Gamification in Smart and Sustainable Mobility - A Review and Roadmap

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Abstract. *Gamification represents the introduction of computer game related concepts into other, not game related processes in order to foster motivation of participants. There have been numerous studies which have shown that gamification can and should be applied to various aspects of mobility and have provided promising results in encouraging smart and sustainable forms of transportation. Herein, we provide an overview of these studies. Nevertheless, only particular aspects of gamification have been applied so far and there are still many more methods that gamification has to offer. Thus, we provide a roadmap of possible application areas in future developments.*

Keywords. gamification, sustainable mobility, smart mobility, smart city

Sustainable mobility is one of the key aspects of smart cities, sustainable development, and sustainable living (Lombardi and Giordano, 2015; Salat et al., 2011). Moreover, developing a society that is engaged and invested in sustainable development, a part of which is sustainable mobility, is a process that requires willingness, commitment, and investment from all the stakeholders. The most numerous out of those are citizens, i.e. the general public. In order to change the developed behaviour patterns of the general public, the change must be motivated, either by the demand, the supply, or by some other factor.

Sustainable mobility options have existed for decades (e.g. bicycles), and some of the historically big pollutants are being developed into sustainable units (e.g. electric vehicles). The comfort and convenience of using personal vehicles is one of the significant obstacles to the public shift to some more sustainable and environment-friendly means of transportation, especially in large cities. Therefore, many attempts have been undertaken in order to incentivise and motivate the shift of the public behaviour patterns in favour of sustainable mobility options.

Gamification (Deterding et al., 2011) is a wonderful approach to encouraging engagement, motivation, and feeling of success of participants in various types of activities. Although the set of game-inspired methods is rich and varied, the existing and past gamified approaches to encouraging smart and sustainable forms of transportation use only a small subset of those. Further planning and research is needed, in order to identify the most useful gamification methods in the domain of forming and altering public opinion. Apart from the latter, gamification can be used in many more scenarios in the context of smart and sustainable mobility, as is presented in the following sections.

This paper is structured as follows. Section 2 is gives a short definition and introduction to gamification. Section 3 provides a review of a select set of examples and research on various implementation of gamification in the context of smart and sustainable mobility. Section 4 consists of a short discussion related to the contents of Section 3, followed by Section 5: a roadmap of possible application areas of gamification on sustainable mobility.

1 Gamification

Gamification can, in general terms, be described as a process of applying game-bound elements, design techniques and mechanics to non-game context (Deterding et al., 2011; Kalmpourtzis, 2018; Matallaoui et al., 2017). One of the more prominent goals of using gamification, i.e. gamifying a certain non-game context, is motivating users to "achieve certain behavioural or psychological outcomes." (Matallaoui et al., 2017) There is a multitude of domains whereupon gamification is applicable, including, but not limited to, education, sport, medicine, etc.

Although the first documented use of the concept of gamification is observed in 2008 (Deterding et al., 2011), or possibly as early as 2002, the idea of applying game-related concepts to non-game context has evolved various forms, spanning from simple implementation of leader boards to advanced role-playing and serious games. Yet, even though the science of gamification sparked interest in both academia and industry, it is still in early stages of development and research in many of its application domains (Schatten et

al., 2021; Smith et al., 2021).

Game mechanisms used most often in gamifying a select process or experience include score boards, badges, various kinds of points, levels, progress bars, virtual currency, and player avatars (Dicheva et al., 2015; Smith et al., 2021). Most of these concepts can be grouped together and classified as reward mechanisms, but the others are vital for the full gamified experience as well. Additionally, three categories of game elements were identified in (Werbach and Hunter, 2012) as relevant to gamification: dynamics, mechanics, and components, wherein the category of dynamics comprises the most abstract game elements, while the category of components encompasses the most specific elements that are visible to the users. The main goal of gamification through such game mechanics and related concepts is increased user engagement, higher user motivation, and increased interaction frequency with the gamified experience.

Even though gamification is concentrated on using game elements in application domains which lack game elements by default, the recurring result is a designed game-like context that utilises select ideas from both the game and the non-game domains. In other words, it is often found that domain-specific games are being developed in order to foster how game elements are used towards achieving a certain goal, e.g. a location-based game is developed in order to motivate people to move more. Therefore, a set of categories of games emerges, based on their set of functions and expected types of application, although most of these depend on mobile devices. The most interesting of those, considering the scope of this paper, and the contents of Section 3, are location-based mobile games (Frith, 2013), and activity-based mobile games (such as fitness and step-tracking applications).

