

REVIEW

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Initiatives and challenges in using gamification in transportation: a systematic mapping

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Abstract

Summary: Gamification is a new theme that has been applied in different fields and has contributed to different types of behavioural change. This paper aims to describe how gamification is adopted in the context of transportation.

Methods: We performed a systematic mapping of the scientific literature of Web of Science and retrieved 211 studies. After the inclusion and exclusion criteria were applied, 66 studies were selected. After the full texts were read, 30 studies remained to be analysed.

Findings: The results show that the most commonly used gamification elements are goals/challenges and points. Gamification provides support for outcomes such as changing travel behaviour, improving driving behaviour and encouraging bicycle commuting. The use of gamification has changed the behavior of travelers, promoted sustainable travel modes, encouraged safe driving, reduced carbon dioxide emissions and reduced energy consumption. Although gamification has achieved many positive results related to transportation, there are still many difficulties and challenges.

Keywords: Gamification, Transportation, Systematic mapping

1 Introduction

The rapid development of urbanization has led to the rapid growth of urban populations and vehicles and led to new requirements for urban development. Therefore, the burden on the transportation infrastructure is increasing, and traffic congestion and traffic safety have become major threats to urban development. Cities waste considerable time and productivity on transportation, resulting in air pollution and energy waste. Promoting more sustainable travel patterns and habits is an increasingly important global goal. Today, people have gradually come to agree that these problems can be solved, or at least alleviated, by new technologies [80]. A major challenge

is how to use advanced technology to promote positive change in individual and collective behaviour. Promoting voluntary travel behavioural change is regarded as a key issue of sustainable urban transportation [4].

In recent years, gamification has been considered one of the most popular persuasive technologies. It has become a phenomenon and appears increasingly in people's daily lives. In several different definitions provided in the literature, we recognize that gamification refers to the use of game design elements in a nongame environment to support the creation of users' overall value through game-related enhancement services [33, 39]. Gamification uses game elements and mechanisms to combine functionality and participation [45], improve usability [13], interest and satisfaction [57], create a more pleasant experience [27] and promote behaviour change [4]. It has been applied in transportation.

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The key to understanding gamification is to understand the difference between gamification and serious games. Gamification means applying game elements to different types of systems and services [47]. The purpose is to provide an experience similar to game creation, but it is not a game in essence but a design method. The experience of game creation includes a sense of enjoyment, flow, autonomy, achievement and so on. Serious games refer to games designed for main purposes other than pure entertainment [7]. They are essentially games.

Although the first documented use of gamification was in 2008, gamification did not become popular in different industries until early 2011 [39]. Gamification was first applied as a digital marketing strategy to enhance customer participation [33]. Because it can effectively stimulate specific behaviours and result in happiness, gamification has begun to be applied in other fields, such as education [11, 12, 22, 24, 27, 57], health care [18, 30, 36, 62, 79], organizational effectiveness [46, 66], software development [56], software design [55, 68], e-commerce [5, 9, 53] and marketing [58, 76].

Gamification has also been explored in the field of transportation. In particular, it seems promising in promoting sustainable travel behaviour. According to Tsirimpa et al. [78], in addition to promoting enthusiasm and participation in activities among travellers, gamification encourages them to make more use of public transportation, bicycles or walking, which not only reduces carbon dioxide emissions and energy consumption but also reduces dependence on cars and the use of cars. Steinberger et al. [72] indicates that gamification promotes driving more ecologically and safely, improves drivers' attention and arousal during the journey, and reduces boredom while driving.

In the field of transportation, researchers and travellers have become aware of potential benefits of gamification. Gamification can reward travellers if they change all aspects of an activity and complete each target task. Gamification not only represents a way to reward sustainable behaviour but also makes travel more interesting [4].

To the best of our knowledge, this is the first up-to-date and comprehensive overview of the use of gamification in transportation. It systematically maps relevant publications scattered across various conferences and journals and provides readers with a clear picture of how gamification is applied in transportation. The increasing number of publications on this topic may indicate that the field is aware of the novelty and contribution of gamification to creating change through persuasive behaviour. More specifically, this paper proposes and discusses the following:

- Gamification mapping in the context of transportation;
- Which gamification elements are used and in which research topics are used;
- The benefits of gamification;
- What research methods have been used thus far; and
- Difficulties and challenges in the implementation of gamification in the field of transportation.

The rest of this paper is structured as follows: Sect. 2 describes the related work, and Sect. 3 describes the planning of the systematic mapping. Section 4 reports the results of systematic literature mapping, focusing on gamification elements, gamification-supported topics, realized benefits, research methods used, and difficulties and challenges in implementing gamification. The results are discussed in Sect. 5. Finally, conclusions and future research directions are discussed in Sect. 6.

2 Related work

At the beginning of this study, no relevant work (systematic mapping, literature review) was found that discussed the application of gamification in the field of transportation. However, the existing secondary research can be summarized.

Previous research reviews on gamification, such as [40, 45, 69], have summarized the positive findings on the effectiveness of gamification. Baptista and Oliveira [7] conducted a meta-analysis of gamification and serious games. Klock et al. [44] reviewed the research on customized gamification.

Reviews of studies on gamification in business also exist; for example, Larson [47] conducted a literature review on serious games and gamification in an enterprise training environment. Wanick and Bui [81] conducted a systematic literature review on gamification in management. Hassan and Hamari [34] used a systematic literature review to summarize the research and findings on gamified e-participation.

The application of gamification in education has also been studied; for example, Lopez-Belmonte et al. [48] conducted a literature review on gamification in education.

Other works have focused on gamification in the field of software engineering, such as Alhammad and Moreno [2]'s literature review on gamification of process improvement in software development. Khakpour and Colomo-Palacios [41] conducted a systematic literature review on the integration of gamification and machine learning. Dalponte Ayastuy et al. [23] conducted a systematic literature review on adaptive gamification in cooperative systems.

Finally, we found three reviews in the field of transportation, but none of them focused on the overall field. For example, Warmelink et al. [82] conducted a literature review on production and logistics gamification. Pajarito and Gould [63] conducted a literature review on promoting urban cycling through mobile devices and gamification and found that gamification seemed very useful in encouraging behavioural change and cycling in the city. Andersson et al. [4] reviewed the literature on smartphone applications promoting sustainable travel behaviour.

Although the contributions of all these studies, we found the field of gamification in transportation to be incipient, and so a review study is still unavailable.

3 Mapping process

This paper follows the systematic mapping approach proposed by Petersen et al. [65]. System mapping is secondary research that can classify and analyse early research and help to identify research opportunities (outline the research field and construct a research field). It has something in common with a literature review of the more widely used secondary research system (for example, in terms of search and research selection), but they are different in terms of objectives and data analysis methods. Systematic literature reviews collect and evaluate all research results of selected research topics (comprehensive evidence). The search terms of system mapping are more general because they are used to classify and construct the research field, and the purpose of the system literature review is to summarize and evaluate the research results. Kitchenham and Brereton [43] also discussed these applications and pointed out that if there is only a small literature review on the selected topic, system mapping may be particularly applicable, and a comprehensive understanding of the field is needed.

Systematic mapping classifies and structures the areas of interest in research by classifying publications and analysing their publishing trends. In addition, system mapping can also analyse what research has been carried out in this field, as well as research methods and results. This method summarizes the scientific achievements in the research field and helps to identify research opportunities. It includes the following activities: research problem definition, searching for related papers, screening papers, extracting data and mapping the results. Each of these activities is described in order.

3.1 Research questions

The main purpose of this article is to understand the latest view of gamification in the field of transportation. We aim to outline where and how gamification elements have been used in the field of transportation. This overview

includes the main gamification elements that are used, in which research topic they are used, how to change traffic behavior to achieve sustainability by using them, what research methods are used, and the difficulties and challenges in implementing gamification.

