Smart Mobility, the Role of Mobile Games

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Abstract. Cities are increasingly making accommodations for increasing bicycle use as one of the smart city strategies on mobility planning. Our study addresses the use of mobile applications (apps) to incentivize the increased use of cycling for commuting to work/study, we conducted a survey to identify trends and gaps in smart mobility research, especially on urban cycling promotion through mobile devices and games supported by geospatial analysis. The analysis of 140 publications, provided insights from the smart mobility concept like the constant support of mobile devices and location-based services on this research field as well as a strong bias towards experiments and a few theoretical reviews, the frequent use of intrinsic motivation when designing games, and customised platforms for experimenting instead of commercial applications. Finally, the lack of integration between game narratives and the capabilities of geospatial analysis is considered the biggest research challenge for game designers and smart city advocates.

Keywords: Serious games · Gamification · Urban cycling · Geospatial

1 Introduction

Before the automobile revolution, bicycle commuting was normal practice in European cities. However, due to industrial and cultural changes, just a few cities are considered cycling commuting leaders with about 30% of bicycle commuting share [29]. Optimizing public spaces for cycling, walking and public transportation usually means adding restrictions for private cars [16]. Better cycling spaces or bike-friendly spaces, help on reducing the frictions preventing people from commuting by bicycle.

Cities are still deciding if they will support bicycle commuting or adopt some sort of behavioural change campaign for engaging alternative commuters [29]. Such decisions can change the mind of certain citizens that perceived cycling as a dangerous and uncomfortable activity, cycling infrastructure as deficient, or simply prefer to have a car and use it for any kind of trip. Environmental conditions also prevent people from cycling due to the effort needed in hills, the risks of staying outdoors in polluted areas, or simply the uncertain traffic or weather conditions that could produce delays [43]. To create bike friendly spaces and promote its use improve urban mobility and pedestrian safety, such results are better perceived when citizens take part on participatory decision-making processes [36].

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Enhancing citizen participation and improving living conditions help on define the "smart city" concept, defined as the union of information technologies with sustainable development and citizen empowerment and participation [33]. Alternative commuting, especially cycling, is considered an environmentally-friendly solution for building sustainable cities, and could improve the traditional top-down approach of policy-making if cyclists are allowed to provide "on the road" feedback on their experiences. Enthusiastic cycling advocates aim to overhaul transport systems to include urban cycling as a normal component of multi-modal systems, and they use information technologies for supporting their analysis as well as for increasing participation.

Geospatial technologies are the kind of technologies that help monitoring and analysing spatial relationships within cities. Urban transport systems usually deal with relationships between paths, origins, destinations, roads, vehicles, goods and persons; therefore the use of geospatial technologies for transport systems goes beyond the basic analysis of x, y, z points with time stamps, to fully adopt the concept of trajectories [26]. Although some of those technologies are becoming popular within cyclists (i.e. search for places to visit, estimate the shortest path, record bike trips) and virtual rewards are commonly used by mobile applications, existing computing capabilities are capable to process a higher volume of data using parallel computing and data stream processing [11] in the background, providing better and more complete feedback to a mobile client device.

Described elements drive the concept of smart mobility, that applied to urban cycling, involve elements like geospatial technologies for analysing urban cycling, gamified tools for increasing enjoyment as well as citizen participation for helping on urban planning, that together could be formulated as in (1):

$$\{UrbanCycling \cup GeospatialTechnologies \cup Gamification\} \subset Smartmobility \quad (1)$$

This review critically analyses scientific outcomes regarding smart mobility and existing initiatives for promoting urban cycling; focusing on cyclists' motivation and engagement as well as the role of geospatial technologies and mobile devices on these tasks. The review also gives insights into selected scientific publications that consider urban cycling, gamification, geospatial technologies and mobile devices; presents tendencies and gaps of smart mobility promotion; and concludes with research directions and recommendations.

2 Methodology

The review started with a concept-based search on four scientific repositories, a set of documents were briefly described according to applied methodology, relationship with urban transport, and use of gamification; the analysis was made after selecting those reporting the use of game elements on promotion of cycling, research trends and gaps were identified as well as conclusions and a short description of future tasks.