2 Literature Review

The following is an overview of use cases and application domains of gamification in the context of mobility, encompassing personal transportation, public transportation, and mobility as a concept describing how people behave while moving through the physical space. The second part of this section gives an overview of use of gamification in the domain of personal vehicles and related contexts.

2.1 Gamification and Mobility

Considering the popularity of wearable devices, such as smart bands and smart watches, one of the most used ways, and arguably the easiest, of introducing gamification to the general audience in the domain of mobility, according to the amount of published research, are fitness applications and step trackers, i.e. applications that count the number of steps performed in a calendar day (Bucher et al., 2016; S. R. Greysen et al., 2021;

Nakashima et al., 2017). Such applications feature, in the very least, various kinds of reward mechanisms, for example:

- leader boards that include users on a local, national and regional level,

- badges that users are awarded with for achieving specific challenges, such as a predefined number of steps, consecutive days of satisfying activity, or other specific achievements,

- scores based on the steps walked within a day, possibly enriched with other physical activities.

Two studies are selected to be presented here in favour of the above application domain of gamification in the context of mobility. The first (Nakashima et al., 2017) is a smartphone application designed to foster and promote Mobility Management, a set of policies and strategies with the goal of promoting a modal shift towards the more sustainable means of transportation. The developed application motivated users to walk more, counted their steps and spent calories, and even featured images for each of the specific four categories of number of steps, so as to encourage its users to walk. In the end, the conducted survey showed that there are, on average, no benefits of using the developed application, or the methods contained within. However, a statistically significant increase in the number of steps was identified in users who had a below-average step count before using the application.

A similar result was presented by (S. R. Greysen et al., 2021). The system presented in this paper was developed with the intention of increasing mobility after hospital discharge, i.e. it counted the number of steps performed by former patients. One of the elements to foster motivation here is social engagement, i.e. the developed system is connected to social media, and a specific close contact was selected for each user – this close contact was to be used as a personal motivator for each user. Furthermore, the system allowed for interaction with the user's social circle using interfaces towards various social network application. The results of this research are similar to the one described above – users who used the system, along with its full gamified capabilities, have not performed better, i.e. made more steps within a calendar day, than the users in the control group. However, the difference was statistically significant when a subset of participants was observed – in particular those with higher levels of social engagement prior to participating in the study.

An interesting use case of gamification in public transportation domain presents itself in the context of motivating users to use the available means of transportation in specific periods in time (Cardoso et al., 2019). An example of the former is promoting use of public transportation out of rush hour by providing greater rewards when users use the available public infrastructure in the goal time slots, or providing incen-

tive to users who use a city-wide bicycle network instead of driving to work in the morning or using other means of public transportation if they live within a certain distance of their work destination.

Mobility, i.e. moving in traffic, can itself be observed as a game, although such a game might be described as serious and pervasive, meaning that it is not created with the goal of having fun, and it expands out of the social, temporal, and physical boundaries of regular games (McCall et al., 2013; Montola, 2005). One such system described in the paper from 2013 featured instant rewards, status rewards, and basic collaboration and competition mechanisms, such as grouping and inter-group competing. The results of the research presented in (McCall et al., 2013) indicate that the monetary value of incentive that can induce change in behaviour can be relatively small. Another approach is identified by Frith in the location-based social network application Foursquare (Frith, 2013). Frith argues that "[...] earning the badge is often enough reward in itself to encourage behaviors." Furthermore, a gamified approach that overlays virtual context over the real world, such as is provided by Foursquare, is argued to be influential in building a person's image, affect consumption, and alter the way game participants observed and experienced their non-virtual surroundings.

