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## SURVEY

# Games for Health in Transportation Systems

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**ABSTRACT** Transportation systems design might be supported by participatory approaches refining service design, user experiences, and safety research. The evaluation of mobility alternatives as design improvement strategies requires more advanced instructional techniques with new structures of complexity that can demonstrate, analyze, or compare system performances in order to achieve environmental sustainability in general and the well-being of the end-users in particular. As an emerging technology, games are capable of representing operations and management of passenger freight transportation and increase situational awareness of capacity bottlenecks. However, few research efforts have been devoted to the synthesis of the research progress. Based on the profiling methodology that has been previously employed in retrospect of healthcare simulations, this article presents a bibliometric review of games for health in transportation systems. The study carries out a literature analysis of the modelling methods to assemble gamified scenarios from a planning and managerial perspective. The Web of Science Core Collections are used to identify research items and investigate all the game-based studies in the cross-disciplinary research area of transportation and public health. The technology, game mechanism, and the health-related issue addressed are grouped into broad categories. The research findings are three-fold. (1) The majority of publications are classified into research efforts revolving around slow and road transportation modes. (2) Although scores, badges, and challenges are considered as the frequently seen gamification features, environmental simulation, avatars, and narratives appear as game mechanisms for the activation of the individual decision-making process. (3) Introducing system dynamics, human-computer interaction design, and a stakeholder accountability framework into the multi-stakeholder simulation setting leverages gaming outcomes with health benefits amid transportation system end-users. The literature study concludes with an integrated framework summarizing the best design practices between 2002 and 2022 on how the lessons learned from serious gameplay in virtual environments could translate into real mobility improvements. A selection of future research questions is curated to envisage new links between transportation and health research communities.

**INDEX TERMS** Design improvement strategy, participatory approach, public health, game for health, transportation system.

## I. INTRODUCTION

Incorporating games into design activities to identify performance characteristics of transportation systems that cannot be captured by analytical models holds significant promises for urban planning [1]. Until this far, the research direction in the field has predominantly revolved around technical and

non-technical skills acquisition in work environments – in order to realize high-fidelity simulation, a wide variety of instructional techniques are employed, including sponges [3], boards [4], in-situ simulations [5], mannequins [6] or their computerized apparatus, and many other pedagogical instruments [7], [8], [9]. Although there have been studies into the development, validation, and verification of simulation models describing various transportation processes [2], there has been few research efforts devoted to the application

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of games for health in the planning and management of complex systems. Although it is possible to calibrate public health scenarios and create user experiences to inform best mobility options according to the instructor's preferences, planning and management of social-technical systems could benefit from adopting a game-based intervention that places service designers, providers and operators into future design activities. This article defines games in the subject area of transportation as an intervention method that aims to technologically assist individuals with a service platform powered by user experiences and stakeholders with opportunities to elicit domain-specific knowledge from gamified scenarios. In order to identify emergent effects between participatory members, games for health are characterized by effective information visualization, the processes that explains how transportation planning and management prevent chronic diseases or injuries, debriefing after team-based activities, and the comparative study of system performances. The stakeholders are expected to transfer lessons learned from a game-based session to a knowledge production space as participatory members confirm, challenge, and extend existing norms.

In recent years, new services by passenger and freight transportation agencies on the physical and mental health of the population makes it necessary to understand the influence of digitalization on mobility. On one hand, there is an increasingly important role of digital accessibility in traveler's daily lives nowadays with extensive use of virtual reality, augmented reality, immersive environments, and armchair travel. This implies a research requirement on the cognitive, social, and personal resources of travelers to realize the potential of emerging technologies. Unlike extensive usability studies conducted for different types of technologies, there is a lack of investigations on the methodological properties of participatory approaches, which opens up areas of exploration for the role of networked practices in virtual environments. Furthermore, understanding the relationship between unique characteristics of the complex system and the causes of general well-being—such as mental health [10], physical health [7], aging [11], public hazard mitigation [12], adolescent travelers [13], virus control [14], and others [15], [16]—calls for overcoming the significant technical and social barriers to designing games for health powered by contextual relevance. Participatory methods have attracted considerable interest in sustaining health benefits over extended duration. These aspects require enhancing the use of games for health in the intersection area of transportation and health, as well as incorporating transportation scenarios into computer simulations with game elements. The application of behavioral classification and other quantitative methods can facilitate the effective implementation of games for health amid travelers.

Existing research on games for health in the transportation sector primarily focuses on analyzing the effects of new technologies on the physical well-being of travelers and assessing users' self-efficacy when deploying these tools in daily lives – this is based on data collection and

analysis, semi-structured interviews, surveys, and mixed-method approaches [17], [18]. In relevant studies, the intended outcomes from the game principal's standpoint usually point to overall accessibility improvements. The current literature lacks an integrated research framework that illustrates the processing of behavioral data and user profiles to elicit domain-specific knowledge from performing certain tasks in virtual environments. This is due to the fact that a large proportion of previous application-oriented studies are primarily concerned with predicting mobility pattern changes, examining the evolution of the social-technical system, and the parameters configuration of large-scale simulation models. Prior research in this field has examined a singular mode of transportation, a limited range of health conditions related to travels, inadequate options of design improvement, or employed a single research method. Furthermore, the application of game mechanisms in virtual environments for strengthening participatory engagement have not been adequately discussed.

This study focuses on identifying different types of digital media that may be used to create games for health in the area of transportation system planning and management. It envisages the interests in immersive digital games that allow human-computer interaction issues to be explored for assistive technologies and in general games for strategic planning. The literature study groups each paper's investigated mode of transportation, technology, game mechanism, health-related issue, data collection method, design improvement strategy, theoretical foundation, and vendor into broad categories, based on the context the corresponding study exploits. Specifically, data collection method in transportation systems focuses on gathering essential information on parameters such as journey distance, duration, and traffic volumes, which are critical to make informed decisions in virtual and real environments. These approaches prioritize readily available, up-to-the-minute information to apply in real-world scenarios. Because the case studies are intended to have practical implications, design improvement strategies integrated to their theoretical foundations – namely the design science - are proposed to expand the functionality of formal production. User experience encompasses aspects of user interaction with the apparatus to obtain a key insight into public needs, concerns and views.

It comes up with an integrated framework that can serve as a blueprint for game-based studies to address public health issues in transportation systems. Based on the aforementioned points, the aim of this article is to conduct a comprehensive literature analysis in order to answer the following research question:

- What planning and management insights could emerge from serious gaming between stakeholders if they are exposed to health-related challenges in transportation systems?

## II. METHODOLOGY

A step-by-step examination was used in the profiling methodology based on a synthesis of computer simulation

models in healthcare logistics [19] and a retrospective study of healthcare simulations [20]. As shown in Figure 1, the first step of the bibliometric review is to perform an article retrieval process by executing certain queries. The retrieval establishes sample cohorts to identify all interdisciplinary research papers. After this, the following steps abort publications that will not reach the inclusion criteria. In order to satisfy the inclusion criteria, research articles are expected to involve case studies, describe the mode of transportation, and associate the health-related issue with the implementation of the immersive game - their findings are expected to analyze performance metrics related to human mobility phenomena with individual distinctiveness.

### A. DATABASE SEARCH AND INFORMATION RETRIEVAL

In this work, the academic contributions after database searches are identified by thoroughly searching four scientific databases. These scientific databases comprise top-notch research outcomes in transportation, health, technological innovations. Table 1 provides a brief summary of the database search in Web of Science, PubMed as the life science and medical database, SAGE Journals as the collection pertaining to behavioral subjects, and JSTOR as the digital archive of high-quality social science studies. All search tasks identify research items in specific contexts. The information retrieval after the overall database search is realized by the Web of Science index system, which supplies bibliographic information into the CiteSpace software, a tool was validated for its visual exploration of research trends as well as the visualization of sociogram-like knowledge centers to highlight the prominent contributors in a particular research area [21].

### B. INCLUSION AND CLASSIFICATION OF RESEARCH ARTICLES

According to the previous studies, the research interest on promoting health-driven transportation planning can be explained by the requirement to obtain a deeper understanding of the relationship between movement patterns and health outcomes [22], [23]. It also aims to address previously overlooked issues identified in systematic literature reviews [24] and to investigate the technical advantages of advanced quantitative models, such as system dynamics [25]. Most literature reviews adhering to the PRISMA checklist include steps such as thoroughly examining each evidence-based research and present a meta-analysis for synthesizing evidence from multiple items.

In order to identify all eligible items, the implementation of inclusion criteria does not solely depend on the synthesis of research findings. In this study, the inclusion criteria for research articles is that the principal or investigator will deploy key features of games for health to answer important research questions in this domain. Studies aiming to fill the knowledge gap should investigate the health concern related to technical advancements in system design. Records that do not have agreement from both reviewers regarding inclusion

TABLE 1. Queries for the search engines.

