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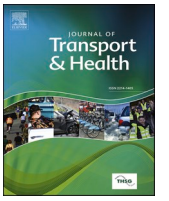

Serious gaming to co-create a value-based mobility mix in a multi-objective arena

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ABSTRACT

Introduction: The world is facing multiple challenges, e.g. in the realm of health, urbanization, climate change and social inclusion. Mobility can be part of the problem yet has the potential to be part of the solution. Serious games can support decision-making in a complex environment. This paper describes a serious game that aims to stimulate individual learning of (future) professionals in transport and urban planning, and facilitate discussions on goals and arguments concerning different (new) mobility options.

Methods: This paper presents the first version of the serious game: 'the Optimal Mobility Mix'. This card game was developed and played in five sessions in the Netherlands, India and the USA with over 100 participants. Feedback was collected informally in a debrief, through a survey (N = 25) and through observation.

Results: During the game, participants formed small groups and collaborated to select a mobility mix using playing cards that aligned with the five societal goals (effective mobility, efficient city, economy, environment & health and equity), of the 5E framework (Van Oort et al., 2017). The survey indicated that the game was highly interactive, fun and relevant. Although the game's 'reflection of reality' scored relatively low, it still remained positive.

Conclusions: Overall, the game successfully facilitated discussion on societal goals and transportation modes and appears positive on its learning objectives. The effect of the game in policy and decision making practice will be tested in future research. Striking a balance between capturing the complexity of reality and creating an accessible and flexible model for professionals to interact with – in the form of a game, is an ongoing challenge. Future developments aim to involve key players and broader planning-related policies through a codesign process with game design iterations. To support this process, observations and recordings can be intensified to improve feedback processing.

1. Introduction & societal context

The world is facing multiple grand challenges, for instance in the realm of health, urbanization, climate change and social inclusion. In these challenges, mobility can be part of the problem yet has the potential to be part of the solution. Motorized transport emits greenhouse gases accounting for around a quarter of the EU's total GHG-emissions. Just over 60% of this share is emitted by cars

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(European Commission, 2020, p. 141). Motorized transport also lowers air quality, increases noise levels and reduces road safety, affecting citizens' health.

On the other hand, transport is crucial for our economies and wellbeing. The mobility system is what connects people and goods to places (e.g. housing, offices, industry). Therefore, an effective and attractive mobility system has the potential to provide equal and affordable access to goods and services for all, without harming the natural environment. Particularly active modes may improve both mental and physical (e.g. cardiovascular) health (Nieuwenhuijsen and Khreis, 2016).

Considering these pros and cons and the fact that space and resources are limited, trade-offs on how to design the mobility system have to be made. These grand challenges can only be tackled by integrated solutions that acknowledge the complexity of the challenges faced and the range of stakeholders involved in the multi-objective policy arena (Bertolini, 2012).

A mobility system may not only support transport related goals (e.g. accessibility), but also different, wider goals and ambitions, for instance including health, land use, sustainability and equity (Van Oort et al., 2017), serving both the transport users and wider societal needs. Governments play an important role in developing mobility systems on a local, regional and (inter)national level. However, it is often unclear how and which trade-offs could be made by governments, and how and which values of stakeholders may be incorporated, in order to support transition to an optimal mobility system.

Serious games can enhance stakeholder engagement, learning, consensus and awareness building (Ampatzidou and Gugerell, 2019). We created a game to assist policy makers and university students in decision-making, guided by different goals a mobility system may deliver. The underlying research question addressed in this paper is:

> "How can an individual cognitive learning game for (future) transport and urban planning professionals be designed and enhanced to serve its learning purposes, and what can other game developers learn from this process?"

The goal of our game is therefore to support learning through discussing, exploring and informing policymakers and (future) professionals about the potential (wider) goals of transport systems, as well as the potential contribution of all (emerging) modes and services.

This paper first explains the research context in section 2. Next, the development of the serious game: 'the Optimal Mobility Mix' is presented in section 3. In section 4, various gaming sessions are described and the collected feedback presented. Finally, using insights from research on serious game development and (mobility) transitions, an approach for further development in co-creation with the end-users is presented as part of the conclusions & discussions in section 5.

2. Research context: serious gaming, mobility system and transition

Serious games use simplifications of reality and can be used for different purposes (Peters and Van de Westelaken, 2014). This section introduces relevant serious gaming theory (paragraph 2.1), as well as different frameworks and insights from practice to describe the real-world context for the game (2.2 and 2.3).

2.1. Serious games and learning

Serious games can serve a range of purposes, both for research and practice. Serious gaming is considered a tool to enhance stakeholder engagement, learning, consensus and awareness building, according to Ampatzidou and Gugerell (2019). Similarly, Mayer et al. (2004) describe three purposes of a gaming approach: research, intervention and learning. *Research*-focused games enable its developers to study participant-game interactions. *Intervention* games support strategic policy-making, engaging real (or represented) stakeholders to address actual challenges through 'open' games, where outcomes emerge from social interactions. The game discussed in this paper primarily facilitates *learning*. In such games, in a simplified, safe environment, participants can explore and understand new systems or policies, encouraging experimentation and reflection on the results.