This study has two objectives. First, we determine which gamification elements are used and why. Second, we determine which traffic research topics use gamification and how to change traffic behavior to achieve sustainability by using them. To better guide the research, the main objectives are mapped to specific research issues as follows:

RQ1. What gamification elements are used in the field of transportation?

RQ2. Which research topics of transportation adopt gamification?

RQ3. How does gamification change traffic behavior to achieve sustainability?

RQ4. What research methods are used?

RQ5. What are the difficulties and challenges in deploying gamification in transportation?

3.2 Data sources and search strategy

The literature search was carried out in the Web of Science (WOS) database. This database was selected because it is one of the most important sources of global academic information. It contains more than 18,000 of the most authoritative and influential academic journals in the world and contains many kinds of database resources. For the sake of rigor and clarity, it is better to search as few comprehensive databases as possible rather than searching in multiple databases [64]. In addition, compared with other databases, experts in this kind of analysis choose to analyse this database to present a greater amount of literature [61, 71, 74]. In addition, the database contains a large number of studies related to social sciences, i.e., knowledge fields related to gamification and transportation [21, 48].

When searching, we did narrow the time range of the search results because research on the use of gamification in the field of transportation began only recently, and any such restrictions might have resulted in overlooking relevant content. To construct the search string, we selected the main terms and synonyms found in previous known studies. After some preliminary tests, we decided to supplement the string with additional synonyms to make it as comprehensive as possible, as shown in Table 1. The search for literature in the WOS database was conducted using the search query: TITLE-ABS-KEY [(gamification OR gamifying OR gamify OR gamified OR funware OR “serious games”) AND (transportation OR traffic OR transit OR transport OR “urban mobility” OR “mobility behavior” OR “smart city” OR “urban accessibility”)].

Table 1 Search terms

Major terms	Alternative or synonyms terms
Transportation	Traffic, transit, transport, urban mobility, mobility behavior, smart city, urban accessibility
Gamification	Gamifying, gamify, gamified, funware, serious games

This study excluded papers, programs, and book chapters that developed gamification in areas other than transportation or applied games to solving computing problems as well as those in the form of abstract only or a presentation. Table 2 summarizes the inclusion and exclusion criteria.

Table 3 summarizes the selection strategy and the following steps:

- (I) Apply the query string to the data source search engine.
- (II) Export the query results with the title, abstract and author of each paper to a CSV file.
- (III) Filter duplicate entries.
- (IV) Apply inclusion/exclusion criteria to abstracts and keywords.
- (V) Read the full text of each paper to review and classify the main articles.

3.3 Data extraction

To answer the research questions listed in Sect. 3.1, we established six data extraction steps and classification schemes:

- (I) Research metadata: We compiled the year of publication, publication venue, publication type, and country of author affiliation.

Table 2 Inclusion/exclusion criteria

Inclusion	Papers that fulfill the search string Academic journal, conference, workshop papers, and book chapters Discipline: Transportation Abstract and keywords are available
Exclusion criteria for titles and abstract	Study written in a language other than English Study that is not identified as peer-reviewed
Exclusion criteria for full text	Publications without abstract Study related to gamification topic but not to transportation Study related to transportation but not to gamification concepts Full text of the study is not available in the respected source

Table 3 Summary of selection strategy

	Selection strategy
Datasources	Web of Science (core collection)
Target items	Journal paper, Conference papers, Workshop papers, and Book chapters
Language	Papers written in English
Data fields	Title, Abstract, Keywords
Publication Period	Since 1900–2021

- (II) Analysis of gamification elements used (RQ1): The classification of gamification elements adopts the compilation standard of Dicheva et al. [26]. Gamification elements are composed of two levels, the game mechanism and the gamification design principle, which are described in detail in Table 4.
- (III) Determine the research topic in the field of transportation with Gamification (RQ2): We analysed and studied different research topics in the field of transportation supported by gamification.
- (IV) Analyze how gamification can achieve sustainability by changing traffic behavior (RQ3): We analyze the research according to the direct and indirect behavior changes obtained by Gamification.
- (V) Determination of research method (RQ4): For the types of studies, according to the classification criteria proposed by Wieringa et al. [83]. According to Wieringa et al. [83]'s suggestion, the research methods can be divided into three categories: case studies, experiments and investigations.
- (VI) Determine the difficulties and challenges in the implementation of gamification (RQ5): analyse the difficulties and challenges in implementing gamification in transportation.

3.4 Search process

The literature search was conducted in April 2021. The search engine investigated was WOS. The search included the title, abstract and keywords of the research.

There were four main steps in the retrieval process, as shown in Fig. 1. In the first step, the search was applied to the database, and a total of 211 articles were retrieved. The second step was to delete the duplicate papers. The third step was to apply inclusion and exclusion criteria. We then read the title, keyword and abstract of each article and discarded game-related search results in other fields. In addition, due to the improper use of different terms, we discarded papers that had been incorrectly included, resulting in 66 papers. Finally, through full-text reading, we

Table 4 Game mechanics and gamification design principles

Game mechanics	Points, badges, levels, progress bars, leaderboards, rewards and avatars
Gamification design principles	Goals/challenges: clear, specific, moderately difficult, immediate and actionable goals/challenges Personalization: personalized experiences, adaptive difficulty; challenges that are perfectly tailored to the player's skill level, increasing the difficulty as the player's skill expands Rapid feedback: immediate feedback or shorten feedback cycles; immediate rewards instead of vague long-term benefits Visible status: reputation, social credibility and recognition Unlocking content Freedom of choice: multiple routes to success, allowing players to choose their own sub-goals within the larger task Storyline/new identities Time restriction Social engagement: individual and team competitions, cooperation and interaction with other players

identified 30 major studies, as shown in Table 5. Works that applied game theory or showed mature games or serious games in non-transportation activities were discarded.

4 Results

4.1 Analysis of study metadata

Figure 2 shows the distribution of major research on gamification in the field of transportation, divided by journals, conferences, workshops and book chapters. The earliest study was in 2015, which shows that the application of gamification in the field of transportation is a new problem. Figure 3 illustrates how the mapping of articles was distributed among these categories. It shows that the number of journals was the highest, followed by meetings, book chapters and workshops.

For the author's country/region, Table 6 shows that Australia had the largest number of published studies (4), followed by Spain (3) and the United Kingdom (3).

4.2 (RQ1) What gamification elements are used in the field of transportation?

To answer this research question, we completed the search for each gamification element in the basic results. Table 7 shows the number of times each gamification element was applied as well as the relevant studies that applied it. Note that the calculation is based on explicit references in the study.

As shown in Table 7 and Fig. 4, the most common gamification elements are goals/challenges and points, followed by rewards. Next are the leaderboard and social engagement elements, which appeared 15 and 12 times, respectively.

Goals/challenges: Setting goals/challenges can effectively "attract" users to their desired behaviour according to the gamification goals and maintain users' interest and participation over time [S30]. Allowing users to set their own goals and indicators can have a substantial impact because when they challenge their chosen goals, they create a self-competitive environment that can lead to personal efforts and progress [S17]. With reasonable efforts to achieve self-set goals within a reasonable time frame, you can obtain a sense of satisfaction and achievement. For example, in [S3] [S20], the gamification application invites travellers to set their personal goals from five pre-set goal options ("reduce car use", "increase public transport", "reduce energy consumption", "increase slow travel" and "reduce carbon dioxide emissions").