Items	Search Query
Web of Science Core Collections	(TS=(serious gam*) OR TS =(serious gaming) OR TS = (participatory simulation) OR TS = (virtual reality) OR TS = (augmented reality) OR TS = (immersive simulation) OR TS = (interactive simulation)) AND (TS=(transportation) OR TS=(traffic) OR TS=(travel) AND (TS=(collision) OR TS=(incident) OR TS=(collision) OR TS=(crash) OR TS=(fall) OR TS=(traffic safety) OR TS=(disaster) OR TS=(hazard) OR TS=(health) OR TS=(well-being) OR TS=(wellness) OR TS=(mental) OR TS=(emotional) AND (TS=(plan) OR TS=(management) OR TS=(structure) OR TS=(organ*) OR TS=(strategy)))
PubMed	(serious game[Title/Abstract]) OR (serious gaming[Title/Abstract]) OR (participatory simulation[Title/Abstract]) OR (virtual reality[Title/Abstract]) OR (augmented reality[Title/Abstract]) OR (immersive simulation[Title/Abstract]) OR (interactive simulation[Title/Abstract]) ) AND ((transportation[MeSH Major Topic]) OR (travel[MeSH Major Topic]) OR (traffic[MeSH Major Topic]) ) AND (health[MeSH Major Topic])
SAGE Journals/JSTOR	serious game OR serious gaming OR participatory simulation OR virtual reality OR augmented reality OR interactive simulation) AND (transportation) AND (management) AND (well-being OR wellness)

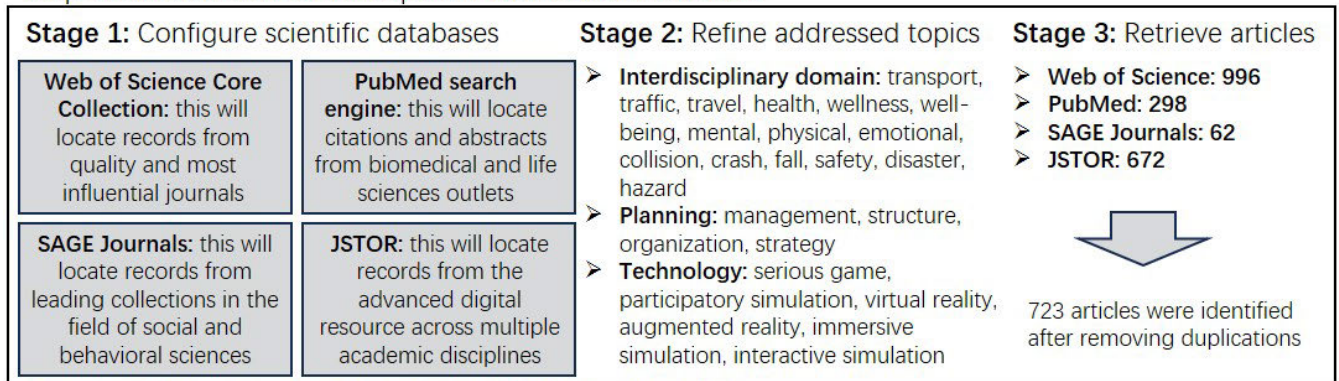
and classification might be examined by the third reviewer. The profiling methodology updates the sample cohort and guarantees the fulfilment of the inclusion criteria.

### C. SUMMARY

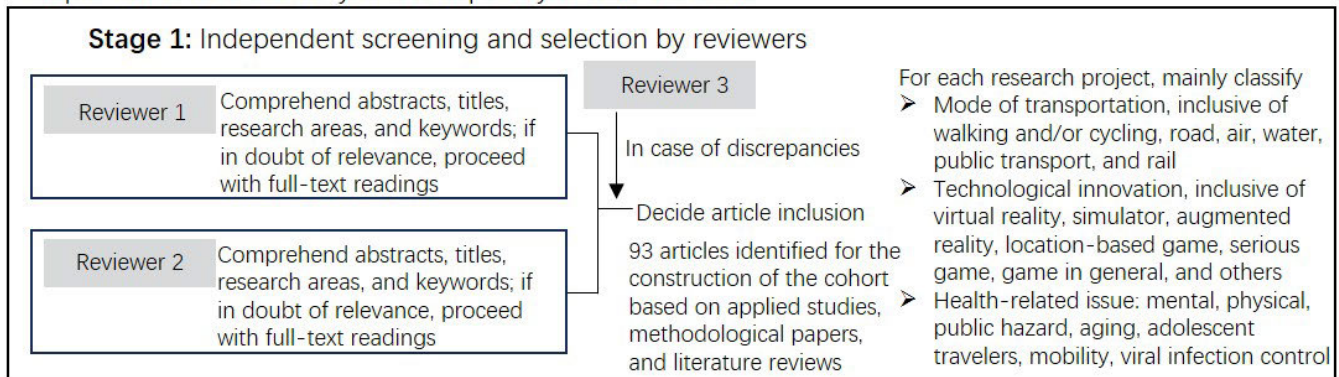
A screening and selection procedure is used to create a collection of case studies related to passenger transportation, freighting, and general travel after database for the bibliometric analysis is established. The involved game mechanism of the corresponding case study is discussed in the second step of the investigations, grouped into the catalogue of design features that are frequently deployed to foster participatory engagement (i.e., positive consequences arising from new policies and improved accessibility thanks to debriefing sessions to reflect on and share one's experience, etc.). The bibliometric visualization is then carried out to obtain the co-citation patterns, knowledge centers, and the traits of pivotal contributions that help realize ambitious research goals.

Application-oriented forecasting research is frequently conducted to highlight how solving problems related to public health could benefit from understanding human mobility patterns. In serious gaming, technological forecasting allows for the comparison of prediction results with and without player interaction – it could also develop forecasting models based on decision-making processes to involve stakeholders in the loop across all levels of the organization. Methodological studies are undertaken to evaluate the design, analysis and

Step 1: Structure and execute queries on scientific databases



Step 2: Include and classify interdisciplinary research articles



Step 3: Perform a bibliometric-based, literature analysis

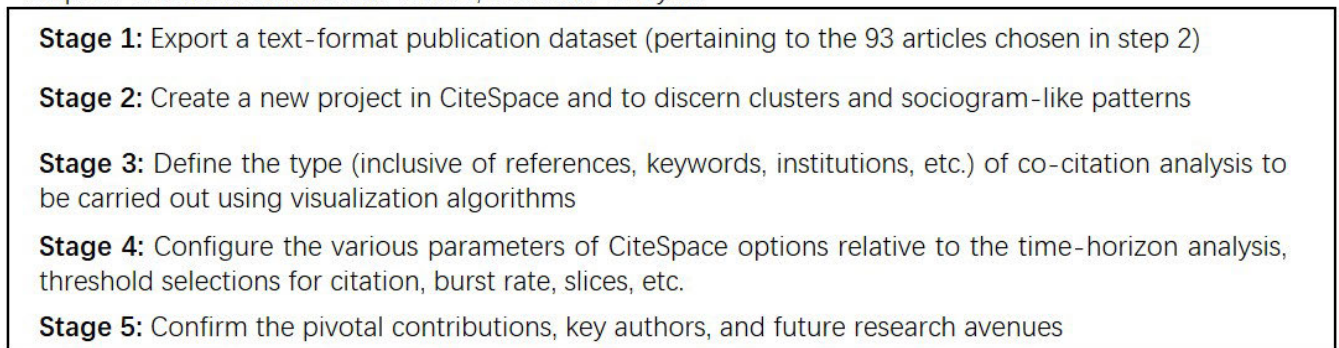


FIGURE 1. The literature profiling methodology used in this bibliometric review.

reporting of research processes on the mental and physical well-being of travelers. In light of this variety of research nature, this study identify items of the following types:

- Application-oriented research. The study includes at least one kind of interactive user interface and employs a game for health to understand the causal relationship in system design, leading to reduced emissions, lower pollutant concentrations, and, better health outcomes in transportation systems.
- Synthesis and methodological reflections. The article reflects the basic principles required in the design of application-oriented research so as to inform running games to promote research in transportation and health.
- Literature reviews. The study includes a comprehensive review of the existing literature, provides a synthesis to

situate them within the scholarly context, looking into theories and practices employed to further advance this intersection area.

CiteSpace software is utilized to uncover temporal citation patterns. The tool offers clear and understandable summaries of scientometric data further analyzed based on their frequency and burstiness characteristics. The depiction of a research front and its intellectual structure can be accessed through the use of clusters, time zones, and networks based on specific time periods. The time period spans from 2000 to the present, with a one-year gap between each interval. For each category, the articles among the top 10 % of are selected, using a scale factor of 25. The pruning process and term labelling employ a minimum-spanning tree and labels to networks, respectively. This is configured by a threshold

of 3, using a font size that is 50% of the maximum value, and a node size that is 20% of the maximum value. The layout is defined by parameters of iteration, improvement, and movement, with respective values of 894, 0.01, and 30. The detection model is configured with a state count of 2, a gamma value of 1, and a minimum duration of 2.

### III. RESULTS

The database identified 93 records articles from the Web of Science Core Collections after removing duplications. These items are published and indexed between 2002 and 2022 (see Table 2).

The 2023 release including articles published before print without Web of Science search index is excluded from the pool. A large number of case studies investigate the planning and management of slow and road transportation. The technology includes virtual reality, simulators (such as driving laboratories for the visual and street designs in urban contexts) to understand transportation service design, and augmented reality (such as the process of creating viewpoints of the transportation system using advanced displays). Furthermore, the principals apply game mechanisms including environmental simulations, avatars, narratives, and visualizations, besides frequently seen elements such as scores, badges, and challenges.