This purpose of *learning* is most applicable for the aim of the game: for its players to learn through discussion and decision-making about goals and arguments concerning different (new) mobility options. In section 3, the game design is presented.

Many types of games that serve the purpose of learning exist. For this game, the focus is on *cognitive* learning (Den Haan and Van der Voort, 2018). Such cognitive learning can take place at various levels, e.g. individual, group-based or network level (de Kraker et al., 2021; Flood et al., 2018; Vallat et al., 2016; Van Bilsen et al., 2010).

Often learning is limited to the involvement of stakeholders in playing the game only. However, in line with Mildner and Mueller (2016), we recognize the added value of involving stakeholders in *cocreating* games. Therefore, in this paper we assess three types of potential added values that can be generated through interaction with stakeholders during game development (Ampatzidou and Gugerell, 2019; Winn, 2011). Those are: input for the rule set, input for functioning of the structure, and input for embedding in the context. This will be further discussed in section 2.2. (context) and 2.3 (ruleset and structure).

2.2. The context of a transition of the mobility system: 5E framework

This subsection provides building blocks to help understand the real-world context and complexity of developing the mobility system. Berger et al. (2014, p. 307) explain how the concept 'sustainable mobility', may become diluted as an increasingly broad range of definitions is used, with the risk of becoming meaningless and offering little guidance for policy-makers and scientists. An effort was made by Van Oort et al. (2017) to create a conceptual model that specifies various potential goals of the mobility system (see Fig. 1). They argue that in transport (e.g. planning and assessment of infrastructure projects and services) the focus is mostly on direct mobility

impacts such as travel time gains, while projects often have wider (desired) impacts. The 5E model addresses all these potential goals and impacts and can be summarised as follows.

1. *Effective mobility* – Effectiveness of transport and mobility, such as speed and reliability of services (e.g. Anderson and Daganzo, 2019).
2. *Efficient city* – Suitability of spatial use and spatial/urban (re)development (e.g. Knowles and Ferbrache, 2015).
3. *Economy* – Prosperity and wellbeing in/for cities. (e.g. Hensher et al., 2021)
4. *Environment & Health* – Decreasing carbon footprints; sustainable cities; climate impacts; air quality and healthy lifestyles, lifecycle impacts (e.g. Kapetanović et al., 2019)
5. *Equity* – Inclusive mobility, accessibility for all (e.g. Durand et al., 2023)

The extent to which every E is considered to be important differs per government and case and is part of the political discussion. Trade-offs have to be made and priorities have to be set. Sometimes, the different E's conflict and prioritizing different E's will lead to other policies and design of infrastructure and services. The 5E model proved to be valuable in multiple transport projects to find and balance costs and benefits, such as bicycle and transit projects (Van der Bijl et al., 2018). More details and examples of all E's, including the embedding in appraisal schemes can be found in van Oort and Yap (2021).

When we move from the 'why' of goals, to the 'how' of implementation, a framework by Van Nes (2002), that describes the mobility system helps to guide policy planning and action. According to this model the passenger transport system consists of three layers: passengers, vehicles and infrastructure (see Fig. 2). The top layer are the passengers and their travel patterns whom define the transport demand. To facilitate this demand, transport services are offered, using a variety of vehicles (middle layer). These are supported by the bottom layer: the traffic networks, which are defined by their infrastructure. In a balanced situation, this transport supply equals the traffic demand that is facilitated by traffic networks via infrastructure.

This model can help to structure the different policy instruments and design choices that policy makers may have to shape the transport system on all three levels, aiming at the goals as addressed by the 5E model. As a serious game uses elements of the real world, a mix of all three may be included.

2.3. Changing the mobility system in practice

Considering the challenges and opportunities mentioned in the introduction of this paper, a change of the mobility system is desirable. However, change is complex. In their paper, Berger et al. (2014) describe various challenges that make transition to a more sustainable mobility system complex. These include the various technical sub-systems (vehicles, infrastructure and energy) each with their own vested interests, as well as a policy focus on efficiency rather than alteration and reduction of certain modes.

In addition to sustainability (part of the E of 'environment & health'), the mobility system encompasses other goals as described with the 5E model in the previous paragraph. These can conflict due to real-world constraints such as budget, stakeholder interests and physical space. Local, regional, and global objectives each come with their own goals, complexities, stakeholders, and measures. On a local level road safety and air quality may be high on the agenda, whilst nationally economic competitiveness and CO_2 emissions are top priorities. Achieving integrated decision-making is thus challenging. Some examples can illustrate these multi-objective topics.

Fig. 1. The 5E framework.