2.1 Concept-Based Search

The search was performed over four scientific repositories SpringerLink, ScienceDirect, IEEEXplore, and Scopus, aiming to focus on information technologies repositories. It was driven by the concept of smart mobility; therefore, it considered the following keywords "Cycling", "Urban Cycling" and "bikeability"; complemented with "GPS", considering location based services and mobile devices, and "Gamification", considering game tools on non-gaming contexts. To link those keywords logical connectors were used, first "OR" operators linked cycling related keywords, then "AND" operators linked the two last keywords to just consider publication reporting location-based services and gamification. The final expression used for searching is shown in (2) while the relationships between keywords are shown in Fig. 1. A temporal window from 2014 to 2017 was defined so that the search is considering only recent and comparable publications.

$$\{\{Cycling \vee UrbanCycling \vee Bikeability\} \wedge GPS \wedge Gamification\} \quad (2)$$

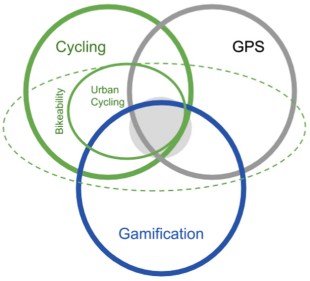


Fig. 1. Conceptual relationships considered on the review

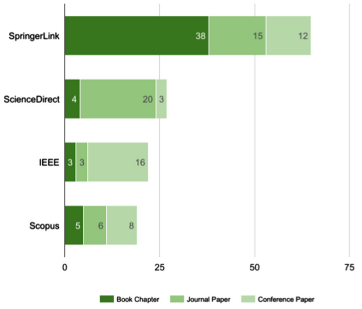


Fig. 2. Book chapters, journal and conference papers reviewed

2.2 Document Description

The search produced one hundred and forty scientific documents (140). From these documents, simplified meta-data was generated with features like access URL; year of publication; years of the most recent and oldest reference; and the number of citations [31]. Each document was described considering four topics and a set of features listed in Table 1.

2.3 Selection of Cycling Related Publications

The subset of cycling related publications was defined by the fields of the second topic (Relationship with urban transport and cycling) and complemented with features like the type of mobile device, use of location services, applications or platforms, city and country of the experiment, and finally the use of quantitative or qualitative methods.

Table 1. Structure of the description table

Topics	Field description
Reported methodology	- Literature review, when reporting text compilation and analysis
	- Experiment or test, when reporting experiments or tests of hardware, software, applications or algorithms
	- Design, when reporting new methodologies, platforms, information systems or frameworks
	- Survey, when reporting data gathering from participants, interviews, workshops or derived analysis
	- Reported participants, when reporting the number of participants in a survey or experiment
Relationship with urban transport and cycling	- Urban traffic, when reporting analysis of traffic conditions
	- Health, when reporting measurement of health benefits
	- Sports performance, when reporting performance measurements
	- Environmentally friendly actions (green living), when reporting behavioural change towards green living
	- Related to cycling, when reporting use of bicycles in urban areas
Relationship with location based services - LBS	- Location services, when reporting usage of GPS or any other location technology
	- Mobile devices, when reporting usage of mobile devices
	- Wearables, when reporting usage of wearable devices, mobile accessories, virtual reality headsets or similar devices
	- Social networks, when reporting interaction through social networks
	- Web pages, when reporting interaction through websites
	- Virtual survey systems, when reporting non-personal surveys
	- LBS Related, an aggregated description using “No Device”, “Device Enabled” or “Mobile and Location enabled” categories
Relationship with urban transport and cycling	- Intrinsic motivation, when reporting intrinsic motivation
	- Extrinsic motivation, when reporting extrinsic motivation
	- Negative impacts of gamification, when reporting evaluation of gamified tools
	- Gamification relationship, an aggregated description using “gamified” or “non-gamified” categories

2.4 Analysis and Comparison

The analysis was supported on set of graphics that provided insights of each of the described features, multiple comparisons between topics allowed to identify such patterns, tendencies, and gaps; and related work used for defining smart mobility was considered during analysis. Contrasting cycling and non-cycling related publications helped to identify trends and gaps. A selection of relevant graphics were compiled and annexed to this paper [31].

2.5 Discussion and Conclusion

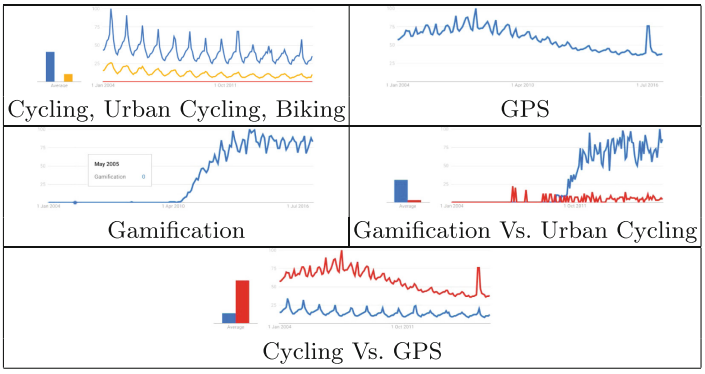
The discussion was driven by the identified trends and gaps, they allowed to identify future works and conclusions about urban cycling promotion as well as the way that such works would help emerging open smart cities.