As illustrated in Figure 2, mental health conditions in transportation studies, among other issues, indicate psychological and social well-being of individuals in escalating circumstances. Physical health concerns are handled with design improvement strategies to mitigate the circumstances of frailty and disability in the presence or absence of traffic collisions. Studies regarding public hazard are performed to safeguard the dwellers in the vicinity of transportation infrastructure. The older adults and adolescents are considered travelers with vulnerable health profiles - relevant studies attempt to evaluate assistive technologies, production systems, and software to create user experiences. Mobility of the traveler is investigated as a promising feature on generalizing conclusions or implications of the research findings. In particular, inter-modality implies an on-going research trend in the activity-based travel chain in order to account for efficient transfers between transportation modes. Last but not least, virus control has been the research direction over the last few years under the impact of the pandemic, especially in the case studies of domestic travel.

Human-computer interaction and the user experience it delivers demonstrates possible effects of user responses to innovative products, increasing the likelihood of attitude change and successful persuasion depending on the innovative mobility option. Since evaluating user experience in transportation systems requires authentic environments, a design and evaluation process is carried out to ascertain the willingness of users 'buy-in' to gamified scenarios. This process of creating online travel platforms encompasses a well-thought combination of mechanisms that encourage exploration within the virtual environment, which involves a series of steps to guide the research process in the structured

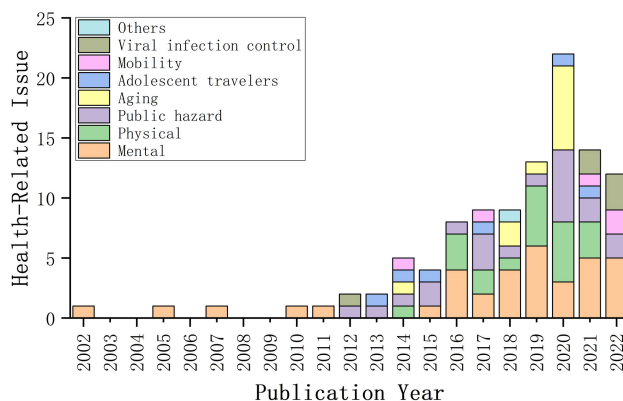


FIGURE 2. Health-related issues in serious gaming studies.

manner of the methodological framework. Collecting points or frequent travel miles are adopted by airline operators [25] as well as infrastructure managers [26]. Apart from these, environmental simulation refers to the recreation of the real working environment to cultivate a safety culture, as pointed out by Lanzotti et al. from the ergonomic perspective [27]. The avatar takes the form of a computerized character when the digital objects (i.e., traffic facilities, cargo, or the traveler's themselves) consist highly immersive environments. In contrast, narratives proposed in previous studies support interactive storytelling and therefore impact their relationships. Last but not least, visualization is often realized with two-dimension or three-dimension editing functions in the specialist software. To summarize what has been stated so far, these alternatives in transportation studies remark a shift from the development of pure incentives provoking behavioral changes at the behavioral level into the gamification of the transportation system, the latter of which is more effective for policy making to satisfy transportation agency requirements.

#### A. MODE OF TRANSPORTATION

Figure 3 shows that road transportation is the most frequently seen mode in the literature, given the high market share of this mobility option as a service in urban environments. This is also due to the advances in innovative 'last-mile' solutions in the automobile industry thanks to the growth of electric vehicles, autonomous driving and other innovations. Ruotolo et al. evaluated the impact of road noise on human health based on virtual reality [9]. Results showed that short-term verbal memory was influenced by the infrastructure condition, indicating that the immersive scenarios helped bring in noise reduction measures for people living near highways or busy road segments. Costa et al. investigated the psychological responses of participants with driving phobia, identifying their less distorted thoughts and anxiety [28]. The authors confirmed the usefulness of game-based sessions populated by car-driving scenarios describing the disadvantageous situations in urban settings. Road traffic noise levels and their trade-off relationship between spatial façade variables affect

TABLE 2. Catalogue of reviewed papers.

Mode	Reference	Technology	Game mechanism	Health-related issue	Data collection method	Design improvement strategy	City population
Slow	[5] [7] [13] [30] [31] [32] [33] [34] [37] [39] [41] [42] [43] [45] [48] [49] [53] [54] [55] [56] [58] [59] [60] [61] [62] [63] [66] [67] [68] [69] [70] [71] [72] [73] [74] [75] [76] [77] [78] [79]	Virtual reality (27); Simulator (3); Augmented reality (6); Location-based game (4); Adaptive learning system (4); Others (4)	Environmental simulation (30); Avatar (8); Visualization (7); Score (7); Badge (4); Challenge (5); Scenario (1); Miscellaneous (3); N/A (2)	Mental (18); Physical (12); Public hazard (12); Aging (9); Adolescent travelers (7); Mobility (4); Virus control (3); Others (4)	Questionnaire (27); User-system interaction (18); Formal assessment (12); Bio-physiological record (5); Interview (3); Miscellaneous (2)	User experience (14); Ergonomics (10); Built environment (13); Service design (1); Destination image (4); Behavioral change (1); Others (6)	High (22); Medium (17); Low (2)
Road	[9] [17] [28] [29] [34] [39] [40] [46] [50] [52] [54] [57] [69] [80] [81] [82] [83] [84] [85] [86] [87] [88] [89] [90] [91]	Virtual reality (17); Simulator (9); Augmented reality (1); Adaptive learning system (1); Game, general (4); Others (3)	Environmental simulation (18); Avatar (3); Visualization (5); Narrative (2); Score (2); Challenge (1); Scenario (5); Miscellaneous (2); N/A (1)	Mental (11); Physical (6); Public hazard (13); Aging (1); Mobility (2); Virus control (2); Others (2)	Questionnaire (14); User-system interaction (8); Formal assessment (5); Bio-physiological record (8); Interview (5); Others (2)	User experience (4); Ergonomics (10); Built environment (7); Service design (5); Destination image (1); Behavioral change (1); Others (3)	High (8); Medium (12); Low (4)
Air	[15] [18] [35] [36] [37] [39] [44] [51] [86] [89] [90] [92] [93] [94]	Virtual reality (7); Simulator (6); Augmented reality (1); Adaptive learning system (1)	Environmental simulation (12); Visualization (3); Narrative (2); Score (2); Scenario (4)	Mental (7); Physical (4); Public hazard (3); Aging (1); Mobility (1); Virus control (1); Others (1)	Questionnaire (10); User-system interaction (3); Formal assessment (2); Bio-physiological record (4); Interview (2); N/A (1)	User experience (6); Ergonomics (7); Built environment (1); Service design (1); Destination image (1); Others (2)	High (4); Medium (6); Low (2)
Water	[14] [37] [38] [40] [47] [93] [95]	Virtual reality (4); Simulator (1); Adaptive learning system (1); Others (1)	Environmental simulation (7); Visualization (1); Narrative (1); Scenario (2)	Mental (5); Physical (2); Aging (1); Mobility (1); Virus control (1)	Questionnaire (5); User-system interaction (1); Formal assessment (1); Interview (1); Others (1)	User experience (4); Ergonomics (3); Service design (1); Destination image (1)	High (2); Medium (3); Low (1)
Transit	[39] [96]	Virtual reality (2); Simulator (2)	Environmental simulation (1); Scenario (1)	Public hazard (2)	Questionnaire (1); User-system interaction (1)	Built environment (1); Service design (1)	High (1); Medium (1)
Rail	[34] [39] [40]	Virtual reality (2); Simulator (1); Adaptive learning system (1)	Environmental simulation (3); Visualization (1)	Mental (1); Public hazard (1); Mobility (1)	Questionnaire (3); User-system interaction (1); Others (1)	User experience (1); Built environment (1); Service design (1); Destination image (1)	High (1); Medium (2)
Not specific	[16] [64] [65] [97] [98] [99]	Virtual reality (4); Others (2)	Environmental simulation (3); Avatar (1); Visualization (1)	Mental (3); Public hazard (1); Mobility (1); Virus control (1)	Questionnaire (5); Others (1)	User experience (3); Ergonomics (3); Destination image (1)	High (5); Medium (1)
Method paper	[10] [100] [101] [102] [103]						
Review	[104] [105] [106] [107] [108]						

human perception and mental state in densely populated urban environments, according to Chung et al. [29]. Their realization of audio-visual scenarios through immersive virtual reality sheds light on neighborhood dwelling design. These projects inform future planning and management guidelines for context-dependent built environment affecting mental and physical health.

Slow transportation mode primarily refers to walking, cycling, and the utilization of scooters as well as armchairs. This has remained one of the most frequently discussed topics throughout the entire time span thanks to the scholarly focus on pedestrian safety in recent years [13], [30] as well as the research paradigm shift towards promoting healthy and sustainable lifestyles [31]. This mode has lately become more popular as an option to subvert the negative effects of motor usage on the environment and public health. Marquet et al.'s pilot study utilized Pokémon Go to motivate physical activity. Results show that all groups received health benefits, although the players perceived traffic as an obstacle to the adoption of the location-based game [32], highlighting the importance of exercise design. Physical activity benefits were identified while travelers discovered new places, as per Xian et al.'s conclusion [33]. Recently, innovative apparatus appeared as part of the effective tools for stimulating travel motivations. Skard et al. performed a virtual reality study in order to support the hypothesis of the stronger impact of virtual reality on the mental imagery of destinations [34]. Their findings illustrated the effects of vivid marketing tools on individual choices. In order to promote cycling, Lieze et al., via the same apparatus, investigated street characteristics [7]. Research findings suggested no significant differences in metrics between the methodologies, but headsets were advantageous to computer simulations in terms of usability.