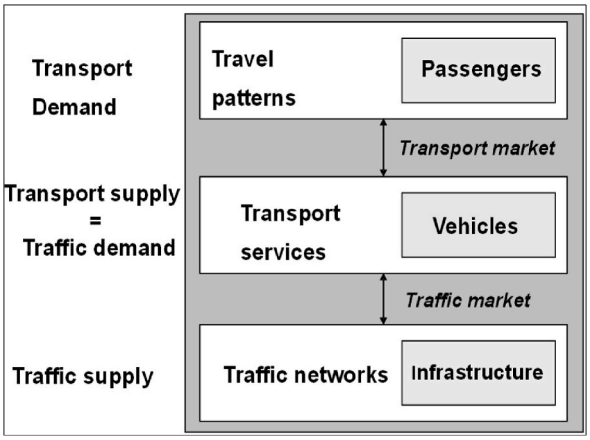

Fig. 2. TRAIL Layer model (Van Nes, 2002).

- Transport (including logistics) is responsible for around a quarter of CO_2-emissions worldwide. Switching to electric cars will decrease emissions (E: Environment & health) but take up as much space as ICE cars. This is often public space, which is particularly scarce in an urban context (E: Efficient city) or private space which may drive up housing prices and thus living expenditures (E: Economy and E: Equity).
- Safety (E: Environment & health) is a priority for policy makers worldwide. This leads to policies on lowering traffic speeds and changing infrastructure to slow down cars and give space to other modes. However, the effect may be negative on (car) travel time (E: Efficient transport) and decrease access - typical indicators for economic opportunities.

The context and complexity touched upon in this paragraph was taken into account for developing the serious game, to achieve its aim.

3. Game design

To explore, discuss and learn from the complexity of decision making and design in mobility systems, a serious game was developed in late 2022: 'the Optimal Mobility Mix'. The game serves as an interactive method to clarify and discuss goals (using the 5E's), as well as consider the multi-objective nature and diverse range of (emerging) transport services and vehicles. The target audience includes policy makers and (future) professionals (including university students) involved in transport and land use planning. It was developed by a small group of researchers using one feedback loop. In Spring (2023), a first version of 'the Optimal Mobility Mix' was played in five different sessions. The main purpose is 'gaming as learning' (Mayer et al., 2004), and more specific individual cognitive learning, as described in paragraph 2.1.

3.1. Theoretical basis for the game

The goal of the game is to support learning through discussing, exploring and informing policymakers and (future) professionals about the potential wider goals of transport systems, as well as the potential contribution of (emerging) modes and services. Based on

Fig. 3. Different cards in the game. See appendix A for an overview of all included modes.

our experiences in gaming and the field, we tentatively assume two things. First, that by making both goals and underlying arguments for various options explicit through group discussion stakeholders are better equipped to develop more optimized mobility systems in practice. Second, we assume that exploring and discussing the positive or negative impacts of (new) modes and services better integrated transport planning and policy may be reached.

To reach this objective, the game stimulates *individual* cognitive learning, using concepts and elements that are related to individual understanding of the mobility system - and potentially reframing that understanding. As a crude way to understand this mobility system, the focus is on the middle layer of the TRAIL layer model (see section 2.2): a mix of transport services and vehicles.

3.2. Game elements: transport services to create the 'optimal mix'

About 35 modes and services are presented on cards, which are randomly divided amongst game participants. Fig. 3 below shows an example of some cards. Every card presents one mode and the 5E framework, supporting the participants to think in a wider context. The total choice set depends on the selected case study area and aggregation level. See appendix A for a list of all modes and services included in the game.

In addition to traditional modes, such as cars, bicycles and public transport, also emerging modes and technologies are included, for instance electric propulsion of different vehicles, air mobility and ride-hailing. Also a small number of non-vehicles are included, such as teleworking, as a popular form of non-mobility (Ton et al., 2022). Furthermore, the card deck includes a number of shared (micro) mobility options. Over the past decade, the concept of sharing of services or products has attracted a lot of attention. Although sharing itself is nothing new, the development of IT and online platforms has provided the infrastructure that allows for new ways of sharing while also facilitating older ways of sharing on a scale never seen before (Belk, 2014). A growing body of literature is exploring how shared mobility services can help solve transportation problems related to congestion, parking, sustainability, and accessibility (Montes et al., 2023; Torabi et al., 2021; Van Marsbergen et al., 2022). Finally, to ensure that there is room to also consider local specific modes, the game contains "Joker" cards, with which participants can add a mode of interest.

3.3. Ruleset and structure of the game

Our serious game has three parts. A gaming workshop begins with a plenary brief in the form of an interactive presentation by the facilitator. Next, the actual game is played in smaller groups of 4–6 people. The workshop ends with a plenary debrief, where lessons learnt and experiences are shared amongst the groups, both regarding the wider goals and the modes and services discussed.

The game participants have to imagine being in charge of the mobility system for a predefined case study area (e.g. a city or region) in a specific moment in time (e.g. today or in 2040). They have to decide in their group what they consider the most important goals of the total transport system for their case and what optimal mix of vehicles they want to facilitate/stimulate to achieve these goals. The game encourages them to discuss both these goals and modes and forces them to make decisions together. Doing this, the game participants are provided with an opportunity to learn about (each other's) arguments and assumed impacts regarding societal goals and modes. Such learning could support them in the process of dealing with multiple perspectives, objectives and multimodal solutions.