3 Results

The relevance on the web of the words used for search allowed to understand the interest on those terms through time. Table 2 shows a constant and usually low interest for general concepts like "Cycling", "Biking" or "Urban Cycling" on the one hand, and a sequence of stationary variations during the northern hemisphere summer on the other. The "GPS" concept showed a decreasing interest tendency, probably associated with its ubiquity and massive integration with more complex devices and tracking systems (i.e. fitness trackers, onboard computers, driving assistants, etc.), while the relevance of "Gamification" significantly grown from 2011 when emerged as a novel and trendy concept.

The review was made up of over one hundred and forty (140) scientific publications, of which, sixty-six (66) from SpringerLink, thirty (30) from ScienceDirect, twenty-four (24) from IEEE Xplore and twenty (20) from Scopus. Figure 2

Table 2. Concept interest on the web from Google trends



shows not only the high contribution of publications but also the strong proportion of book chapters from SpringerLink; the large number of journal papers from SpringerLink and ScienceDirect as well as several conference papers from IEEEXplore and a balanced distribution of publications from Scopus. Not shown in the figure were seven (7) publications reporting either abstract compilation, workshop synthesis or lecture notes.

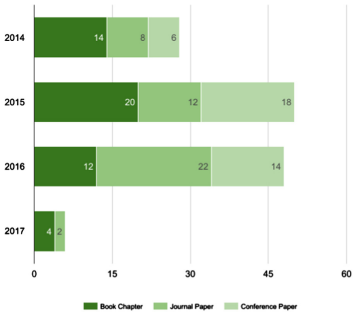


Fig. 3. Distribution of publications through selected years

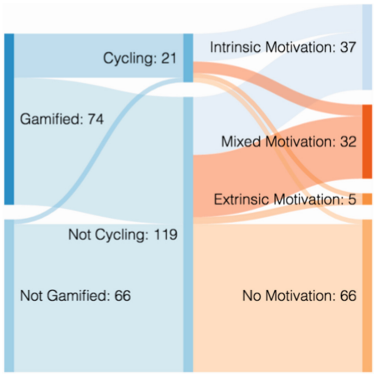


Fig. 4. Number of publications related to urban issues

The number of publications from 2014 to early 2016 has increased as can be seen in Fig. 3. But, although journal and conference papers show a constant growth, the number of book chapters decreases in 2016. Some journal papers and book chapters could under publication processes and therefore unaccessible yet. Reported methodologies were mainly literature reviews with sixty-two (62) publications (close to 45%) or experiments and tests with fifty (50) publications (close to 35%), the remainder reported either design issues (20), or surveys (7), for close to 20%.

Just thirty (30) publications (close to 20%) explicitly reported human subject participants. Most of them were experiments, tests or surveys, but also design. In these, participants played roles beyond traditional form-filling or instruction-following tasks to get involved during the design and operational phases. Participants were reported as contributing to an existing citizen science platform [21], sensor calibration [7], and platform functionality tests [13].

While surveys usually included more than two hundred and fifty (250) participants, there were three publications found with 275 [40], 394 [39] and 405 [38] participants. Far fewer participants were reported for experiments and tests. Only one operative platform reported one thousand (1.000) participants [21] while eighteen (18) publications reported from ten (10) to fifty (50). Among those numbers, it is interesting to see the job of [8], with more than three hundred and five (305) participants using a mobile social learning platform in a

primary school for testing the convenience of virtual badges to reward learning achievements; as well as by [42], with two hundred and thirty-nine (239) employees taking part in a campaign that mixed gamification, motivation and social dynamics to promote bicycle commuting. These two last publications had the highest number of participants from this review, and they provide a reference for future gamification experiments about the number of participants to be recruited.

