make the right choices for the right reasons: potential perversity and jeopardy of behavioural change campaigns in the mobility domain. Journal of Transport Geography, 39, pp.141–144. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0966692314001495.

Transport Malta, 2016. Transport Master Plan, Valletta. Available at: http://www.transport.gov.mt/admin/uploads/media-library/files/Transport Master Plan rev 2.0.pdf.

Wunsch, M. et al., 2016. Gamification and Social Dynamics: Insights from a Corporate Cycling Campaign. In N. Streitz & P. Markopoulos, eds. Lecture Notes in Computer Science. Toronto, ON, Canada, pp. 494–503. Available at: http://link.springer.com/10.1007/978-3-319-20804-6.

Yeboah, G. & Alvanides, S., 2015. Route Choice Analysis of Urban Cycling Behaviors Using OpenStreetMap: Evidence from a British Urban Environment. In Springer, Cham, pp. 189–210. Available at: http://link.springer.com/10.1007/978-3-319-14280-7_10 [Accessed February 7, 2018].