Fig. 4. Rules of the game presented in a scheme.

The rules and structure of the game are presented in Fig. 4 below. A game exists of multiple rounds. Per round, one mode is selected from the cards that are open on the table. Participants make this decision together, based on what they argue is the mode most supportive of a pre-determined goal (one of the 5 E's).

Due to the randomness of the order of cards, in every group and in every round, different games are played. Each turn, participants are unknowing of the card they will open. This aims to spark creativity when reasoning out loud the way in which a mode may (or may not) support the selected goal. Only the first participant per round is allowed to select a goal that he or she feels the drawn card may support best. All participants are encouraged to explain their mode. Particularly during the selection of cards (step 4 in Fig. 4 above), a discussion may arise on what mode supports a certain E the best. For instance the contribution of a hyperloop versus a night train regarding equity, or walking vs. working from home, concerning environment.

4. Results: game playing and collected feedback

Since its creation and testing from end 2022 – Summer 2023, five gaming sessions have been played. As explained above, we focused on the cognitive learning, and therefore applied questionnaires and observations to record experiences of the players and facilitators (see Den Haan and Van der Voort, 2018). The first two sessions only included informal feedback, via the facilitator at place. In the last three sessions, feedback was collected via a short online survey, see appendix B for the survey questions. The survey were inspired by the MEEGA + model (Petri et al., 2018), that is often used for evaluating educational games for computer education and tailored to fit the target audience and studied game. This section of the paper briefly describes the sessions and presents the received feedback in detail.

4.1. Five gaming sessions

The five international gaming sessions were played with professional stakeholders or students. All games were played with at least one author of this paper being the facilitator whom also delivered the brief and debrief. The sessions were done in person and held in spacious rooms that allowed the facilitator to move around freely to observe and answer any arising questions, see Fig. 5 for an impression. The sessions are briefly described below.

- With around thirty different policy makers from municipalities in the Province of Zuid-Holland, the Netherlands, the game was played as part of an afternoon long session on mobility transition. The selected case was the commuter area of Katwijk close to the city of Leiden. The area houses around 80,000 people. Participants were asked to consider a transport strategy for 2025. Groups of five players were formed and informal feedback was gathered.
- In India, forty transport planners from the state of Karnataka played the serious game with the case study Mysore, a city of one million inhabitants. This session was part of a capacity building design week on cycling infrastructure, organized by the Dutch Cycling Embassy. Informal feedback on the game was collected.
- At the Urbanism Next Conference in Portland, USA, a mix of policy makers and researchers played the serious game. The case study was a new development in East-Portland, an area with 171,000 inhabitants. In addition to informal feedback, Formal feedback was collected via the online survey directly after the session.
- As part of a public transport course, a dozen graduate students participated in a serious game at Delft University of Technology, the Netherlands. They worked in three groups of four to five students each, focusing on the metropolitan region of The Hague – Rotterdam. Formal feedback was collected directly after the session via the online survey, in addition to informal feedback.
- As part of a transport training week, a dozen professionals played the game with the mobility system of Amsterdam (where the session took place) as a case. Here too, participants were asked to fill out the survey and informal feedback was gathered as well.

In total, over hundred professionals and students played the game. For all games, Informal feedback was collected directly after the

Fig. 5. The game in action in sessions in the Netherlands and India. Pictures taken by author/shot from promotional video from the 'Cycling Infrastructure for Urban Environments' projects in India.

game by the facilitator(s) in both the plenary debrief and individual talks with the players and teams. The facilitators also observed the participants during the game, discussions and results and made notes of it. The survey was filled out by 25 participants.

4.2. Feedback on game: participant interaction

Feedback was collected informally as well as formally at the end of the sessions in a survey. The most interesting findings are presented in this paragraph. In all sessions, the participants played sufficient rounds to have discussed all 5Es and to create an 'optimal mix'.

4.2.1. Informal feedback and observations

Based on the facilitators observations and feedback, participants clearly enjoyed playing the game and recall it vividly. Note that in most of the examples described in this paper, the game was part of a longer conference day or training week, perhaps making it stand out next to lectures et cetera more similar in style.

People appear to be naturally competitive and want their group members to select 'their' card as part of the mobility mix. This lead to a number of fierce pitches, where the level of sound arguments differed per group (e.g. professionals were more knowledgeable than students), but which often lead to new perspectives. Students seemed to be more open to think outside the box than policymakers, who often already have a position in political discussions. To help teams with the selection of one card for their mix, the cases in the briefing were often decisive. This also made the link to reality more tangible. Game improvement can particularly be made at the debrief. This is where the link to the reality outside and daily practice can be made more explicitly (Zigmont et al., 2011).