Research on air transportation has shown that the implementation of games facilitates capacity-building processes in air traffic planning, infrastructure management, and service design. Their focus is on game-based solutions for training, suggestions, and assessments of technological innovations. In 2014, Karikawa et al. carried out the performance analysis of traffic controllers exposed to high-fidelity, human-in-the-loop settings [35]. According to the authors, visualizing the workflow process contributed to the control strategies classification. In addition, Truschinski et al. investigated how task difficulty and complexity affected the emotional and cognitive states of controllers, as a whole eventually affecting their performance [36]. The schema of the virtual environment played a key role in the creation of air traffic scenarios as well as the synchronization of the parameters. Sancho-Esper et al.'s technology acceptance model explored mobility recommendation strategies supporting older adults travel [37]. The promotion of visiting places was critical for the population segment potentially encountering much higher travel bars in retirement communities. Last but not least, virtually visited places became especially relevant at the time of the pandemic. Specialized and effective guidance for various traveler profiles increasingly drives new trends in

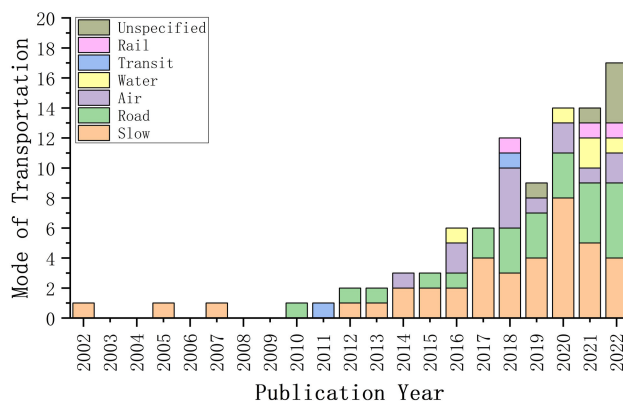


FIGURE 3. Category of modes in serious gaming studies.

the travel sector, together with mobile applications spanning from the development of location-based games to the virtual environments.

Since 2018, more than half of research efforts committed to the improvement of mass transportation by water, transit, and railway; planning and managing multimodal transportation systems with health benefits has recently warranted more scholarly attention. Specifically, public transportation was considered an option to subvert the negative effects of motor dependence. Yuen et al. examined the determinants of virtual reality adoption by marine personnel [38]. In addition, behavioral theories could support explaining the intention towards similar technologies that substituted conventional travel in favor of the ecology system. Lugten et al. performed a virtual reality experiment [39] in order to mitigate the noise levels often seen at transportation terminals. The scenarios were generated by concurrently visualizing fleets, urbanity, the surface, and vegetation, leading to the discovery of the almost identical degrees of sound quality enhancement in residential and commercial dwellings. Raghothama et al. created a gaming simulation consisted of digitalized road, river, and rail transportation infrastructures. This remarkably contributed to a thesis on the strong ties between game design and multimodal transportation planning [40]. By adopting a layered approach, it will facilitate the implementation of scenarios into the latter phases of the city-wide design project and enable prompt evaluation of the impacts by modifying the parameters.

## B. TECHNOLOGY

From 2002 to 2015, as shown in Figure 4, virtual reality is the most prevalent apparatus for the activation of serious gameplay. As an example, Shen et al. recreated a pedestrian-friendly environment to trigger actual street crossing behavior among adolescent travelers [41]. The authors identified temperamental fear and gender as risk factors for collision events. Zeuwts et al. investigated how mental fatigue accumulation affects visual search behavior for young cyclists [42], leading to the conclusion that hazard perception ability decreases in complex traffic situations.

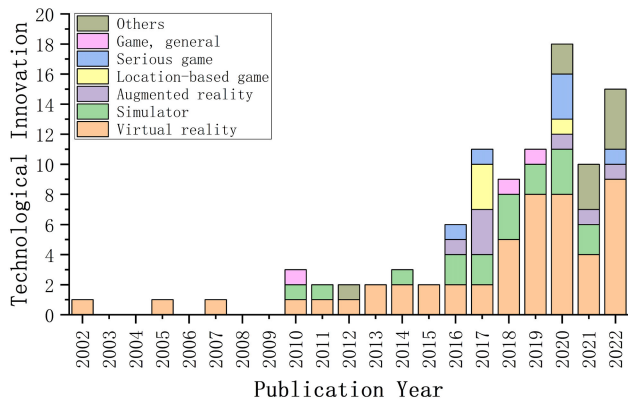


FIGURE 4. Category of technologies in serious gaming studies.

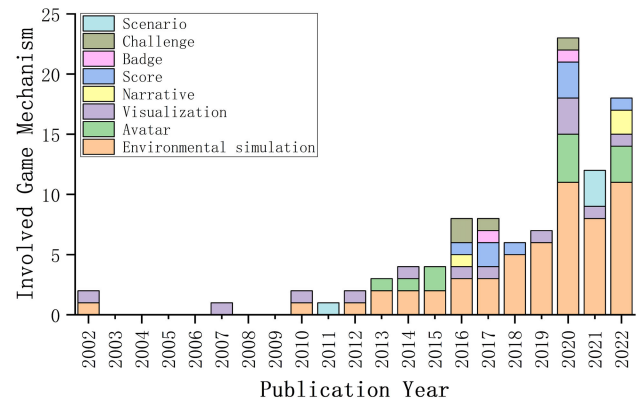


FIGURE 5. Category of game mechanisms in serious gaming studies.

Across the time span, simulators have been designed and applied mainly for the prevention of reduced travel and discomfort. This is illustrated by Coeugnet et al.'s mobility enhancement study, in which the authors defined vibrotactile guidance instructions as being more effective than those from paper maps [43]. Similarly, Raduntz et al. carried out a mental workload assessment on top of their management and operations simulator [44]. Air traffic controllers must interact with crew-like characters during various traffic load scenarios and exceptional events. Additionally, augmented reality apps have been created to provide passenger flow statistics for urban areas [45]. Over the last five years, there has been a remarkable increase of research efforts exploring different types of games. While game for health are not clearly defined in most items, there have been serious gameplays analyzed to showcase scenarios, assess skill comprehension and objectives achievement.

#### IV. GAME MECHANISM

This article discovers several game mechanisms associated with a scaffolding process in the adaptive learning system to demonstrate health benefits available to the passengers. Figure 5 indicates that environmental simulation is strategy to stimulate gameplay interest. In order to bring in a convincing and trustworthy experience, the digital objects may simulate streets [46], cranes [47], buildings [48], and travel destinations [49]. Following this, avatars provide participants with a sense of ownership, diversity, and inclusion. Facial expression was simulated using non-player characters in Huang et al.'s spatial analysis of transportation networks [50]. Results showed that the methodology for projecting reactions to urban noise could be extended to investigate environmental perception. It is not just 3D techniques; 2D visualization design not only resembles game-like displays, but also supplies convenient interfaces to understand transportation system use. Rohacs et al. demonstrated the potential implementation of an enhanced controller station via the use of graphs, aiming to solidate air traffic management procedures by automating more routine duties [51]. Participants found narratives, a novel kind of

storytelling, helpful in understanding their own traits. Lee et al. conducted a mobilization training course that used a mix of virtual reality and simulation to investigate the relocation of patients to hotels and hospitals in order to reduce instances of cross-infection [52]. The scenarios portrayed a unique storyline as the cornerstone of the curriculum, bridging the performance gap between experts and novices. Furthermore, scores, badges, and challenges as traditional elements of gamification are inserted into existing systems to carry out non-game-like transportation activities. The use of these templates facilitates the description of status and the competitive nature among stakeholders, resulting in an higher level of engagement and possible formulation of shared mental maps amid participants.

#### A. DESIGN IMPROVEMENT STRATEGIES

A wide variety of design improvement strategies are streamlined by systematically comparing the interventions. It can be seen from Figure 6 that the recommendation to improve user experience by focusing on a holistic understanding of how travelers benefit from health is a promising avenue. This is addressed by a growing number of studies, including Roberts et al.'s focus group research to justify digital content at the disposal of older travelers [53] and Che et al.'s personalized information system to visualize health risk areas affected by air pollution. Between 2012 and 2022, research items report changes made to the physical surroundings, showcasing how locations enable more healthy behaviors. Zambaka et al.'s between-subjects experiment provided first-hand data to examine the correlation between modes of transportation and perception of the environment. Oduor and Perälä used web-based augmented reality to examine the correlation between the number of completed activities and the number of mobile application downloads [54]. The researchers found that the integration of elements such as light traffic displays and swings significantly promoted urban exploration during games. This helped address health issues stemming from obesity or sedentary lifestyles. Service design research has been a remarkable trend over the past five years as design thinking is found more and more useful to align with the



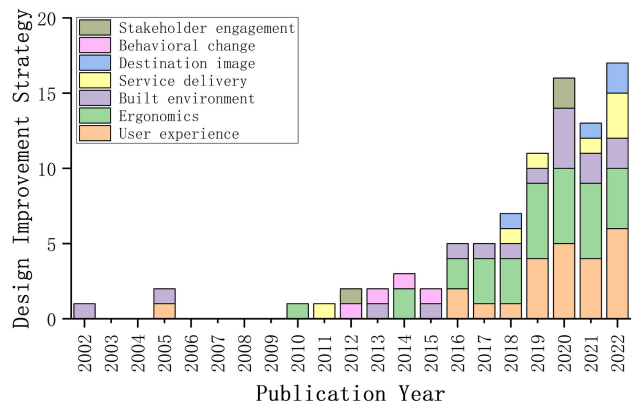


FIGURE 6. Category of design strategies in serious gaming studies.