Even though "gamification" was considered as the concept that would provide publications reporting the use of serious game elements (see Fig. 1), just half of the obtained publications (74 of 140) effectively were reporting this use, whereas the remaining publications solely contain the keyword in sections like conclusions, recommendations and related or future works. Gamification usually considers two types of motivation: intrinsic, when it comes directly from users' preferences, or extrinsic, when it comes from external valuable elements [17]. Selected publications mostly relied on intrinsic motivation and avoid the negative implications of extrinsic motivation on long-term engagement [23]. Few documents reported extrinsic motivation as the main strategy (5 of 74, close to 7%) while some others reported it mixed with intrinsic motivation (32 of 74, close to 43%).

Regarding the use of technology and research production, the review provides additional insights. A few publications (less than 10%) did not report the use of any mobile device or web tool while the huge majority used tools like these two as well as wearable accessories, augmented reality headsets or biometric sensors; this evidences the strong support of information and communication technologies to this research field. Moreover, Thirty-three (33) publications had at least one citation (23%) with a ratio of 1.24 citations per publication being obtained from dividing total citations by all reviewed publications (174/140); although the low estimated ratio, the relationship between cycling and urban transport is an important research driver [16] that would need some additional time to improve not only the number of publications but also indicators like citation indexes.

3.1 Results from Urban Cycling Publications

When focusing on the use of gamification and mobile devices for promoting urban cycling, a subset of twenty-one (21) (15% approximately) cycling related publications were selected. Although modest in number, the subset provided new insights in terms of fewer documents reporting "Literature Review", from 45% to just 10%, and more documents reporting "Experiments and Tests", from 35% to 70%. These changes show a different state of research, with a higher focus on testing gamified tools that promote urban cycling than theoretical development or literature reviews.

Publications related to urban transport, urban traffic, environmental impacts of transportation, sport performance or health had also changed when contrasted against those cycling related; from a uniform participation of each topic (close to 10%) to a bias towards topics like sport performance (rising to 60%) and

urban transport (rising to 50%) within the cycling related subset. Almost half of cycling related publications reported the use of location-based services and mobile devices, while three quarters-reported only the use of mobile devices (up to 70%).

Just three (3) cycling related publications reported use of publicly available applications, SmartMo [19], Moves [32] and SocialCyclist [37]; however, only Moves had a considerable number of users, up to one million downloads from the Google play store, while the others had less than one thousand downloads on the same store in February 2017. The use of mobile applications on cycling related publications are mainly based on prototypes that are not published on commercial platforms.

The previously identified bias towards gamification was expected on cycling related publications. Figure 4 shows that ninety percent (90%) of them reported gamification; of which those reporting intrinsic motivation were eighty percent (80%), mostly as the only kind of motivation but sometimes combined with extrinsic motivation. A small number of publications reported only the use of extrinsic motivation, a fact probably linked to the negative consequences of extrinsic motivation for behavioural change [23].

Although quantitative methods are mainly used for mobile and geospatial related research and nineteen (19) cycling related publications reported this approach (close to 90%), a remarkable number of them reported either a mixed method (5 of 19, close to 23% of the total) or a qualitative one (close to 10%). There is a lack of quantitative research about gamification and behavioural change that not only report insights from the technological perspective but also from the human and social.

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3.2 Existing Trends of Cycling Related Research

After reviewing twenty-one (21) cycling related publications, four research trends were identified: gamified platform design, experiments with gamified tools, behavioral change strategies, and data collection; they were grouped and described below.

Gamified platform design. This section groups publications reporting tests for gamified tools like the SocialCycle mobile application [27] that are designed to encourage people to either start or increase bicycle riding. It considered requirements from a cycling experience survey as well as those from a users' evaluation of existing mobile applications. It groups the user interfaces into four categories: encouraging, enabling, engaging and exemplifying cycling.

The physical activity monitoring device for aging people - PAMAP uses the concept of "ambient assisted living systems" for motivating balanced training ([7] and provides personalized feedback from sensors and GPS location. Testers have found it useful for balancing aerobic and strength workouts. The Individual Persuasive Eco-Travel Technology - IPET added a set of gamified tools based on pervasive technologies and support behavioural change. Volunteers were willing to adopt sustainable transport alternatives for large scale travels [25].

A mixed platform used virtual reality headsets for engaging users with physical activity, Occulus headsets, and Microsoft Kinect devices and provided virtual rides that increased enjoyment, connectedness and motivation of participants [18]. A virtual immersion of cyclists into bike trips successfully motivated them to work out; the bike-attached sensors controlled navigation within the virtual environment, while the exergame rewarded them based on their displacements [15]. Based on the term "Fitnessifying" in which popular video games are modified to include physical exercise setting, the static bicycle has been changed into an augmented gamepad and it provided more enjoyment to participants than the original game [20].