The game was played on multiple continents, and the results had some specific accents accordingly. While in India, the focus was

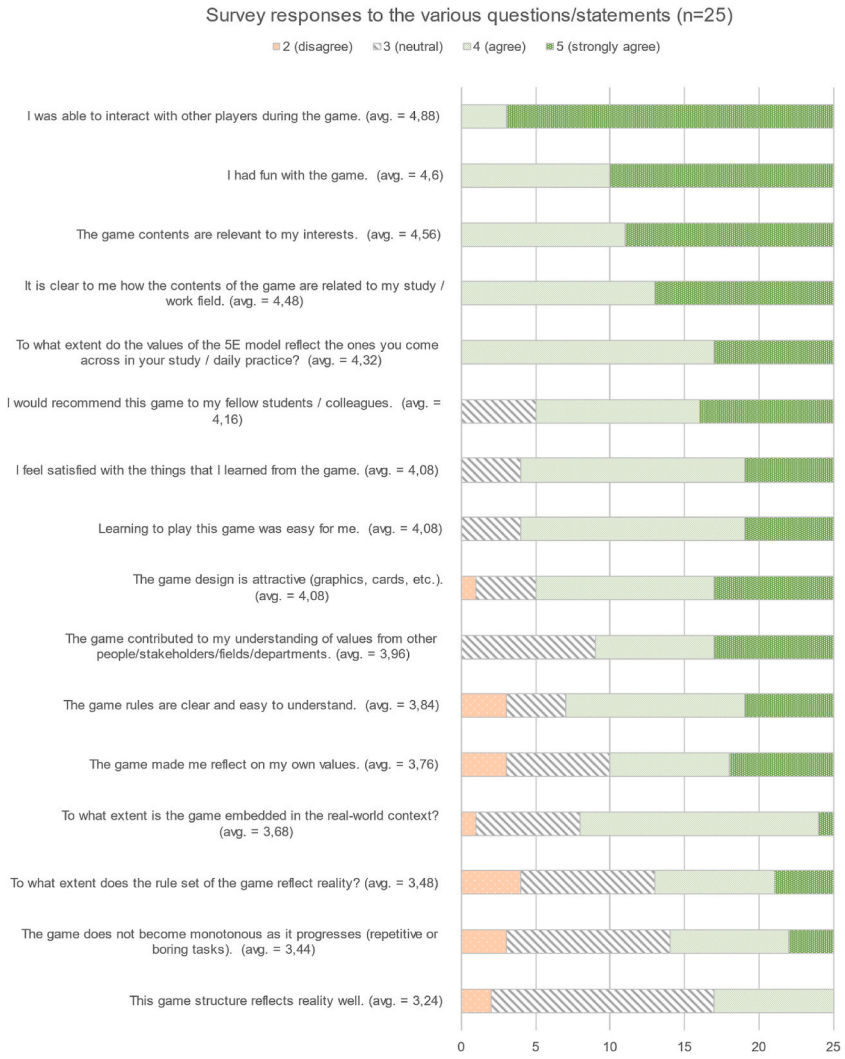

Fig. 6. Results from survey amongst game participants, responses to Likert scale questions.

much on equity impacts: stimulating a transport systems that could serve all people of a society, in the Netherlands the discussions focused on a good mix of modes, to guarantee accessibility in all areas. In the workshop in Portland, USA we also observed more attention to equity than in Europe. There we also noticed more arguments in favor of emerging high-tech modes like autonomous vehicles, as means to serve the goals of equity and effective cities. In the session with students, more attention seemed to be given to the topic of environment & health which led to the selection of multiple active modes in the resulting mixes and arguments related to health as well as space usage. Indicating that perhaps the gamers age or generation plays a role too. In India, active modes got less attention, and more opportunities were found with public transport. There we observed less interest in emerging modes.

4.2.2. Overview survey sample

In total, 25 game participants responded to the survey: 7 from the session in Portland, 10 TU Delft graduate students and 8 people from the training in Amsterdam. The total population consisted of 11 students and 14 professionals. In this last group, nearly half had 11–20 years of work experience. The majority of the sample (n = 13) indicated having played serious games "a couple of times", 10 of which were stated by participants from the students and workshop in Amsterdam. The large majority of participants (n = 23) filled out the questionnaire directly after they played the game, therefore we may assume a clear recollection of them playing the game.

Respondents were asked a total of 25 or 29 questions, for the game with students or professionals respectively. 16 of those were mandatory questions or statements, with a 5-point Likert scale ranging from 1 ('strongly disagree') to 5 ('strongly agree'). Fig. 6 gives an overview of the average scores and standard deviations per question/statement, sorted from high to low. Note that the sample is relatively small, nevertheless, they provide an indication for participants' opinions. See Appendix B for the full survey.