Points: In a gamification application that encourages drivers to drive ecologically, the points are the environmental protection scores calculated according to the driving style of drivers on the way, and the scores encourage good driving behaviour [S7] [S20]. In a gamification application that changes the travel mode of travellers, points are obtained based on the travel distance and the sustainable level of the means of transportation used for each trip [S5] [S16] [S21] [S30]. Generally, the more sustainable the model is, the more points participants receive. In general, gamification applications allocate points proportionally as long as they detect the number

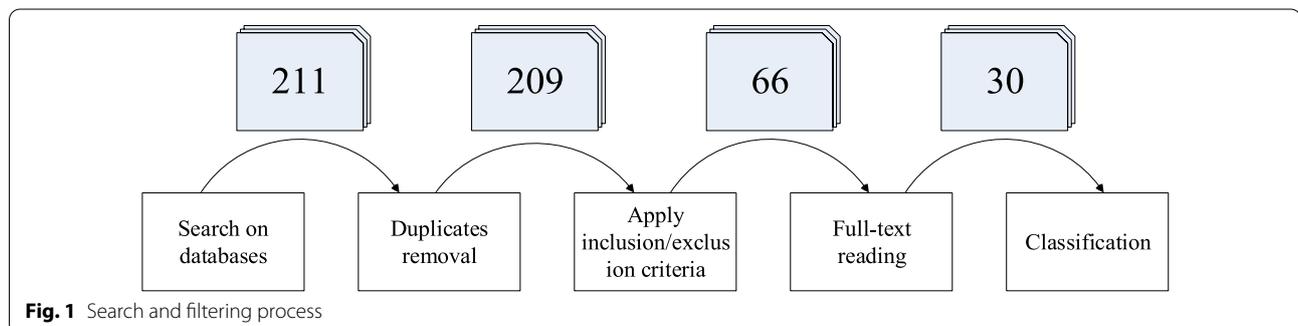


Fig. 1 Search and filtering process

Table 5 Primary studies

Id	Reference	Title	Year	Forum
[S1]	Magana and Munoz-Organero [50]	GAFU: Using a Gamification Tool to Save Fuel	2015	Journal
[S2]	Brito et al. [13]	Towards a framework for gamification design on crowdsourcing systems: The GAME Approach	2015	Conference
[S3]	Poslad et al. [67]	Using a Smart City IoT to Incentivise and Target Shifts in Mobility Behaviour-Is It a Piece of Pie	2015	Journal
[S4]	Hiraoka et al. [35]	Cognitive Function Training System Using Game-Based Design for Elderly Drivers	2016	Conference
[S5]	Castellanos [17]	Delivering modal-shift incentives by using gamification and smartphones: A field study example in Bogota, Colombia	2016	Journal
[S6]	Millonig et al. [54]	Gamification and social dynamics behind corporate cycling campaigns	2016	Conference
[S7]	Steinberger et al. [72]	Designing Gamified Applications That Make Safe Driving More Engaging	2017	Conference
[S8]	Steinberger et al. [73]	From road distraction to safe driving: Evaluating the effects of boredom and gamification on driving behaviour, physiological arousal, and subjective experience	2017	Journal
[S9]	Pajarito and Gould [63]	Smart Mobility, the Role of Mobile Games	2017	Book chapters
[S10]	Marcucci et al. [51]	Gamification design to foster stakeholder engagement and behavior change: An application to urban freight transport	2018	Journal
[S11]	Ambrey and Yen [3]	How perceptions influence young drivers' intentions to participate in gamified schemes	2018	Journal
[S12]	Andersson et al. [4]	Promoting sustainable travel behaviour through the use of smartphone applications: A review and development of a conceptual model	2018	Journal
[S13]	Olszewski et al. [60]	Solving "Smart City" Transport Problems by Designing Carpooling Gamification Schemes with Multi-Agent Systems: The Case of the So-Called "Mordor of Warsaw"	2018	Journal
[S14]	Ferreira et al. [29]	A Blockchain and Gamification Approach for Smart Parking	2019	Book chapters
[S15]	Cellina et al. [19]	A Large Scale, App-Based Behaviour Change Experiment Persuading Sustainable Mobility Patterns: Methods, Results and Lessons Learnt	2019	Journal
[S16]	Tsirimpa et al. [78]	A reward-based instrument for promoting multimodality	2019	Journal
[S17]	Cellina et al. [20]	Beyond Limitations of Current Behaviour Change Apps for Sustainable Mobility: Insights from a User-Centered Design and Evaluation Process	2019	Journal
[S18]	Martins et al. [52]	Collaborative Gamified Approach for Transportation	2019	Conference
[S19]	Adornes and Muniz [1]	Collaborative technology and motivations: utilization, value and gamification	2019	Journal
[S20]	Nousias et al. [59]	Exploiting Gamification to Improve Eco-driving Behaviour: The GameCAR Approach	2019	Journal
[S21]	Yen et al. [84]	Gamification in transport interventions: Another way to improve travel behavioural change	2019	Journal
[S22]	Dorcec et al. [28]	How do people value electric vehicle charging service? A gamified survey approach	2019	Journal
[S23]	Caroleo et al. [16]	Measuring the Change Towards More Sustainable Mobility: MUV Impact Evaluation Approach	2019	Journal
[S24]	Arnab et al. [6]	Player Interaction with Procedurally Generated Game Play from Crowd-Sourced data	2019	Workshop
[S25]	Cardoso et al. [15]	When Gamification Meets Sustainability: A Pervasive Approach to Foster Sustainable Mobility in Madeira	2019	Workshop
[S26]	Grajales et al. [31]	Collaboration or competition: The impact of incentive types on urban cycling	2020	Journal
[S27]	Maca et al. [49]	Incentivizing Commuter Cycling by Financial and Non-Financial Rewards	2020	Journal
[S28]	Caceres et al. [14]	Smart data at play: improving accessibility in the urban transport system	2020	Journal
[S29]	Tripathy et al. [77]	WeDoShare: A Ridesharing Framework in Transportation Cyber-Physical System for Sustainable Mobility in Smart Cities	2020	Journal
[S30]	Khoshkangini et al. [42]	Automatic generation and recommendation of personalized challenges for gamification	2021	Journal

of kilometres travelled by participants using sustainable vehicles. This means that participants who ride bicycles in their spare time while commuting to work by car will be rewarded with points. Such a point system may encourage participants to travel more just to earn more

points. Instead, this eventually exacerbates rather than improves the impact of their liquidity [S17].

Rewards: When participants reach certain milestones, incentive measures for rewards can be tangible or intangible, can be expressed in money or in