Providing users of gamified applications with incentive to change their mobility behaviour and sway it in the more sustainable, or *green* as it is often called, direction is a recurring topic in research on gamification and its application in the domain of mobility, e.g. (Broll et al., 2012; Cellina et al., 2019; Di Dio et al., 2019; Ferron et al., 2019; Froehlich et al., 2009; Kazhamiakin, Loria, et al., 2021; Khoshkangini et al., 2021; Lee et al., 2013; Marconi et al., 2018; Zinke-Wehlmann and Friedrich, 2019). This observation grows in importance when put into the context of smart cities, since sustainable urban mobility is one of the key issues for sustainability (Lombardi and Giordano, 2015; Salat et al., 2011). One solution towards sustainable urban mobility is the gamification framework presented in (Kazhamiakin, Marconi, et al., 2015), which explores gamification mechanisms that can be utilised in incentivising change of commuters' behaviour in the direction of sustainable mobility solutions. This gamification framework is further developed into a gamification platform described in (Kazhamiakin, Loria, et al., 2021), wherein the authors identified three application scenarios of sustainable mobility: home–school, commuting, and large-scale mobility, i.e. regular citizens' use of public transportation and their movement throughout the city. A similar approach, in the context of motivating users to utilise sustainable mobility solutions, is presented in (Zinke-Wehlmann and Friedrich, 2019). Another example is presented in (Di Dio et al., 2019) as a mobile activity-based game that engages three stakeholders in the domain of building and encouraging sustainable mobility: citizens, local businesses, and public authorities. A successful approach to motivating player behaviour through challenges is presented in (Khoshkangini et al., 2021), where authors describe a devised solution for automatically generating personalised challenges for individual players, based on their preferences, history, and past performance. Users who participated in using Play&Go game described in (Ferron et al., 2019), a "long-running open-field urban mobility game promoting voluntary travel behaviour change," demonstrated perceived change of behaviour in favour of more sustainable mobility patterns.

2.2 Gamification and Personal Vehicles

In the automotive domain, gamification approaches are found to be applied within at least six use cases - eco-driving ((Günther et al., 2020; Helvaci et al., 2018; Inbar et al., 2011; Magaña and Organero, 2014)), driving safety ((Helvaci et al., 2018; Shi et al., 2012; Steinberger et al., 2015; Wang et al., 2014)), marketing (Tillström, 2012), vehicle user interfaces training (Diewald et al., 2015), increasing social awareness (Wang et al., 2014), and increasing trust in autonomous driving (Häuslschmid et al., 2017). Eco-driving and driving safety scenarios could be integrated in the vehicles' infotainment systems, and as such could award points and badges for safe and ecological driving (Diewald et al., 2015).

Reducing average energy consumption and enhancing the driving range of battery electric vehicles (BEV) is discussed in (Günther et al., 2020). Authors included the influence of a gamification approach as one of the three persuasive strategies on the average BEV energy consumption used over 22 months on 108 participants on the field study in Germany. The results showed that the use of game design elements and financial rewards "significantly reduced energy consumption as compared to baseline or mere feedback regarding energy consumption".

A system that tries to identify driving style mistakes and rate the driving with a score is presented in (Helvaci et al., 2018). There are three components to the system, namely data capture from the vehicle CAN bus, mistake identification with multiple criteria, and score presentation in real time. With the usage of gaming elements such as achievements and leader boards, the driver is motivated to sustain a positive score while driving.

Similarly, (Magaña and Organero, 2014) analyses and validates the impact of using gamification techniques for improving eco-driving learning. Authors use game mechanisms such as the score and achievements systems to motivate driver for an efficient driving. The system warns the driver each time it detects "an inefficient action of the driver to a previously known situation such as a bad reaction to a detected traffic sign or a detected traffic accident". Authors have validated

their proposal on 14 different drivers on more than 300 rides with 5 different models of vehicles on 4 different regions of Spain and showed "a positive correlation in the use of gamification techniques and the application of the proposed of eco-driving tips, especially for aggressive drivers". What is interesting, the implemented techniques showed potential to prevent drivers from regressing to their previous driving habits. They used OBD2 diagnostic port in order to obtain the vehicle telemetry and the knowledge base containing rules on the driving efficiency.

Some cars are suffering from user experience problems. In a slightly different usage scenario, a paper is tackling gamification application on exploration and practicing on user interfaces and vehicle functions (Diewald et al., 2015). If a driver is using the car with interfaces and functions that are unfamiliar to her, it could quickly became a challenge to navigate through those interfaces as well as become a safety concern. Authors have thus created "a gamified automotive exploration and practicing framework" which would allow exploring vehicle functions and user interfaces as found in the real vehicles - the framework consists of a mobile application that "recreates the vehicle cockpit for allowing offline exploration and training, and an in-vehicle application that replaces the owner's manual and provides hints and tips for the driver".