When breaking down the survey sample into smaller subgroups and their respective responses we can make a few more detailed observations. Note however that considering the small total sample size (N = 25) these findings may be considered illustrative but not conclusive. The following five subsample differentiations were analyzed: game session, USA-based vs Europe-based, studying vs working, years of work experience (with students as a sub category) and previous serious gaming experience. There is some overlap between these subsets: all 11 participating students were European (of which 9 Dutch) and 6 out of 7 respondents at the Portland session were USA-based – except for one European-based student. Those playing the session in Amsterdam had relatively much experience with serious gaming: 75% responded to have gamed "a couple of times", which was 52% on average.

4.2.3. Explorative analysis survey

The total averages indicate that all statements or questions score 3+ so better than 'neutral', with the lowest observed score (3.24) for the statement "This game structure reflects reality well". This reflection on reality is also captured by two other statements at the bottom five of the list. No participant has answered 'strongly disagree' on any statement. As was already observed informally, all participants agreed or strongly agreed with the statement "I had fun with the game". The same counts for player interaction and the relevance of the game content to people's interest and relevance which score high (all above 4.5 average).

The differences per game session were limited: all except two were less than 0.4 different from the average. When looking at work experience, the group aged 11–20 years (n = 6) is most positive and the group aged 0–10 years least. Students (n = 11) reported to find the game more monotonous and made them reflect less on their values than professionals (n = 14). Another noticeable difference was found for the statement "The game rules are clear and easy to understand" when comparing gaming experience. Those whom had never played a serious game before, scored this statement neutral (3.2 by n = 5) whilst those whom had either experienced a game once (n = 7) or a couple of times (n = 13) scored it 4.0. Possibly indicating that more gaming experience makes the game easier to understand.

Particularly large (partly overlapping) differences were found when comparing USA-based vs European-based participants. Participants from the USA scored every single statement more positively than their European counterparts. The statement: "the game made me reflect on my own values" even scored 1.2 points higher than the total average score of 3.8. Also when excluding students, USA-based professionals were still more positive yet slightly less (0.3 point difference vs 0.4) than European professionals. Except for the statement: "the game becomes monotonous as it progresses" which they felt less positive about.

Considering aforementioned overlap in samples (e.g. most students were in the TU Delft session and Europe-based), these outcomes might also be session and session-context related. For instance, whilst both the Portland and Amsterdam game were part of multiple-day trainings or conferences, the session with students was part of an average university day. Plausibly, a gaming session stands out more as 'non monotonous' in a range of presentations than in a lecture day at university.

The open questions all focused on direct feedback. They were not mandatory thus response is limited and relevant suggestions are included in the next paragraph.

4.2.4. Input on the ruleset, game structure and context-embedding

As described in paragraph 2.1, there are three elements of game improvement for which interaction with stakeholders is helpful: input for the ruleset, input for functioning the structure, and input for embedding in the context (Winn, 2011). From both the survey and the informal feedback, input was gathered on all these elements.

For the *ruleset*, the charm of its simplicity was mentioned in the open questions and also observed while gaming. All participants needed limited explanation and started to game quickly after the introduction. Even in India, where none of the participants were familiar with serious gaming in a transport planning context, the game was played well and appreciated. Learning from informal feedback, we changed the explanation of the rules from bullet-points on a slide read-out by the facilitator to a visual that was presented on a screen without verbal explanation (see Fig. 4 earlier). The main goal was to increase clarity on the purpose and prevent confusion within groups. Examples of the confusion included whether or not participants were allowed to see the cards before-hand. Feedback in the open questions mostly included suggestions to add financial constraints, like budgets or chips. Also, adding objective information

to the modes was suggested. This may also lead to a more realistic gaming experience (see embedding in the context) and be of particular value to players with less extensive knowledge on various modes.

The *structure of the game* did not receive much particular feedback. The 5E framework was clear and the selection of modes in the card deck was sufficient. A suggestion was to make the resulting optimal mobility mix consist of five modes maximum. Also, health and liveability could be more explicitly addressed when explaining the 5E goals. Particularly the session with students received survey feedback on the monotony of the game. This aligns with our observations as facilitators that people with less experience in the field may have more difficulty coming up with arguments from different perspectives, leading to repetitive argumentation. For such a target group, it could be of interest to add more context, interventions, roles or rules as the game progresses. Also, for specific game sessions, dedicated modes were added, such as the rickshaw in India. The aforementioned 'joker' card, was used only a few times by participants, and were used to add e.g. a shared cargo bike, a horse carriage and air balloon.

The third element: '*embedding in the context*' is a relevant point of feedback, considering its relatively low score on the Likert scale (the average scores on the three related survey questions lay between 'neutral' and 'agree'). Suggestions that can be linked to this element include adding a map of the geographical area of the case as well as our own observation to be more considerate about the debrief. Nevertheless, considering there is always a trade-off between reality and complexity, it will be important to reflect back on this particular games' objectives. In the outlook (paragraph 5.3), more ideas are shared. Feedback regarding the options in the cards were also given. As introduced by the model of Van Nes (2002) earlier, the cards in the current game focused mostly on transport modes and services. However, more system elements like spatial planning, regulations and digital alternatives to travelling may be included in the future to represent the wider range of the policy toolbox.