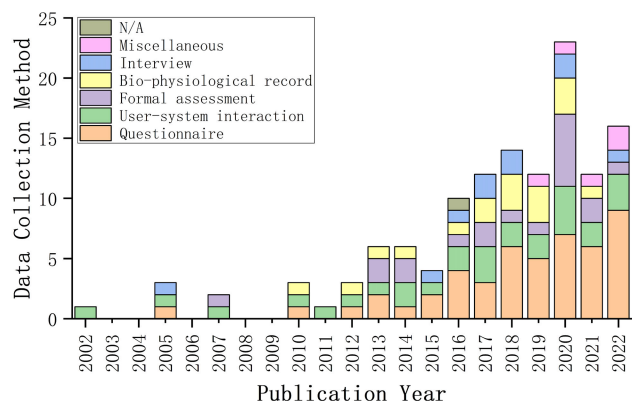


FIGURE 7. Category of data collection methods in serious gaming studies.

expectations from the user's perspective, in the case of armchair travel experiences. As a novel strategy, stakeholder engagement successfully integrates transportation service design into the innovation phases. In games for health, this could be informed by the opinion dynamics of the decision-making process for the planning, management, and network optimization of the transportation system.

## B. DATA COLLECTION METHOD

Figure 7 indicates that the literature proposes various data collection methods for understanding, interpreting, and analyzing behavioral responses. In this instance, the investigation relies on measuring individuals' reactions, approaching their interactions with the system, and recording bio-physiological traits, in addition to conventional survey procedures such as formal evaluations, interviews, and questionnaires. Yu et al. implemented a virtual reality experience for understanding motivational factors in outdoor travels [55]. Replies to the questionnaire demonstrated the health benefits of simulated urban objects for middle-aged and older adults. In order to study people's direction in a fire emergency, Lin et al. gathered human wayfinding data from the Xbox Joystick interaction with the Immersive Virtual Environment [56], leading to the discovery of the influence of repeated exposures to building blocks and mental stress on performance. Their study showed that the hazards significantly increased the travel time and distance of the participants when completing the egress task.

Across the time span, score comparisons based on validated assessment tools are used to evaluate the degree to which research findings can be extended to subgroups of the general population. The Situation Awareness Global Assessment Technique, resembled by Lehtonen et al., has been administered to the diverse user groups of a learning game for young cyclists [5]. Bio-physiological data has lately been a prominent enabler of real-time assessment without requiring over reactions from the participants. As an example, skill performance scores revealed profound differences in high-fidelity and low-fidelity simulation groups in Mangala et al.'s randomized control trial [57]. They concluded that

preparation work before transporting the critically ill relied on adequate communication and teamwork. Data collection techniques employed in recent years include conducting interviews with older adults experiencing cognitive and physical limitations [58], analyzing flow data in the assessment of travel bars during the pandemic, and utilizing user-generated comments to investigate the case of Airbnb, which supports the social dynamics within the traveler community [59].

## C. THEORETICAL FOUNDATION

The theoretical foundation a case study can base on for improving the performance of transportation systems is found to be interdisciplinary. Theoretical frameworks are adopted and applied to envisage new research directions within the field, as Figure 8 presents. Researchers complied with cognition-related theories to study pedestrians' environment scanning behavior in order to obtain cues for route planning [60]. Findings suggested a higher falling risk and uncovered the relationship between the cognitive process and changes in travel path fixation. Decision-making processes were approached for a more comprehensive understanding of how travelers engage elements of the transportation system through digital technology. This could be exemplified by Araz et al.'s table-top exercise study, in which many significant policy implications arose from the interactions among stakeholders [61]. Between 2016 and 2020, there was an increased focus on physical exercise due to the need to prioritize public health in the face of changes in travel habit. This was defined by research initiatives focused on Pokémon GO, namely the examination of the correlation between gaming, mobility, and familiarity with new metropolitan locations [62]. During the last few years, the theory of reasoned action has been the most prevalent theoretical framework, thanks to the development of technology acceptance models in usability studies [63], [64]. Stimulus-organism-response also supported developing structural models. According to Schiopu et al.'s conceptual model of environmental stimuli and behavioral responses, the effect of travel constraints on the intention to deploy virtual reality for visiting international destinations is ascribed to the

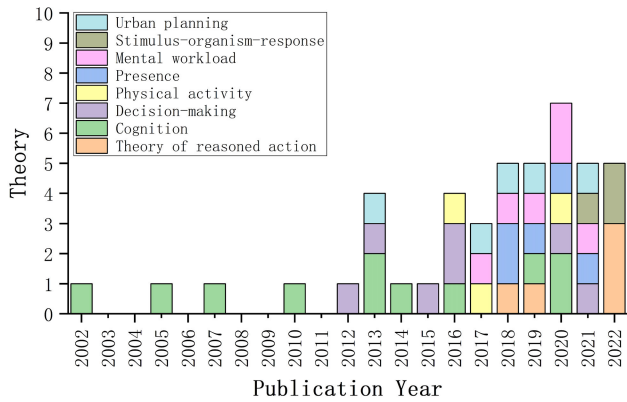


FIGURE 8. Category of theoretical foundations in serious gaming studies.

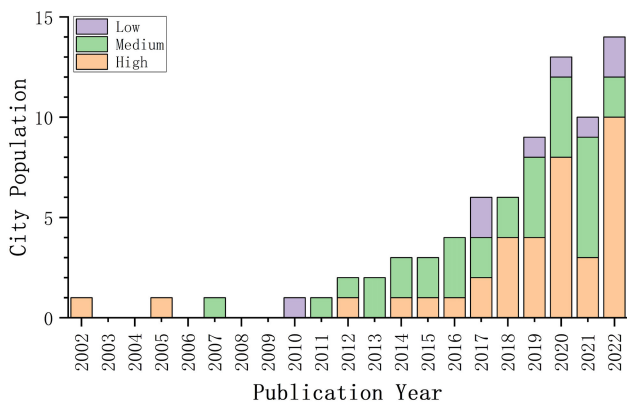


FIGURE 9. Category of urban densities in serious gaming studies.

perceived usefulness of the apparatus [65]. Last but not least, it is worthwhile to note that urban planning theories refer to principles of neighborhood and housing designs, preventing accessibility obstacles compared to the general population.

Within the existing body of research, three scenarios could be classified based on the level of population density: highly populated (like New York, Shanghai or Istanbul), medium populated (like Rostock, Oulu or Adiyaman), and low population cities (like New Haven, Anyang or Raleigh) according to where they fall in the first, second or third thirty-three percentiles. These scenarios have been the context of studies conducted in this field. As can be seen in Figure 9, between 2002 and 2016, the primary focus of research efforts has revolved around incorporating game elements into transportation systems in highly and medium populated cities. From 2016, there have been two notable changes in academic focus. One change is that the attention has now turned towards densely populated cities. Specifically, there is only one year when the number of articles focused on medium and low population cities was the most prominent category. While it is anticipated that major cities will continue to expand in the next years, there is also a rising focus on less populated areas as academics become more concerned of the impact of growing population density globally.

The research keyword co-occurrence pattern that a topical evolution can display depends on keywords, titles, and abstracts of documents in the database. The topical pattern could therefore be visualized and identified to reveal the intellectual structure established by recent research trends and the increasing diversity of research areas, as Figure 10 presents. Over 50% of the studies connect to nodes of health, experience, and virtual reality, with the remaining 50% pointing to reality, model, injury, and disorder. The ‘emerging regions’ constitute papers from all time periods of the time span, although a large part of the network is placed around health and impact nodes. Given the connection between different sections at the center of the diagram, evaluation studies would examine technology acceptance, physical activity, public health risk, and applications in the tourism sector. Interestingly, recent advances exhibit the development of the clusters for modelling and injury, respectively. The former represents research efforts to optimize performances in a systems engineering perspective, as demonstrated by targeting passengers who require comfort, safety, and efficiency in their navigation through transportation systems. Unlike focusing on the design of transportation services, injury-related studies prioritize risk mitigation as well as the protection of vulnerable populations. The sparsely connected set of nodes represents the scholarly attention to improve public health - there is a need to facilitate an accessible, socially inclusive transportation system capable of adapting to changing conditions and the local needs of users and personal resources.