The immersive virtual reality (IVR) platform Rift-a-bike was successfully tested for supporting physical exercise and providing a cycling immersive game environment, as it provided multiple insights on the effectiveness for increasing physical activity using bicycles [41]. Finally, the use of two wearables: a smartwatch, and a wrist-worn accelerometer, as input devices enabled a gamified mobile application to potentially promote fitness and exercising based on the huge satisfaction and enjoyment expressed by participants [44].

Experiments with gamified tools. This section groups experiments that evaluated gamified tools with users, starting with the serious game ecosystem called "Serious Games Community Building" that promoted greener transportation using a virtual coin system, interaction through social networks as well as a rewarding system for expert-evaluated challenges. This has received positive feedback for being a reliable business model and sustainable operation [4].

A new methodology for designing user interfaces, considering not only complexity in the interaction, but also exercise intensity [14], was specially tailored after analysis of existing exergames and it allowed users to effectively choose tools that fit into their exercise times. The Pittwater Council supported a set of experiments performed by students from Macquarie University's, which used gamification and mobile devices to identify environmentally friendly routes for protected areas in North of Sydney, as well as serious games for evaluating new business ideas from students while involving experienced businessmen at a Business and Economics Faculty [24].

Behavioural change strategies. This section groups either positive or negative outcomes of gamified strategies. It starts with the evaluation of extrinsic and intrinsic motivation for shifting modal strategies towards environmentally friendly modes of transportation [10]. By using a tailored mobile application,

participants increased walking or cycling after two weeks; however, results had no statistical significance. Applying financial rewards for drivers willing to avoid traffic jams and instead use alternative transport modes during peak-hours produced negative effects such as the very low wiliness to change behaviour after the financial reward ends [9].

Qualitative analysis about negative influences of gamification found not only negative effects when competition is promoted, it can drive enthusiastic users by obsession rather than enjoyment. Moreover, clubs of cyclists expressed their concerns about the increasing use of mobile and GPS enabled technologies, mentioning associated effects on family and personal relationships of competitive cyclists. Finally, they identified common interaction patterns in commercial tracking applications that could be re-used to improve usability [2].

The Biking Tourney strategy that promoted alternative commuting within a group of workers from 14 companies during six weeks [42], created a successful experience with 15% of overall participants starting to use the bicycle for commuting as well as the 30% more occasional bike commuters. The analysis of individual and collaborative challenges to promote personal mobility changes appeared to be relevant to behavioural change support systems [34]. Although challenges themselves are game elements, challenging individual behaviour was better perceived by the subset of users willing to also use information technologies or electronic participation to tackle a challenge. An important role of gamification in policy making and smart city planning was found; although its use is not commonly considered by policy makers, positive effects of including gamified tools in citizen engagement, co-design and participatory decision-making processes were reported [30].

Data collection. This section groups initiatives for collecting data using game elements. They consider the lack of urban cycling datasets, as well as the need of updated and highly-detailed travel behaviour data, in order to increase better research development and decision making. Tools for collecting short, long or multimodal trip paths, as well as those made by alternative modes (i.e. Intermodal walking/cycling, car- and ridesharing, electric cars, etc.) could integrate gamified tools [5]. The SmartMo application could provide information about demand size, citizen needs, attitudes and perceptions towards alternative transport, including measurements of pro-environmental travel behaviour [6]. Finally, analysis of sampling processes for transport related surveys lists other relevant challenges of GPS-based surveys as well as privacy issues linked to them [1].

4 Discussion

Although the review provides a relevant group of publications using the serious games approach for promoting cycling, there are various gaps in this research field. This section discusses how the reviewed publications are helping on either identifying or overcoming the frictions that prevent citizens from bike commuting [29], the tools that better support such strategies, and the existing opportunities

for creating not only novel serious games, but also providing better feedback for both urban cyclists and cities.

4.1 The Serious Game Approach

With just six out of twenty-one (6 of 21) cycling related publications reporting successful behavioural changes towards urban cycling, the use of information and communication tools on serious games is still under development. Although the use of indicators such as distance, speed, saved time, burn calories and non-emitted CO_2 are commonly used incentives in reviewed publications; they are usually considered abstract and not always relevant to urban commuters, consequently, new designs should provide more relevant measurements of comfort, safety, effort, and environmental conditions that are more relevant for urban bike commuters [16].