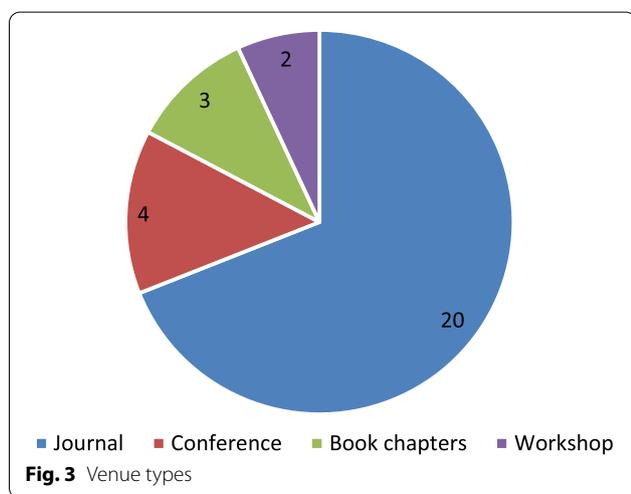
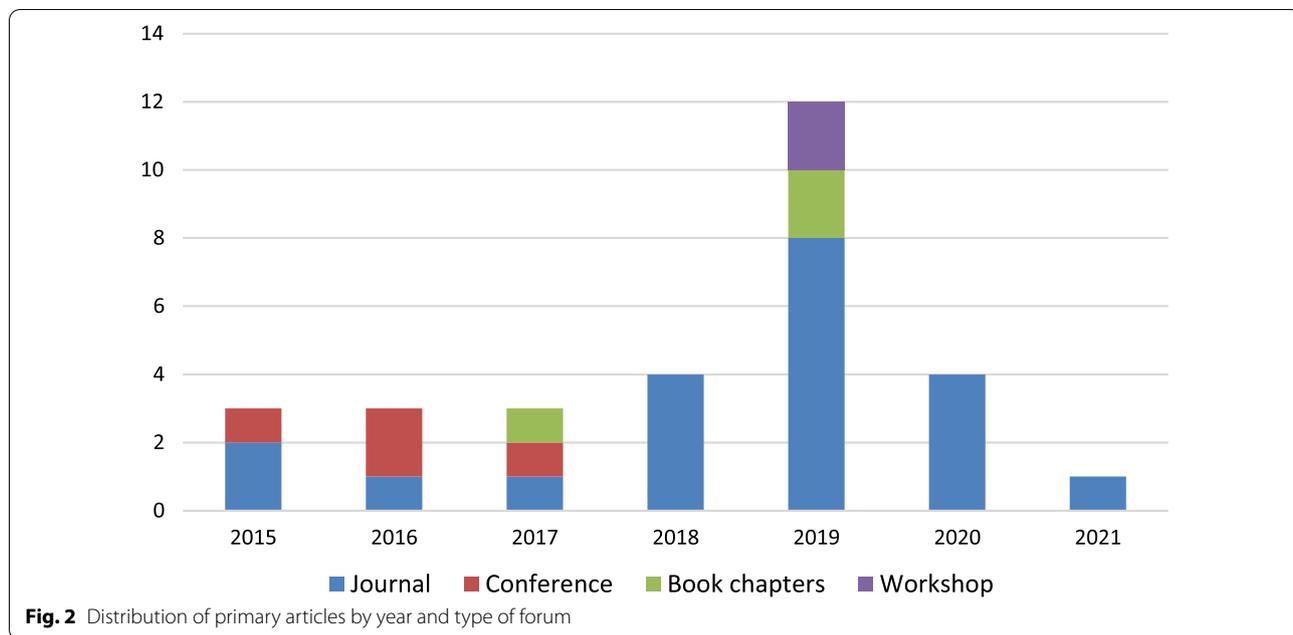


Table 6 Author’s affiliation countries

Country	Number
Australia	4
Spain	3
United Kingdom	3
Brazil	2
Greece	2
Italy	2
Portugal	2
Switzerland	2
Austria	1
Croatia	1
Czech Republic	1
Germany	1
India	1
Japan	1
Norway	1
Poland	1
Portugal	1
Sweden	1

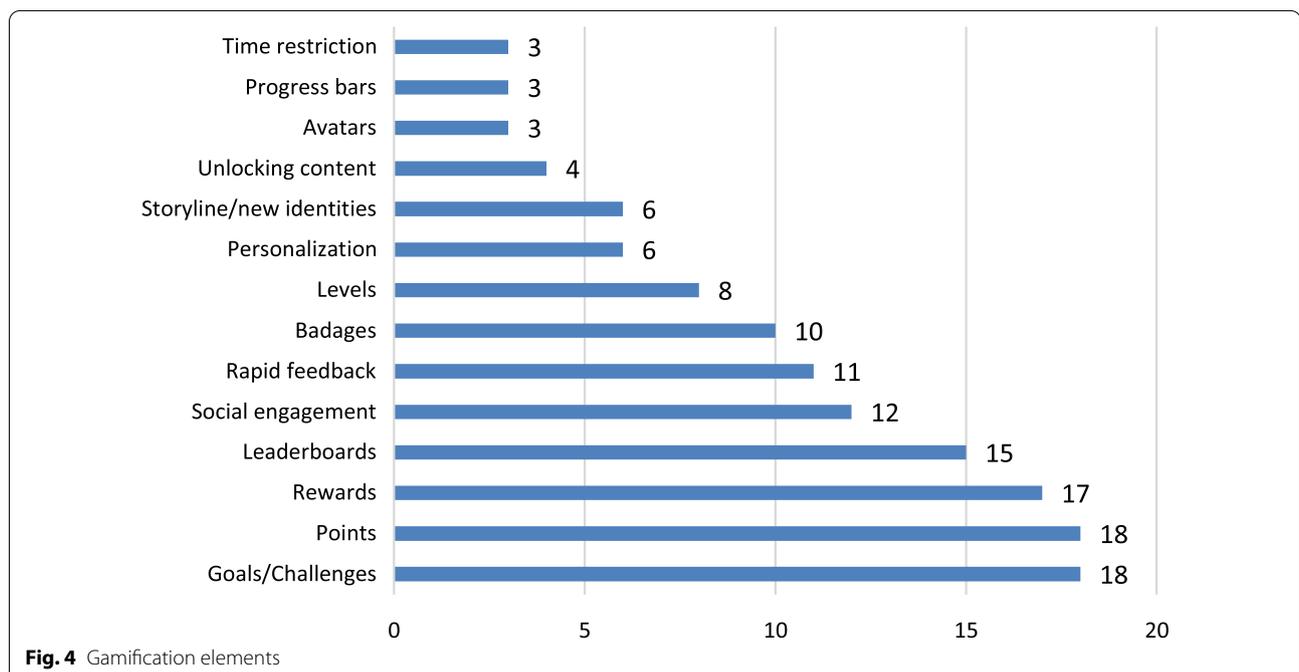
kind, and must be strictly related to individual performance. Rewarding participants who perform well can enhance the motivation of individuals to engage in a certain behaviour [S17]. For example, if the driver completes the task, he will receive a trophy [S15]. The top three users per week will receive monetary rewards [S15]. In addition to direct rewards, other rewards can be provided in a random manner to promote positive behaviour. For example, accidental positive rewards are occasionally obtained in a gaming environment [S20].

Leaderboards: Leaderboards rank the progress and achievements of users and other members similar to themselves to create a sense of competition [S21]. In

relevant research on ecological driving gamification, drivers are ranked according to the ecological scores obtained during their travel. This ranking reflects the extent to which drivers are moving towards becoming high-performance drivers. In the study of changing travellers’ travel behaviour, leaderboards provide individuals with the opportunity to compare their choices and performance with other people or groups they think are

Table 7 Occurrence of gamification elements in selected studies

Gamification element	Number	Studies
Goals/Challenges	18	[S1], [S3], [S4], [S6], [S7], [S8], [S10], [S15], [S17], [S20], [S22], [S24], [S25], [S30], [S26], [S27], [S28], [S29]
Points	18	[S1], [S2], [S3], [S4], [S5], [S10], [S11], [S13], [S14], [S16], [S19], [S20], [S24], [S25], [S30], [S27], [S28], [S29]
Rewards	17	[S3], [S5], [S7], [S8], [S10], [S11], [S13], [S14], [S15], [S16], [S17], [S20], [S25], [S30], [S26], [S27], [S29]
Leaderboards	15	[S1], [S5], [S6], [S7], [S13], [S15], [S17], [S19], [S20], [S22], [S25], [S26], [S27], [S28], [S30]
Social engagement	12	[S2], [S3], [S6], [S7], [S10], [S11], [S17], [S19], [S20], [S26], [S28], [S29]
Rapid feedback	11	[S1], [S2], [S3], [S7], [S8], [S11], [S13], [S17], [S20], [S25], [S26]
Badages	10	[S1], [S10], [S15], [S17], [S20], [S25], [S27], [S28], [S29], [S30]
Levels	8	[S1], [S2], [S4], [S10], [S20], [S24], [S25], [S28]
Personalization	6	[S3], [S13], [S17], [S20], [S27], [S30]
Storyline/new identities	6	[S2], [S7], [S13], [S17], [S20], [S25]
Unlocking content	4	[S2], [S20], [S24], [S30]
Avatars	3	[S7], [S13], [S20]
Progress bars	3	[S7], [S14], [S20]
Time restriction	3	[S4], [S28], [S30]



similar to themselves (such as members of the same community), which will generate peer pressure and imitation desire [S17]. The leaderboard is updated every week [S15], and users can view the points compared with other members or groups in the ranking system [S5].