Finally, also a number of lay-out suggestions were made, including smaller cards so they fit better in one's hand and larger font of the 5E's on the cards, or perhaps described on a separate sheet.

5. Conclusion & discussion

In this paper, a serious game and its playing experiences in multiple contexts were introduced and discussed. The goal of this game is to support learning through discussing, exploring and informing policymakers and (future) professionals about the potential wider goals of transport systems, as well as the potential contribution of (emerging) modes and services.

5.1. Recap of context

Mobility can be part of the problem yet has the potential to be part of the solution for various societal challenges. In this paper we highlighted the opportunities and complexity of (changing a) mobility system(s), and the role of policy makers and (future) professionals. Two conceptual frameworks were presented. The 5E model was introduced to describe how a mobility system may support different goals including effective mobility, efficient city, economy, environment & health and equity (Van Oort et al., 2017), and the layer model to understand a mobility system's underlying components (Van Nes, 2002). Serious gaming can be a tool to help stakeholders understand complexity and reconsider their decision making process. When taking game participants' considerations and feedback into account, a game can improve further.

5.2. Results and feedback on the game

The game 'the Optimal Mobility Mix' presented in this paper was played in five sessions in the Netherlands, India and the USA with over 100 participants, both policy makers and (future) professionals (students). Feedback was collected informally in a plenary debrief after the sessions and in short conversations with the facilitator and formally in surveys in 3 sessions ($N = 25$). In addition, observations by the facilitators were reported. Overall, particularly interaction, fun and relevance scored high (both observed and informal feedback, and in the survey). In terms of the cognitive learning, the games' reflection of reality scored relatively low, although the majority of our sample still responded either neutral or positive on statements like 'This game structure/rule set reflects reality well'. Considering this game was played in different groups with different types of cases, it appears flexible and suitable for various international contexts, and spatial scales (e.g. huge metropolitans, cities or neighborhoods). The game was played on multiple continents, and the results had some specific accents accordingly, e.g. regarding the attention to equity (India), technology driven modes (USA) and active modes (the Netherlands). Students faced more challenges in cognitive learning, compared to the policy makers and professionals. Students' limited deep knowledge and experience in the field made overseeing and discussing the pros and cons of all modes difficult.

5.3. Outlook game development & relevance for policy makers and practitioners

The objective of the serious game described in this study is to support learning through discussing, exploring and informing policymakers and (future) professionals about the potential (wider) goals of transport systems, as well as the potential contribution of all (emerging) modes and services. We assumed that by making goals and the underlying arguments behind certain policies or plans explicit in a serious game, stakeholders are better equipped to design optimized mobility systems in practice. The main learning experience of the game participants is that mobility is a means, not a goal in itself. Too often particularly the goals are implicitly assumed equal amongst stakeholders, whilst that is not always the case, considering the complexity of both a mobility system and differences between stakeholders' agendas. With a framework such as the 5E used for this game, the goals and 'why' are actively

considered before the 'how'. The neutral to very positive reflections on the game in the survey may be taken as a positive signal that the game supports individual cognitive learning on this topic. A follow-up survey that for example tests understanding of the 5E model would strengthen this conclusion although it is difficult to rule out other lessons-learned during the period in between.

With regard to the added value of stakeholder involvement in the game design, we conclude that the feedback collected in the various played sessions, provide some valuable insights on possible refinements, on all three elements of game improvement: input for the ruleset, input for functioning the structure, and input for embedding in the context (Winn, 2011) Particularly to improve the link with daily practice and its complexity, it is vital to bring in those professionals who are working on the mobility transition daily and can signal where and how a serious game is of greatest value. An important example of such feedback included that livability (including health) could be added more explicitly to the game, as well as more modes that may go beyond the typical field of traffic engineering, such as legislation for low/zero emission zones or urban planning for proximity instead of mobility (e.g. mixed-use development, transit-oriented development, 15-min city). For the future development of this game, co-creation with a number of (key) players is desirable and planned.

The game, in its current form, serves the function 'learning' (see Mayer et al. (2004), through individual cognitive learning of the mobility system and the current and emerging transport modes. This serious game has the potential to be played in various contexts through its relatively simple yet effective structure/design: the case and set of cards can easily be adapted. It is of interest to further investigate how local variation may be included best.

Cognitive learning is provided through the game, being shaped through stakeholder interactions. We see, also in our game, that cognitive learning is intertwined with relational learning (Den Haan and Van der Voort, 2018): learning on the roles, values and perspectives of the other players and their arguments (see e.g. Souchère et al. 2010; Mayer et al., 2013). It is recommended to continue providing these engagement options for relational learning and further develop the approach to structurally provide stakeholders with opportunities to contribute. This will enable participants and game designers to learn from each other.