On the one hand, existing sport tracking applications rely on motivation coming from competition between users, usually trying to make them to bike more or faster [2,14]. Game designers must be aware of negative effects of gamification, such as excessive competition or obsession, described by [2]. Moreover, they should include virtual and personal interaction between cyclists and other urban actors to produce long term engagement with sustainable commuting [22].

On the other hand, reviewed publications explore a wider range of purposes, from promoting healthier habits to the optimization of data collection processes. Game narratives can be improved by using pertinent stories for each of the identified purposes, therefore game designers could create new stories that motivate players beyond the marketing strategies that tend to be used by commercial sport tracking applications; they could now gather citizens' participation or help to connect cyclists and expanding their social communities, this novel approaches will demand lots of innovation from designers [4,24].

The incentive behind urban cycling is not always individual, it can also come from the sense of belonging to a community, group achievements or shared benefits [9,42]. Some communities like workers, students, artists, etc. can be motivated with new gamified tools that rely on positive feelings of playfulness, fun, freedom, flexibility, well-being, social and human interaction associated to cycling [9]. This novel approach would provide benefits for citizen participation, civic engagement, social interaction and sense of place, all of them linked to the research agenda of open smart cities [12].

4.2 Technology and Analysis

Surveys are the preferred data collection tool for transport analysis based on trip origin and destination; however, smart mobility is more complex and demands higher detail. Although adding location to a survey with a GPS reference is considered a huge improvement [5], location based services can provide very high detail about cyclist behaviour like the final destination or integration with different modes of transportation [36]. Virtual maps and shortest path estimations are widely provided by mobile phones but they are far from describing

cycling dynamics; geospatial analysis could be used for better describing smart mobility by identifying preferred streets for cycling (i.e. Strava Density map) [3], and cities are asking for those products that better support policy making [35]. Cycling infrastructure is currently integrating public bike sharing platforms, checkpoints, dedicated spaces as well as physical barriers that not only influence cycling dynamics but also provide new datasets [11].

The combination of location technologies like GPS, internet connected cycling infrastructure, sport tracking platforms as well as high capacity computing platform for geospatial analysis offers an attractive environment for research [28], not only for geographic information scientists looking to understand cycling patterns [11], but also for game designers willing to motivate and engage citizens with smart mobility, provide relevant feedback and promote greener ways of commute. This could make up for a combined research field that is not clearly envisioned by reviewed publications.

The global trend of designing open smart cities focuses on citizen participation trough information technology [12] and smart mobility that demands active participation of citizens and games enabling social interaction [9]. The way cities involve citizens on improving urban transport systems will demand civic engagement, then the use of game elements looks appropriated to produce such engagement since they can be personalized to fit into the different levels of complexity demanded [3].

Future research on game design and gamification should consider new strategies that take advantage of geospatial technologies. New narratives should then involve outputs of the multiple sensors deployed by the city, the interaction between players in real-time as well as the use of wearable and virtual reality devices. These products could be part of city planning processes that better engage citizens with public participation and smart mobility.

5 Conclusions

The review investigated the relevant research topic of smart mobility and the role of mobile games and geospatial technologies on promoting urban cycling promotion. The one hundred and forty reviewed publications showed the diversity of authors, topics, approaches, methods, and outcomes. Although there is a balance between the experiments and literature reviews of the selected documents, the review identified biases towards experiments using mobile devices and location-based services on cycling related publications, unfortunately, most the experiment tailored tools are not publicly available except from three publications.

Cycling related research focused on using intrinsic motivation for gamification, moreover, extrinsic motivation should not be considered for promoting urban cycling since its results strongly depends on the external reward. Gamification seems to be useful for encouraging behavioural change towards urban cycling; however, in urban contexts cyclists are less willing to compete but to participate or interact. Game designers should create narratives that link the

sense of belonging to a community, the participation on policy making or the desire of having better cities, and motivation should be linked to the feelings of playfulness, fun, comfort, well-being, freedom, social and human interaction associated with cycling.

Just one commercial platform was reported by a cycling related publication. Since the lack of public research outcomes from commercial applications does not prevent cities from establishing partnerships or joint research efforts (i.e. Waze helping cities with traffic management), it could potentially support urban planning and decision making while improving traditional techniques of data collection based on crowdsourcing and location-based services that would increase not only quality but also the precision of urban datasets.

Finally, the review identified tendencies of urban cycling promotion as well as the lack of conceptual reviews about game design and gamification techniques applied to this promotion. Based on the strong relationship between cycling and mobile devices a higher level of scientific publication was expected.

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