Social engagement: The main motivation of social participation is to provide participants with a means of communication and share their experience and information with each other. Allowing participants to analyse their performance can improve their sense of achievement and

trigger competition, help promote group behaviour and improve trust among users [S3]. The main form is team challenge, which realizes social contact and peer pressure by sharing information through social media [S21].

Rapid feedback: Quick feedback shows how close or how far participants are from reaching their goals [S2]. In ecological/safe driving research, to effectively stimulate users to behave in the desired manner, gamification applications should provide information so that users can evaluate their behaviour and raise their awareness of the

possible negative effects [S20]. Feedback is essential not only to achieve the goals set but also to help participants stay engaged and make progress. In the study of changing travel patterns, personalized feedback on individual travel behaviour is provided. These aims are to provide comprehensive and practical evidence for travellers to improve their understanding of the impact of travel patterns. The metrics used usually include cost, time, distance and carbon footprint. This feature provides users with a way to monitor their behaviour. Suggestions can also be made to users according to their performance and by determining appropriate alternatives [S3].

Badges: In ecological/safe driving research, badges show achievements related to specific driving skill areas and show the progress made by each driver in their own and others' achievements [S20]. In the study of changing travel patterns, travellers will be rewarded with badges when they use a sustainable mode of transportation to achieve certain achievements [S30]. In addition, when the system detects specific sustainable transportation options, such as long-distance travel by bike or train every day for at least five consecutive days, the user will receive a surprise badge reward. This also has a guiding role. Spontaneous actions will receive unexpected rewards, which will make users aware of the positive actions they perform and stimulate them to repeat them in the future.

Levels: The driver or traveller needs to gradually increase the experience value to obtain the level [S3] [S20].

Personalization: In ecological/safe driving research, gamification mobile applications can easily record physiological, behavioural, environmental and vehicle parameters through sensors to form an ecological driving index and then provide personalized active tips to drivers to introduce how to adjust their current driving style to a more environmentally friendly driving style [S20]. In the study of changing traveller modes, the gamification mobile application designs personalized information based on the travel diary data provided by participants or the data obtained from surveys or interviews. It can also provide users with real-time information about the status of the transportation network, such as delay information. The information under these conditions can be combined with personal habitual travel to provide personalized information for each traveller [S3]. It can also introduce highly personalized weekly challenges. These challenges are designed to improve or maintain travellers' game performance by requiring users to achieve their goals (e.g., number of trips and kilometres travelled) through some form of transportation (e.g., cycling, walking, bus or train) [S30]. Such personalized units of playable content

have a significant positive impact on user participation and retention.

Storyline/new identities: The elements of storyline/new identities greatly promote the importance of users' participation and subsequent impact on the environment and behaviour in stimulating users to explore the epic meaning call and boarding stage [S20]. When the storyline resonates with users, it can enhance the expected effect of their immersion and participation [S7].

Unlocking content: If upgrading involves accessing new content, users will have additional motivation to unlock new content through progress, such as advanced data analysis tools or decorative elements [S20].

Avatars: Avatars are provided to users by gamification mobile applications. This provides users with their own virtual version in the gamification platform. When they achieve certain goals in the application, they have the opportunity to upgrade their avatar according to its appearance or other functions. Avatar clothing can be traded with other users in the virtual community platform. Users can view the avatars of other users competing with them, which means that users want their avatars to be better than others [S20].

Progress bars: Clear and definite progress should be provided throughout the gamification stage. In the case of progress stagnation, users should be continuously encouraged to further participate by generating a sense of disappointment [S20].

4.3 (RQ2) Which research topics of transportation adopt gamification?

Table 8 shows the research topics supported by gamification. It is worth noting that currently, changing travellers' travel behaviour is the most common gamification-supported topic (10 studies). The second improving driving behaviour (6 studies). Other transportation topics supported by gamification include encouraging bicycle commuting (4 studies), collecting transportation-related information (3 studies), supporting carpooling (2 studies), goods transportation (2 studies), identifying whether parking spaces are available (1 study), providing support for the development of gamification through a game survey of EV charging willingness (1 study) and data collection on road quality (1 study).

Figure 5 shows the relationship between gamification elements and transportation research topics. It shows how many studies refer to a particular element as support for a particular topic. It should be noted that the same element may have been reported in multiple studies, and multiple elements may have been mentioned in one study. Figure 5 provides evidence of the widespread use of goals/challenges and points as gamification elements

Table 8 Topics supported by gamification

Topics	Number	Studies
Changing travel behaviour	10	[S3], [S5], [S12], [S15], [S16], [S17], [S21], [S23], [S25], [S30]
Improving driving behaviour	6	[S1], [S4], [S7], [S8], [S11], [S20]
Encouraging bicycle commuting	4	[S6], [S9], [S26], [S27]
Collecting traffic-related information	3	[S2], [S19], [S28]
Carpooling activities	2	[S13], [S29]
Transportation of goods	2	[S10], [S18]
Identifying whether parking spaces are available	1	[S14]
Investigation of charging intention of electric vehicles	1	[S22]
Collecting data on road quality	1	[S24]

and great support for research topics. In addition, it is worth noting that avatars, progress bars and time constraints have not been explored much. Therefore, Fig. 4 shows gamification elements that are widely or rarely explored in transportation research topics.

4.4 (RQ3) How does gamification change traffic behavior to achieve sustainability?

To answer RQ3, we determine the direct and indirect changes of using gamification. The results are classified and summarized in Table 9 by topic, revenue from gamification, and reported revenue.

The main contribution of changing travel behaviour is realizing the changed behaviour. For example, [S3] found that travellers change their travel time to avoid peak hours and travel modes and turn to sustainable bicycle travel. [S12] indicated that gamification encourages more sustainable modes of transportation. [S16] found that travellers use more public transportation and walking. The second advantage is reducing carbon dioxide emissions and energy consumption. The third advantage is reducing the dependence on cars and the use of cars.

The main effort of improving driving behaviour is promoting safe driving. [S1] indicated that gamification can be a powerful auxiliary tool for safe and efficient driving. [S4] found that gamification improves the risk perception ability of elderly drivers and promotes safe driving. [S7] indicated that gamification encourages safe driving, driving speed is significantly reduced, and deceleration is earlier and more stable. [S8] found that safe driving helps drivers maintain attention and remain alert throughout the journey. The second advantages are reducing energy consumption and carbon dioxide emissions, making driving more enjoyable, and reducing boredom while driving. The third advantage is improving drivers' skills and interest in fuel saving.

The main contribution of encouraging bicycle commuting is promoting bicycle commuting. The second advantage is making cycling more enjoyable.

Regarding collecting traffic-related information, [S2] collected public transport information, [S19] collected road traffic information, and [S28] collected accessible information on public transportation infrastructure. The greatest contribution of gamification to these studies is improving users' participation and the usability of software. The second advantage is improving users' trust in software and information.