Figure 11 displays the collaborations over time at the international level. The linkage density has increased, and the nodes at the peripheral places are isolated from the rest of the network. North Carolina State University stands out as the influential organization in the publication corpus, as does the University of Oulu appearing near the central linkages. The Federal Institute for Occupational Safety and Health, Humboldt University, and the German Aerospace Centre consist another network pattern in the subject area of ergonomics. As a whole, American and European organizations lead the entire research field, whereas studies carried out by Hong Kong Polytech University and Tsinghua University contribute to the formulation of future research directions in this domain. Similar to the knowledge clusters, the collaboration relationship is sparsely distributed when it comes to recent advances. When the Asian counterparts join the landscape, the network starts expanding, and new links forged from different countries help broaden the international perspective.

Figure 12 presents the time-sliced visualization based on the research keywords. Virtual reality in 2002 is present throughout the time span, and sex differences popular in 2007 are substantially less relevant over the last few years. Since 2010, safety and subsequent research themes have been tightly connected. This is driven by the research purpose to prioritize the general well-being of individuals who may be influenced by the increasing diversity of transportation service provision. The rise of acceptance issues when

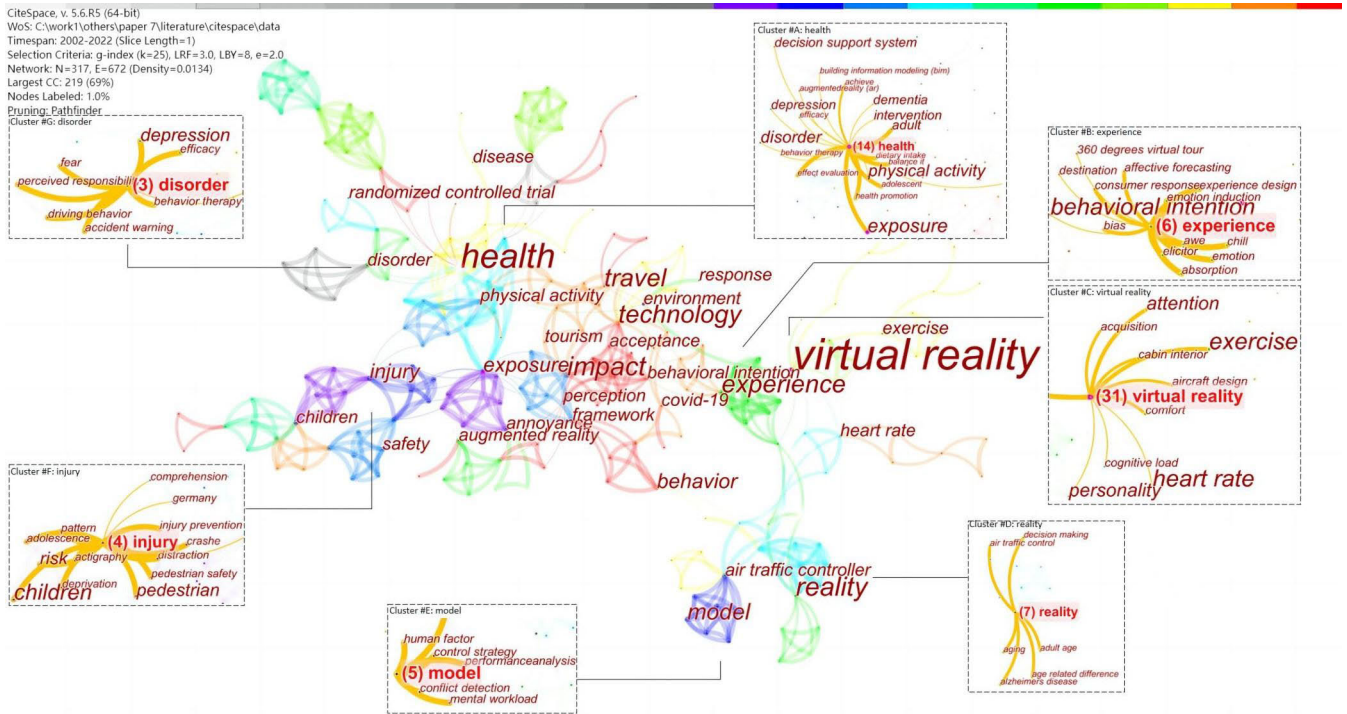


FIGURE 10. Cluster view of keyword co-occurrence of references between 2002 and 2022.

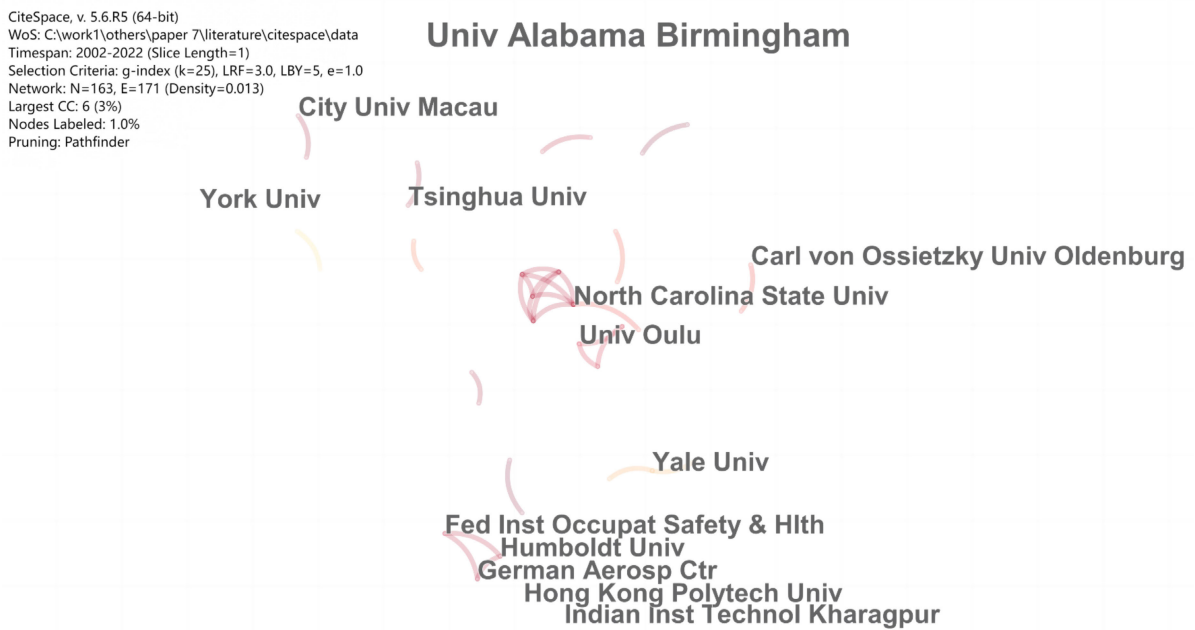
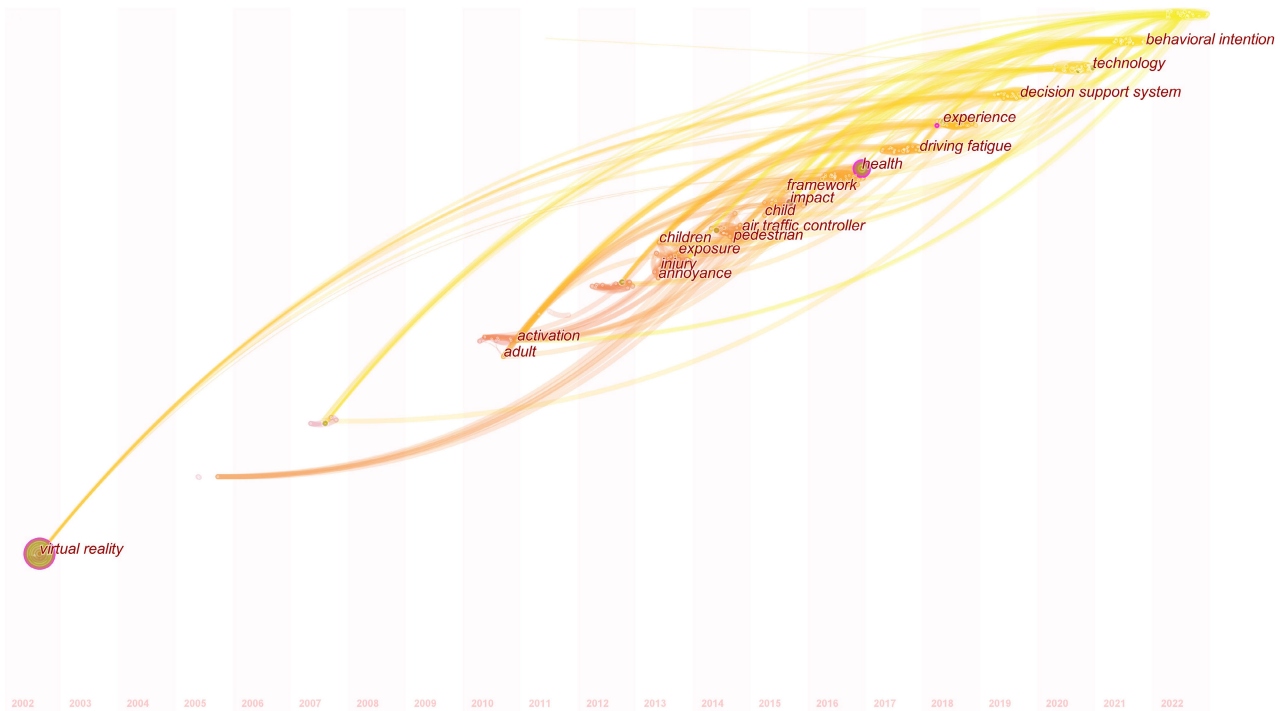


FIGURE 11. Cluster view of institutional collaborations between 2002 and 2022.

evaluating new human-computer interaction technologies is contributed by design thinking and the increasing scholarly attention towards methodological rigor. This facilitates understanding the role of cognition in planning and managing a transportation system.