Increasing trust in autonomous driving was tackled by (Häuslschmid et al., 2017). Authors have developed 3 different visualizations for a user study, which were overlaid to a driving scene - a chauffeur avatar, a world in miniature, and a display of the car's indicators as the baseline. Authors argued that trust "can be increased by means of a driver interface that visualizes the car's interpretation of the current situation and its corresponding actions." The results of the study showed that the world in miniature visualization increased trust the most, but they did not find a significant difference between the chauffeur and the baseline - although there might be a potential in this context.

Authors in (Steinberger et al., 2015) propose a combination of video game design theory and road safety psychology in order to engage safer driving, with 3D AR objects displayed on the windshield of the car.

Expressing the appreciation for other drivers' polite driving behavior is described in the concept presented in (Wang et al., 2014). Social awareness is the foundation for improving the driving behaviour - there is a possibility in this context to give a positive feedback about the driving behavior of other drivers. In a way, a driver thus collects "positive points" which encourages her for improving her driving behaviours.

3 Discussion

The introductory use case example in the last section is about fitness and step trackers. Even though the idea of gamification applied to the most basic mode of transportation and the most basic form of mobility of people seems like an interesting and possibly highly successful idea, the results vary depending on a number of other factors. Based on the research described in the previous section (Cardoso et al., 2019; S. R. Greysen et al., 2021), gamification alone is not enough to motivate people to move more, on average. Specific groups benefit from the added motivation and engagement mechanism they are exposed to and interact with, but the success of those mechanisms depends on the type of person, in either the physical, mental, or social context. The set of recommendations presented in (Cellina et al., 2019) aims at improving the effectiveness of persuasive applications by providing the necessary information just in time, providing goal setting opportunities, social engagement of players, and improved basic gamification concepts, e.g. feedback, and rewards.

The most prominent goal of using gamification in the domain of public transportation is geared towards promoting sustainable transportation options and available public transportation segments that are aligned with sustainability goals. The results, as shown in the previous section, are no all positive, although a positive trend can be observed, i.e. applied gamification methods have a positive impact on changing the public's behaviour towards sustainable. In the context of automotive industry, the list of domains of applied gamification methods features use cases from a broader set of domains. This discrepancy might be argued to have its source in relatively larger population that can take part in using the applications open to use to the whole population, regardless of their means of transportation, as opposed to the automotive industry being focused on the people who can drive.

Although the set of gamification methods is a rich one, the examples described in the previous section usually work with a limited subset of these methods. The most used methods are scoring, leaderboards, and badges. A small number of papers expanded the set of methods to interaction with other players, and cooperation or collaboration within groups of players, or between such groups. Some of the examples utilise the concept of quests, social interaction, and tournaments on various levels, with the goal of directing player behaviour. Some of the examples take a more graphic approach, and use the powers of narrative or graphical immersion, in order to convey the intended message. It should be noted here that it was decided that the previous section would not include applications that are not directly related to mobility, i.e. they might have change in mobility behaviour as a side-product, such as the mobile game PokemonGO (Althoff et al., 2016).

4 Roadmap

By analyzing existing body of research, as discussed in more detail within Literature Review section, we

have identified six application domains for gamification in automotive context: eco-driving, driving safety, marketing, vehicle user interfaces training, increasing social awareness, and increasing trust in autonomous driving. As we have not considered gamification in marketing as a critical use-case that can substantially contribute to the field of smart and sustainable mobility, we exclude it from our proposed roadmap.

Application domains from other smart mobility contexts include increasing overall health, promoting sustainable means of transportation, and targeting non-rush hours as means of a transport time optimization. Putting it all together, we propose a roadmap with hierarchically positioned elements for the further development of the field, with driving safety being the most critical application domain in this context.

Mastering the vehicle user interfaces can contribute to the overall driving safety, as the driver can focus on the driving activity without much interruptions from searching needed functions.

As the driving safety increases, gamification could help drivers with the social awareness and more respectful driving, showing appreciation and understanding for other fellow drivers.

On the other hand, gamification should promote more sustainable means of transportation - cycling, walking, public transportation, which leads to the research concerned with increasing the overall health of the individual, but also potentially, the health of the planet.