Regarding supporting carpooling activities, the main contributions are reducing traffic congestion, reducing fuel consumption, and reducing carbon dioxide emissions. The second advantage is reducing the number of cars on the road and increase participation.

Regarding cargo transportation activities, the main contributions are reducing fuel consumption, reducing carbon dioxide emissions, reducing the number of kilometres travelled, and reducing logistics costs. The second advantage is improving the quality of service.

Regarding identifying whether a parking space is available, the main change is that it saves the time and money spent finding a parking space, reduces the number of kilometres driven to find a parking space, and correspondingly reduces the emissions of carbon dioxide without requiring a great investment in sensors and other equipment.

Regarding the game survey of electric vehicle charging intention, the main contribution is making the gamified survey more attractive, thus improving the response rate and the quality of enjoyment.

Regarding road quality data, the main change is that gamification improves participation and provides open data for traffic and road conditions.

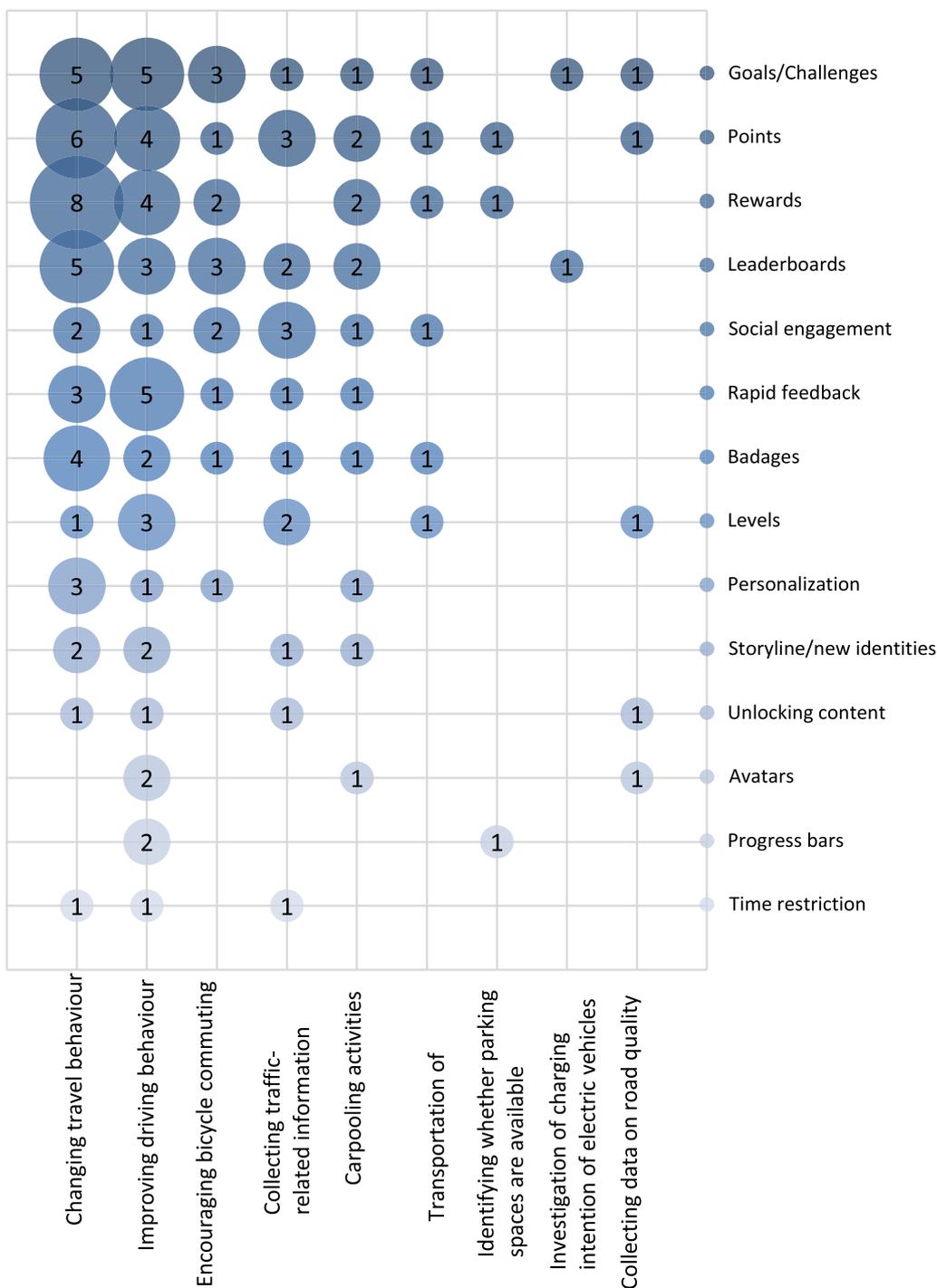


Fig. 5 Number of studies that relate gamification elements to transportation research topics

4.5 (RQ4) What research methods are used in the gamification of transportation?

Table 10 shows the distribution of study types. We noticed that evaluation research and solution proposals

were the most popular types of research, with 9 studies each, accounting for 60% of the selected studies. These two categories represent studies at an earlier stage, which may reflect the short time that gamification has

Table 9 Changes brought about by gamification

Topic	Change	Number	Studies
Changing travel behaviour	Changed the behaviour of travellers	7	[S3], [S12], [S16], [S21], [S23], [S25], [S30]
	Reduced carbon dioxide emissions and consumption	3	[S3], [S15], [S17]
	Reduced car dependency/usage	2	[S15], [S17]
Improving driving behaviour	Encouraged safe driving	6	[S1], [S4], [S7], [S8], [S11], [S20]
	Reduced energy consumption and carbon dioxide emissions	2	[S1], [S20]
	Made driving more enjoyable and reduced boredom while driving	2	[S7], [S8]
	Improved driving skills	1	[S1]
Encouraging bicycle commuting	Increased interest in fuel economy	1	[S1]
	Promoted bicycle commuting	4	[S6], [S9], [S26], [S27]
Collecting traffic-related information	Made cycling more enjoyable	1	[S26]
	Increased participation	2	[S19], [S28]
Carpooling activities	Improved availability	2	[S2], [S28]
	Improved trust	1	[S2]
	Reduced traffic congestion	2	[S13], [S29]
Transporting goods	Reduced fuel consumption and carbon emissions	2	[S13], [S29]
	Reduced the number of cars	1	[S13]
	Increased participation	1	[S29]
	Reduced fuel consumption and carbon emissions	2	[S10], [S18]
Identifying whether a parking space is available	Reduced the number of kilometres driven and logistics costs	2	[S10], [S18]
	Improved service quality	1	[S18]
	Saved time and money spent finding a parking space	1	[S14]
	Reduced the number of kilometres driven to find a parking space	1	[S14]
Investigating charging intention of electric vehicles	Reduces carbon dioxide emissions	1	[S14]
	No need to invest heavily in other devices such as sensors	1	[S14]
	Made survey more attractive, improved response rate	1	[S22]
Collecting data on road quality	Increased enjoyment	1	[S22]
	Increased participation	1	[S24]
	Open data for traffic conditions	1	[S24]

been used in the field of transportation, and some studies are still in the exploratory stage and immature. The other 12 studies were distributed among philosophical papers (4), validation research (3), experience papers (3) and opinion papers (2).

Table 11 shows the distribution of research methods. Nearly half of the studies used experimental research methods, and 13 studies used survey methods. It is worth noting that [S3], [S6], [S8], [S17] and [S27] used both experimental and investigative methods. [13] used both case study and survey methods.