Previous works highlighted the Journal Impact Factor [109], H-index [110] and article-level metrics [111] to

describe the impact of research outcomes. Citation count as the number of times other authors have cited in their own work is considered as the traditional and one of the most reliable metrics to determine research influence [112]. Since the literature study is based on the article dataset taking two decades to accumulate scholarly communications, in this paper, citation count based on references from Web of



**FIGURE 12.** Temporal evolution of research keywords of references between 2002 and 2022.

Science Core Collections is employed to judge the impact of the individual research item. Aggregate statistics are therefore computed by summing up the citation counts of all research items belonging to the authors affiliated to the organizations from the corresponding country.

Figure 13 shows that the United States and China possess the greatest research impact, with counts of 815 and 543, respectively. They are followed by Pakistan and Norway. Europe as a whole obtain the largest regional impact contributed by research items supplied by authors from other member states such as Italy, Sweden, Germany and the Netherlands. It is worth noting that South Africa encounters a higher influence than most other countries, despite the fact that the majority of the continent it is located on has yet to see any publications. Along with Africa, South East Asia and South America hold the greatest potential for expanding research in the future.

## V. DISCUSSION

This section presents an integrated framework to summarize the research progress over two decades and outlines research questions amid technological innovations in the transportation and health sectors. Analyzing these future directions help strengthen the empirical approach to investigate the alternatives to satisfying mobility requirements without compromising individual health benefits.

### A. INTEGRATED FRAMEWORK

The literature study identified almost no synthesis efforts on interdisciplinary studies using participatory methods to provide a composite argument on how games for health

could assist in the planning and management of transportation systems. This study proposes a paradigm with the goal of cultivating a new frontier of systems sciences in order to provide health advantages. The model illustrates the tightly coupled processes between leveraging practical implications for the industrial sector and innovations in all aspects during the delivery of transportation services, as shown in Figure 13. By extending the previous framework in the context of the design process, in this article, the digital media would serve as the gateway to review the ontology, epistemology, and conceptual boundaries of transportation and health sciences, bridging the dichotomy between the technical and communicative rational perspectives [113]. This attempts to foster new design frameworks or the evaluation methods based on emerging technologies, enabled by the new structures of gamifications for eliciting knowledge from principals. The complexity of transportation systems calls for a metaphor allowing flows of meaning and observation of interventions in the virtual environment as the ‘safe container’. Since the traditional agency model in gaming simulation studies was frequently used for training and education purposes, in order to address the complex problems of transportation systems nowadays, pluralism shall be realized through serious gameplay to accommodate decision-making processes related to the planning and managerial disciplines.

Figure 14 presents the overall research process of game-based studies contributing to the advances of the research area in transportation and health between 2002 and 2022. It can be seen from the figure that the most relevant paradigm from a theoretical standpoint provides conceptual guidance to identify the health problem and the behavioral

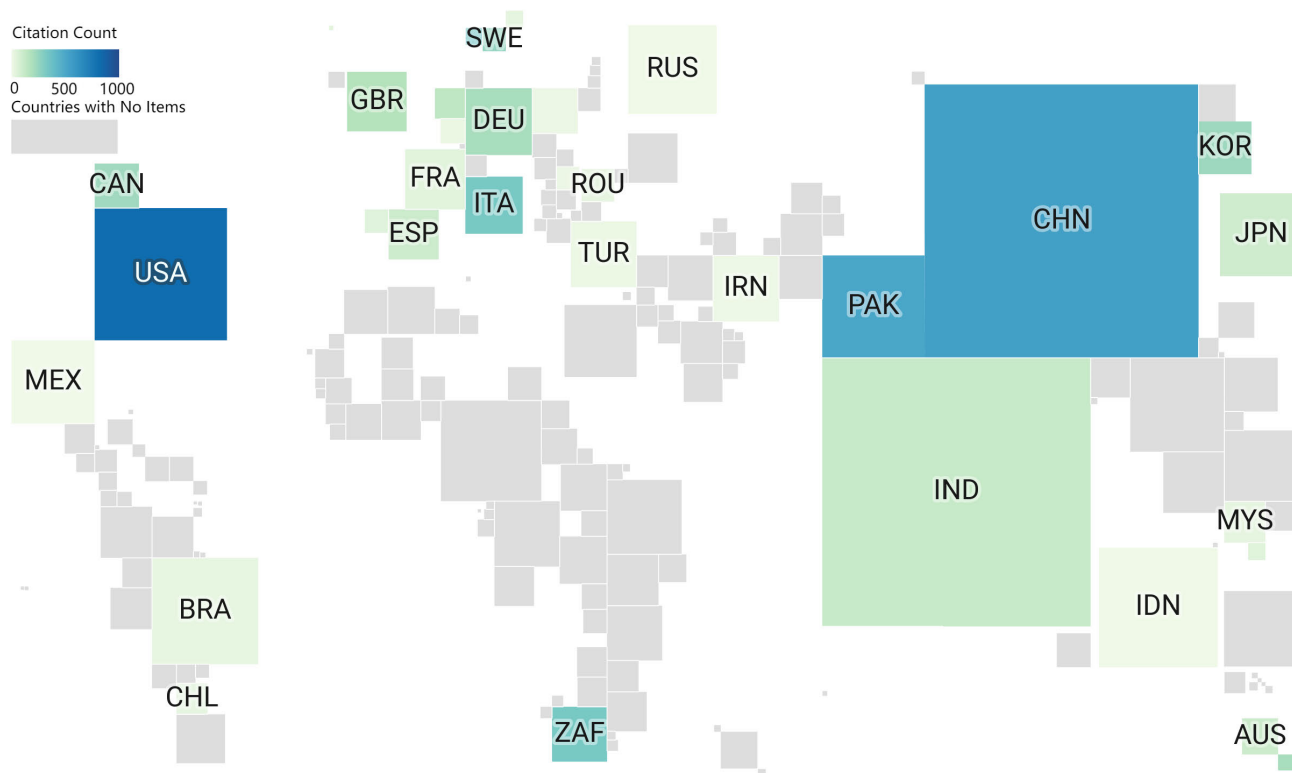


FIGURE 13. Country-wide statistics: impact of research papers between 2002 and 2022.

factors. Choice modeling and participatory simulation are previously integrated into research methodologies to deliver practical lessons as part of the debriefing session. At this point, it is worthwhile to note that the potential of games for health is demonstrated for the purpose of achieving the intended outcomes of the session, user experience, and engagement via advanced interface design. The third stage of the process involves the stakeholders exposed to planning and managerial consequences in a gamified scenario prioritizing hedonic motivation, utilitarian values, and agency. At this step, alternatives for visual design and assistance technology might be evaluated by usability studies enabled by the behavioral classification approach. Following this, in order to construct a mental model, an affinity diagram could be presented based on the similarity of the ‘tasks’ elicited from data collection, followed by clustering a ‘task tower’ and creating mental sets [114]. This delivered either shared or individual mental models in the form of abstract nodes.

**B. TECHNOLOGY ACCEPTANCE**

Previous research has highlighted the fact that the cost and efficiency of simulation and gaming projects may be a disadvantage for service providers, designers, and principals when it comes to the implementation [115]. Addressing usability concerns are the primary focus of the majority of the research that has been conducted on the topic of transportation and health. More specifically,

the study has focused on reducing the amount of discomfort and aggravation that people feel while dealing with transportation systems. The design of human-computer interaction interfaces, which takes into account the functional relationship between game components and mechanisms, as well as the influence that these parts exert on the possibility of obtaining the intended outcomes in planning and management activities, is the fundamental consideration of successfully conducting game-based research programs. However, there is a scarcity of discussions on this topic within the gaming simulation community. Because of the relevance of technology acceptability, principals are required to address the following research inquiries:

- What factors affect whether game developers outside the computing industry will adopt a game for health in the transportation sector?
- What are the design thinking prototypes for games in the field of health that may enhance traditional simulation methodologies like systems dynamics and agent-based simulation?

The authors anticipate that the gaming simulation community will realize the practical implications of solving the second research question as a result of the current implementation of hybrid models that are driven by agent-based simulation [116] and system dynamics [117] and the recognition of co-design as reasonable strategy for renovating public areas that are not accessible by motorized vehicles [118].