Gamification methods could reward individuals for taking the non-rush hours, contributing to the more effective use of smart and sustainable transportation, but also in some aspects to the driving safety.

As we can expect autonomous driving to become a reliable method of transportation in the near future, motivating people to use it will become a challenge – and gamification could tackle this issue.

Speaking of specific gamification methods that we think might be useful in the future of applying gamification to smart mobility, especially in the context of promoting sustainable mobility, the following should be noted:

- **Rewarding mechanisms** in cooperation with local businesses, wherein users might be able to be awarded certain real-world awards sourced in the local business community, especially by the local handicraft shops or various craftsmen, based on their achievements in the virtual world (solving quests, performing specific kinds of behaviour, and similar), measured through a developed mobility application.

- **Local currency** might be used a means of trading between the users who accrue currency by being active in the real world (quests, and achievements), thus creating another bond between the real world and its digital twin (albeit created on a highly abstract level).

- **Titles and appearance** are already shown to be useful and successful in motivating users (who might be called players at this level) to perform specific tasks within a game. In the domain of this paper, the titles feature should be expanded, when compared to that of Foursquare's (described in (Frith, 2013)), for example by awarding titles based on a local (neighbourhood) level, city or municipality level, etc. Some other key title elements might be found in awarding various titles based on players' achievements, recognised types of behaviour, most used means of mobility, etc. In addition to titles, another effective way of motivating users to take part in the activities provided by the game, i.e. the application promoting either sustainable mobility, driving safety, or eco-driving, are visual avatars – user's representation in the game world. This avatar might be completely virtual, or it might be based on the player's real-world experience. The beauty of this approach is that the avatars can be designed in a way that they can be customised, e.g. based on the achievements of their players, their performance, or successfully completed challenges. This way, players can clearly and easily showcase their success visually, which is one of the most popular forms of achieving prestige in massively multiplayer online games in general.

5 Conclusion

There are many application domains of gamification in the context of mobility, especially smart and sustainable mobility, even though the domain of gamification can still be considered as rather new. The currently available applications, or use cases that are available in the real world, use a set of gamification methods that encompasses the most-used methods, and this paper provides an opinion, and a suggestion, on the gamification methods that might be useful in further motivating users of mobility applications, towards achieving the application developers' planned goals.

It has been shown in a substantial body of research that gamification in general can be used to enhance motivation and incentivise a specific kind of behaviour of players. Applications in the domain of promoting e.g. sustainable mobility, driving safety, eco-driving, etc. are shown to benefit from use of gamification methods as well, even though the benefits are not always visible immediately. Naturally, in order to perceive the change in mobility, a specific amount of time must pass, and the change visible in an application alone is not enough.

Although gamification methods have varying effects on the ultimate player motivation and their engagement, their careful combination is what an application or a game benefits from, especially when combined with cultural, behavioural, and social features of its users. Thus, sustainable mobility, and the other domains mentioned in this paper, is a domain worth ex-
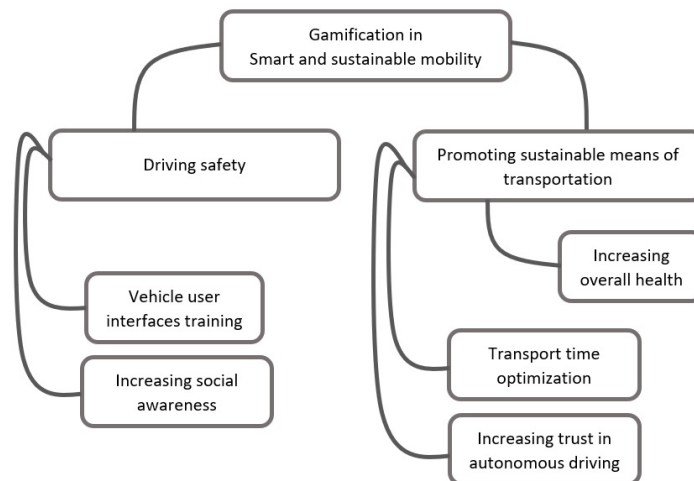
Figure 1: A proposed roadmap for gamification in smart and sustainable mobility (Helvaci et al., 2018)

ploring and enhancing with further and more rich and engaging gamification methods.

Acknowledgement

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