Table 10 Selected studies type

Studies type	Number	Studies
Evaluation research	9	[S2], [S3], [S5], [S6], [S8], [S10], [S25], [S26], [S27]
Solution proposal	9	[S4], [S7], [S13], [S14], [S15], [S17], [S22], [S30], [S28]
Philosophical papers	4	[S12], [S18], [S21], [S29]
Validation research	3	[S1], [S20], [S24]
Experience papers	3	[S11], [S16], [S19]
Opinion papers	2	[S9], [S23]

4.6 (RQ5) What are the difficulties and challenges in deploying gamification in transportation?

As shown in Table 10, a large number of studies are classified as evaluation research and solution proposals. Table 11 shows that a large number of studies used experimental and survey methods. This shows that most of the selected studies were in the early stage of exploration; thus, they inevitably encountered various difficulties and challenges in the implementation of gamification.

The difficulties and challenges in implementing gamification in these selected studies are listed in Table 12. As the table shows, one of the main challenges for these studies was how to design attractive applications. Ten studies commented that it was not easy. [S17] pointed out that the design should be ingenious and user centred. [S30] noted that the design should be convincing.

Another major difficulty was recruiting and retaining users. All 10 studies encountered the problem of insufficient recruitment. [S14] indicated that participation would consume users' resources, such as mobile phone batteries and computing power, which is one of the main obstacles that makes many users reluctant to

participate. Therefore, an incentive mechanism is needed to ensure the participation of users. However, eight studies indicated that offering an effective incentive for users is a challenge. [S18] and [S21] pointed out that it is very important to motivate users to achieve the predetermined goal, and the gamification rule with monetary rewards plays an important role.

One of the goals of these application programs is always to make the design of the interface as simple and easy to use as possible. Eight studies pointed out that simplifying the interface design and making the application as simple as possible are very important.

Seven studies suggested that an important issue in implementation is the challenge of personalization, that is, tailoring an application to the personal data of each participant. [S30] proposed an automatic generation of a personalized challenge method. Although automation has always been the goal, it is not easy to build different automation methods according to different situations.

The accuracy and reliability of information and feedback information are also among the most important difficulties. [S1] pointed out that it is very important to provide correct feedback to the driver, as gamification could otherwise have a negative impact on driving. [S20] pointed out that providing correct information can enable users to evaluate their own behaviour and can effectively motivate them to engage in the expected behaviour. [S17] pointed out that the provision of information should avoid numbers because users prefer graphical and visual information.

Six studies pointed out that the experimental time was limited and the observation time was too short. Four studies on driver behavioural improve noted that

Table 11 Research methods

Research method	Number	Studies
Case study	5	[S5], [S10], [S13], [S21], [S25]
Experiment	14	[S1], [S3], [S4], [S6], [S7], [S8], [S15], [S17], [S23], [S24], [S30], [S26], [S27], [S28]
Survey	13	[S2], [S3], [S6], [S8], [S9], [S11], [S13], [S14], [S16], [S17], [S19], [S22], [S27]

Table 12 Challenges and difficulties in implementing gamification

Challenges and difficulties	Number	Studies
Fascinating design	10	[S7], [S12], [S17], [S21], [S22], [S24], [S25], [S30], [S28], [S29]
Recruiting and retaining users	10	[S2], [S4], [S5], [S14], [S15], [S16], [S30], [S26], [S27], [S28]
Effectively motivating users	8	[S1], [S3], [S6], [S17], [S18], [S21], [S30], [S29]
Interface design	8	[S1], [S2], [S4], [S7], [S8], [S14], [S23], [S26]
Personalization level	7	[S3], [S10], [S12], [S17], [S25], [S30], [S27]
Accuracy and reliability of information and feedback	7	[S1], [S3], [S7], [S12], [S17], [S19], [S20]
Limited experimental time	6	[S4], [S5], [S15], [S30], [S27], [S28]
Reducing interruptions and distractions	4	[S1], [S7], [S8], [S11]
Privacy issues	3	[S3], [S9], [S16]
Data collection	2	[S7], [S16]
Avoiding high cognitive load	2	[S1], [S8]
Difficulty of challenge should be appropriate	2	[S2], [S4]
Classifying players	2	[S10], [S26]
Integrating data and gamification	1	[S24]

reducing interruptions and distractions is a problem. [S1] and [S11] pointed out that gamification should produce as little disturbance as possible to avoid distracting the driver. [S7] pointed out that the trade-off between environmental information and driver distraction should be considered to avoid excessive dispersion of vision, and the form of sound should be considered. [S8] commented that attention should be paid to the position of the screen, which may affect visual attention. Two studies on driver behavioural improve also noted that high cognitive load should be avoided.

Three studies mentioned privacy issues. Two studies pointed out the problem of data collection. [S7] noted that the data were self-reported by participants, which was not objective enough. It is necessary to collect objective data, such as physiological and driving performance information. [S16] commented that carefully tracking people's travel and conducting an in-depth investigation of their attitudes and behaviours are arduous tasks.

Finally, it is also a challenge to categorize players. [S10] pointed out that attention should be paid to the classification of players, which must be weighted and standardized in various categories. Integrating data with gamification is also a major challenge.

Therefore, based on the results summarized in Table 13, we re-examine RQ5 and conclude that there are still many difficulties and challenges in the implementation of gamification. The results of this study can provide a reference for other gamification studies.

5 Discussion and suggestions

Although this research carried out systematic mapping on the use of gamification in the field of transportation, providing insights for research and practice, there are still many gaps in this research field. For researchers, this study provides a complete list of the most important factors in the field of gamification systems and transportation and provides complete and concise summary of challenges that can support future research on this topic.

In the field of transportation, in addition to the most common gamification elements used, it is worth noting rewards, social participation, rapid feedback and personalization. Most participants are initially attracted by rewards, which can stimulate their internal and external motivation and help them maintain participation for the long term. The participants' motivation is not always personal; it may come from the sense of belonging or group achievement of the community [75], so we should pay attention to social participation. Moreover, interaction among participants can enable them to achieve sustainable long-term participation. Rapid feedback can help participants quickly understand their level and immediately promote further participation. We found that

personalized research has a positive impact on behavioural change. Personalized research may provide customized and exclusive challenge tasks for participants, help them perform the tasks, and stimulate their intrinsic motivation [8]. Next, it mainly discusses and gives suggestions on how to implement gamification and get the desired effect on the three research topics of improving driving behaviour, changing travel behaviour and encouraging bicycle commuting.

5.1 Improving driving behaviour

Driving style directly affects the fuel consumption of the vehicle. Drivers that drive without exceeding the speed limit, decelerate/accelerate smoothly, change gears appropriately and maintain a relatively constant speed, representing an efficient driving mode, can save up to 25% of fuel, reduce greenhouse gas emissions, improve comfort and reduce the risk and severity of accidents.

Therefore, improving driving skills is a promising way to explore gamification driving. It can maintain a sense of challenge by providing different gamified themes and various difficulty levels, competing with other users or proposing new driving challenges. Driving challenges can be designed around driving smoothly to maximize passenger comfort, solving the mileage anxiety of electric vehicles around efficient driving, improving the situational awareness of semiautomatic driving or maintaining the skills of drivers because vehicle automation may have adverse effects.

When testing gamified themes, we recommend evaluating user preferences to establish potential matches and mismatches. Gamification elements can be applied with various themes, so custom personalized themes may be an option.

Gamified driving can be activated by certain elements in the road environment. For example, a speed sign or a set of traffic lights can activate a gamified driving task. These interventions can add additional participation based on a continuous feedback cycle.