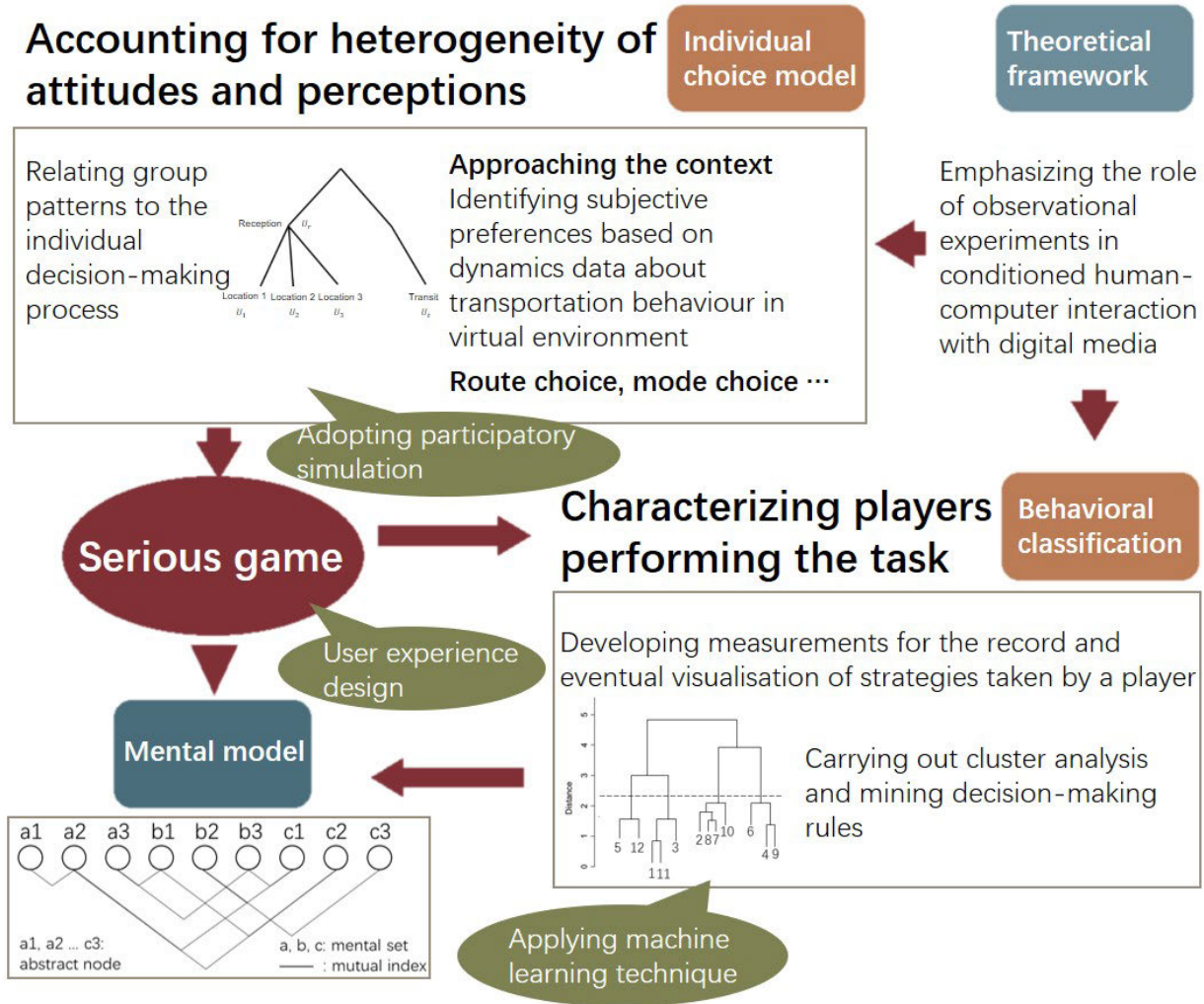


FIGURE 14. Integrated research framework as the summary of the research progress between 2002 and 2022.

C. GAMIFICATION

Design features like as points, badges, and leaderboards are frequently seen in modal-shift projects. Once functional prototypes of games are transferred to mobile application products, the optimal combination of these features may become important study fields if there is no need to accurately calculate indicators. They continue to fulfill a vital function when used in conjunction with other design elements such as avatars and narratives. The principles of gamification are not well explained in the existing body of literature. This limitation is referenced in prior research on transportation interventions:

- Different studies have investigated the impact of gamification on users' behavior but, in general, they do not analyze how to effectively elicit players' preferences to tailor-design gamification mechanics. In fact, gamification per se is not necessarily capable to induce the desired results, but needs to be tailored according to users' preferences [119].

Mobile apps, such as Pokémon Go, in the transportation and health sectors inspire tourists to explore other locations

outside their typical areas of interest. The human-computer interaction approach does not sufficiently address the usability concerns, as researchers prioritize the design features less and focus more on the business model [120]. Given the difference between serious and entertainment games, the question to answer would be:

- How will designers ensure a balance between hedonic and utilitarian values?

D. CO-DESIGN

In order to enhance the performance of the working staff, simulations have been evaluated by the European Civil Aviation Council in the 1980s as an effective medium for training non-technical skills. These simulations have since been adopted in various industries, such as marine transportation, railways, and healthcare, for safety management training. Non-technical skills training based on the expert performance method was first introduced in the field of anesthesiology [122]. Presently, the majority of studies addressing health issues in transportation stick with group negotiation, coordination, and cooperation in

escalating scenarios. However, only one study examines the whole workflow as a co-design practice [123]. The literature has not recommended incorporating stakeholders in the development and feasibility assessments of games as new knowledge into the design domain. The authors propose two research questions in order to reflect the need for developing products, services, and systems that are in line with the latest developments in transportation and health:

- Who will configure the design strategies, resemble the resources according to the design context, and oversee the design process in the creation of games for health ?
- What is the role of co-design in fostering connectivity?

### E. CONTEXTUAL RELEVANCE

Understanding mobility patterns is essential for effectively planning and managing transportation systems. However, the underutilized infrastructure and being exposed to public hazards are still problems globally [124]. Butnaru-Troncota's research on 'Green Gamification' highlights the need for innovative and effective policy solutions to achieve a significant decrease in total CO<sub>2</sub> emissions. Tsirimpa et al. conducted a study on the changes in ridership in European cities [125]. They discovered that the use of multiple modes of transportation by passengers was influenced by a reward system that was included into a domestic travel app. To effectively adopt paradigms that may lead to significant changes in travel chains, it is crucial to assess the impact on public health and the spatial-temporal distributions of current transportation activities. Subsequently, the following research inquiries must be tackled:

- What effect will the use of participatory methods, such as serious gaming, have on the traffic flows?
- How can stakeholders tackle the issue of imbalanced phenomena in passenger and freight transportation when using games for health as a tool for planning and management?

### F. SOCIAL SUSTAINABILITY

Transportation and health stakeholders are also interested in studying the design of social-technical systems steered by digitalization. There has been a growing interest among scholars in the field of last-mile delivery [126] and the provision of services similar to Uber [127]. Currently, service providers devote their own resources to the vehicle-sharing platform without the chance to establish social connections. Rubin and Bertolini's findings indicate that traveling to visit family members in person offers a wide range of social and individual advantages [128]. However, the impact of customer satisfaction, affordability, and other context-dependent factors on the use of interactive media for social sustainability is still unclear. Monila et al. concluded the implications of innovative services:

- Values are related to loyalty in the sense that passengers support the service they use most, but Corporate Social Responsibility does not influence a first choice [129].

The research falls short to provide evidence on the extent to which serious games on travel apps may help to the sustainable operation of transportation networks. From the standpoint of emergency transportation, stakeholders may perceive that rivalry brought by game features might potentially result in a deteriorating work environment, making it more challenging to allocate resources on a regular basis [130]. To tackle these challenges, a wide range of research inquiries must be examined, such as:

- How might participatory methods alleviate capacity bottlenecks in the transportation sector?
- How can games for health effectively demonstrate sustainability issues to stakeholders?

### G. CONCLUSION

This study presents a catalogue of previous games for health, especially those designed for the planning and management of transportation systems. The progress over two decades consisted research efforts covering a wide variety of health-related issues, the contribution of theoretical frameworks, the implementation of qualitative, quantitative, and mixed-method approaches, as well as the proposal of design improvement strategies. The frequently deployed game mechanism and digitalization technique illustrate that the findings might also extend to other industrial settings, with the gaming outcome easily transferring innovations into real-world scenarios. The profiling methodology, as employed by the previous synthesis on healthcare simulation, was applied throughout the literature study to critically evaluate application-oriented, methodological, and review articles, summarizing the findings of nearly one hundred top-notch research papers from the Web of Science Core Collections database. The integrated framework and the research agenda for future studies contribute to the previously unexplored theoretical explanation on gaming outcomes.

Since this literature study is pioneering in this area, a critical reflection on the research progress outlines an array of research questions in games for health in general and for the knowledge acquisition of planning and managing transportation systems in particular. Topics including technology acceptance, gamification, and co-design are proposed – this aligns with the need for transportation services to be contextually relevant and socially sustainable. Further investigations are expected to continue offering a user-centric experience and take an innovative approach to explore possible formats of human-computer interaction to achieve intended outcomes of game-based sessions. In addition, more qualitative studies should gather experiences and perceptions rather than pure descriptions of the player's trajectories in the adaptive learning system; they shall facilitate an in-depth understanding of cultural and context-dependent factors leading to potentially very different situations at the individual level. The application of grounded theory and ethnography, which have remained largely underexplored in the literature, would help address the dichotomy of perspectives and bridge both communities.

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