When the vehicle is not moving, driving challenges or feedback can be displayed before or after driving. For example, ask about a challenge at the beginning of driving ("try to use less than x fuel when driving to work today"), and the challenge mainly occurs on the road. Detailed feedback can be provided after the trip, and leaderboards or similar statistics can be displayed so that users can evaluate their behaviour and raise their awareness of possible negative effects.

To avoid excessive visual dispersion during driver challenges, a trade-off should be made between providing environmental information and driver distraction. Information should be nonintrusive and can be achieved through abstract information visualization,

which skillfully conveys information through simple colour, brightness or sound. For example, environmental red may reflect speeding violations, which can reduce cognitive load.

Drivers themselves can be a source of social entertainment. The application may target other road users to reward achievements, allow social expression, allow accidental encounters or promote a shared road travel experience. Users who drive gamification can compete with each other and compare their progress on the leaderboard.

5.2 Changing travel behaviour

The main objective of many cities and transport authorities is not only to operate effective public transport services and effectively manage transport infrastructure but also, more strategically, encourage millions of their users to travel more effectively and sustainably in cities. More specific goals are usually to reduce the use of private cars in cities and to promote greater absorption of public transport use and human powered travel, such as walking or cycling, by providing appropriate incentives for travellers. An effective incentive measure is to encourage individual travellers to change their travel behaviour to achieve the overall goal, that is, to reduce the use of cars during peak commuting hours, protect the environment and promote people's well-being by reducing air pollution emissions.

Changing people's travel behaviour can be a difficult task, especially when there are many factors affecting people's behaviour. Therefore, we should consider the combination of the four stages of change and gamification to promote changes in people's travel behaviour. The first stage is the pre-consideration stage, in which users have no motivation to reduce car use and do not intend to take any action to change their daily travel mode. Gamification applications track the mobility data of users and provide users with automatic feedback on each route they travel, including distance, time, energy consumption and carbon dioxide emissions. In the second stage, the thinking stage, the above feedback is expected to improve users' understanding of the advantages and disadvantages of changing their behaviour to encourage them to establish the intention of change in the near future. By always choosing the feasible alternative route with the lowest CO₂ emissions on the route, we summarize how they move to stimulate their feedback, that is, the available low-carbon alternative route for any system route they take and its overall "transformation potential". The third stage, the preparation stage, encourages users to set their own personalized goals and challenges and urges them to move forward freely according to their own pace and direction to achieve their own reform goals. The fourth

stage, the operation and maintenance stage, helps users achieve their goals and encourages them to put sustainable travel modes into practice. Effective points, rewards and badges will drive users to implement their action plans. Note that monetary incentives are more likely to promote car sharing, park and ride, rather than monetary incentives, are more likely to promote alternatives related to public transport. The level of reward will affect individual behaviour changes. For example, with age, the higher the reward is, the stronger the behavioural change towards promoting sustainable travel patterns [16].

Social participation and peer influence can be used to change people's travel behaviour. Therefore, social networks and leaderboards can encourage sharing, comparisons and competition with others, which is usually considered to be an effective way to increase the driving force of change. Social networks seem to be a very useful medium for people to exchange skills and experiences.

It is suggested that future gamification applications should better follow the process of behaviour change by publishing application functions in stages.

5.3 Encouraging bicycle commuting

Cycling gamification applications aimed at promoting cycling among urban residents are encouraged. They focus on promoting and motivating self-regulated behaviour change by providing a variety of planning tools, feedback, rewards and experience sharing. Their main functions include bicycle route planning and route tracking linked to badges, challenges and rewards and community experience sharing systems. Commuting to work (or school) every day is the main choice of this intervention. This can not only improve people's health but also improve the liveability of cities by reducing car use and ownership.

It is suggested to provide in kind rewards and a small amount of money to promote cycling. The study found that by linking online stores with physical rewards, people may be more interested in physical rewards than monetary rewards because physical rewards may make users feel more enjoyable and make users more satisfied [37, 70]. Some studies have also found that providing a small amount of money as a reward for users who ride bicycles to work (or school) every day can effectively encourage people to significantly increase the frequency of cycling [S27]. Although rewards can maintain the change of behaviour throughout the activity process, it is still an unknown question whether this change can continue in the long run [10].

Adopting the gamification elements of social participation is suggested. The study found that in urban environments, cyclists are less willing to compete and more willing to participate or interact. Gamification designers

should create narrative links, a sense of community belonging, and a desire to participate in policy-making or have a better city, and motivation should be linked to the feelings of play, entertainment, comfort, well-being, freedom, social and interpersonal communication related to cycling.

Gamification elements of the goals are not recommended. Current bicycle promotion applications usually reward users by directly calculating the mileage of users riding bicycles. The use of goals elements often encourages people to make redundant trips to obtain more rewards, which goes against the original intention of bicycles as an alternative means of transportation for cars. Some studies have also found that setting specific goals for long-term projects may not be conducive to user participation because users will launch them immediately after completing the goals [32].

It is worth noting that some studies, especially those related to cycling promotion, are missing in the retrieval because they do not use the term gamification but use reward or incentive strategies in gamification. For example, Huang et al. [38] used mobile phone app to provide monthly cycling-related challenges for more than 6000 travellers in the Dutch region of Twente, and provided incentives such as point rewards and feedback information. This study analysed the travel behaviour tracked by mobile phone app in a real environment for more than a year and explored the impact of positive incentives on short-term and long-term travel behaviour changes. The results show that the challenge does encourage cycling and reduce car use in the short term. There is also some evidence that these interventions are effective for some long-term behaviour changes. However, due to the small sample size, it is impossible to draw a clear conclusion. At the same time, the paper lists mobile application projects and research examples that encourage voluntary travel behaviour change. The paper by de Kruijf et al. [25] reported the impact of the e-cycling incentive program in the province of North-Brabant, the Netherlands, on travel satisfaction. The program provides a small amount of monetary incentives for e-cycling participants per kilometre, aiming to stimulate car commuters to use e-cycling in their daily commuting. Through a longitudinal design, this study observed changes in travel behaviour and satisfaction. The study found that e-cycling travel satisfaction remained at a high level for up to six months, especially for people who often use e-cycling to work. After one month and six months, travel satisfaction greatly improved.

6 Conclusion and future work

The purpose of this paper is to report the results of systematic literature mapping on the use of gamification applications in transportation. To achieve this goal, the research scope of this study includes the evolution of the number of publications on this topic, what gamification elements have been adopted, which research topics of transportation adopt gamification, how does gamification change traffic behavior to achieve sustainability, what research methods have been used and what are the difficulties and challenges in implementation. The conclusion paper is based on the analysis of 30 selected studies.

Based on these views, we note that the use of gamification in transportation is an emerging field. More importantly, we note that there is no strong empirical evidence, so there are many investigation gaps.

In the analysis of the adoption of gamification elements, as expected, goals/challenges and points are most commonly used. The second most commonly used elements are rewards, ranking and social participation. Gamification is used mainly to change the behaviour of travellers and drivers. The changes brought about by the use of gamification are changing travel behaviour, encouraging safe driving, reducing carbon dioxide emissions, reducing energy consumption and increasing the enjoyment of participation.

The most popular research types are evaluation research and solution proposals, which indicate that research in this field is still in the early stage of exploration. In terms of research methods, most of the studies adopted experimental and survey methods.

Although gamification has recently become a popular topic, some studies have pointed out the difficulties and challenges in its implementation. The main challenges are introducing a winning design, recruiting and retaining enough users, motivating users effectively, and creating an attractive interface design.

Our future research will focus on implementing a systematic literature review (SLR), which will provide an in-depth analysis of all recently published studies on the use of gamification to change travelers' behaviour in the field of transportation to achieve sustainability.

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Author contributions

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Competing interests

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