As a further research and development direction, the role of normative learning, which focuses on the shifting of paradigms and value sets (Den Haan and Van der Voort, 2018), could be explored further. Through repetition over a longer period the (changing) values of practitioners can be mapped and analyzed, revealing normative learning and moving beyond the common critique of games as a one-off experience (Flood et al., 2018). This would fit better the character of the mobility transition that society faces, that increasingly revolves around integral challenges of health and well-being. This broader perspective would mean that the game also transitions from an individual *learning* perspective to a group-based and network learning perspective (Laudien and Daxboeck, 2016) that supports the game as an *intervention* (Mayer et al., 2004).

Regarding the feedback collection and processing, observations and recordings will be intensified in future game sessions, for example by using audio recordings and player notes, and by extending the collection of surveys. These additions to the current formal and informal feedback methods, will yield better insights into the game experience and whether the goals of the game were met. It will also enable more in-depth analysis of the impacts of a specific structure, context, and ruleset. In addition, it makes it possible to investigate longitudinally the experiences with subsequent iterations of the game, as played in various contexts with varying player types.

Finally, to align better with the complexity of reality, not only the content of the gaming sessions is of interest, but also their timing in a policy making process or new department formations may be crucial when testing its impact. This means that When looking at serious gaming as an intervention, it's effectiveness will largely depend on this organizational context.

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Niels van Oort: Writing – review & editing, Writing – original draft, Conceptualization. **Tessa Leferink:** Writing – review & editing, Writing – original draft. **Sander Lenferink:** Writing – review & editing, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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References

Ampatzidou, C., Gugerell, K., 2019. Participatory game prototyping – balancing domain content and playability in a serious game design for the energy transition. CoDesign 15 (4), 345–360. https://doi.org/10.1080/15710882.2018.1504084.

Anderson, P., Daganzo, C.F., 2019. Effect of transit signal priority on bus service reliability effect of transit signal priority on bus service reliability. Transport. Res. Procedia 38, 2–19. https://doi.org/10.1016/j.trpro.2019.05.002.

Belk, R., 2014. You are what you can access: sharing and collaborative consumption online. J. Bus. Res. 67 (8), 1595–1600. https://doi.org/10.1016/J.JBUSRES.2013.10.001.

Berger, G., Feindt, P.H., Holden, E., Rubik, F., 2014. Sustainable mobility—challenges for a complex transition. J. Environ. Pol. Plann. 16 (3), 303–320. https://doi.org/10.1080/1523908X.2014.954077.

Bertolini, L., 2012. Integrating mobility and urban development agendas: a Manifesto, 10.1080/02513625.2012.702956, 48(1), 16–26. https://doi.org/10.1080/02513625.2012.702956.

De Kraker, J., Offermans, A., van der Wal, M.M., 2021. Game-based social learning for socially sustainable water management. Sustainability 13 (9), 4646.

Den Haan, R.-J., Van der Voort, M.C., 2018. On evaluating social learning outcomes of serious Games to Collaboratively address sustainability problems: a literature review. Sustainability 10 (4529). https://doi.org/10.3390/su10124529.

Durand, A., Zijlstra, A., Hamersma, T., Hoen, M., Van Oort, A., Hoogendoorn-Lanser, N., Hoogendoorn, S., 2023. "Who can I ask for help?" Mechanisms behind digital inequality in public transport Cities. https://doi.org/10.1016/j.cities.2023.104335.

European Commission, D.-G. for M. and T, 2020. EU transport in figures - statistical pocketbook 2020. https://data.europa.eu/doi/10.2832/491038.

Flood, S., Cradock-Henry, N.A., Blackett, P., Edwards, P., 2018. Adaptive and interactive climate futures: systematic review of 'serious games' for engagement and decision-making. Environ. Res. Lett. 13, 063005 https://doi.org/10.1088/1748-9326/aac1c6.

Hensher, D.A., Truong, T.P., Mulley, C., Ellison, R., 2021. Assessing the wider economy impacts of transport infrastructure investment with an illustrative application to the North-West Rail Link project in Sydney, Australia. J. Transport Geogr. https://doi.org/10.1016/j.jtrangeo.2012.03.009.

Kapetanović, M., Oort, N. van, Nunez, A., Goverde, R., 2019. Sustainability of railway passenger services: a review of Aspects, Issues, contributions and challenges of Life Cycle emissions. In: 8th International Conference on Railway Operations Modelling and Analysis (ICROMA), Norrköping, Sweden, June 17th – 20th, vol. 69, pp. 548–567, 2019.

Knowles, R.D., Ferbrache, F., 2015. Evaluation of wider economic impacts of light rail investment on cities. https://doi.org/10.1016/j.jtrangeo.2015.09.002.

Laudien, S.M., Daxboeck, B., 2016. Value creation networks, knowledge co-creation, and the foundation of dynamic capabilities–insights from an organizational learning perspective. Journal of Competence-based Strategic Management 8, 83–106.

Mayer, I.S., Carton, L., de Jong, M., Leijten, M., Dammers, E., 2004. Gaming the future of an urban network. Futures 36 (3), 311–333. https://doi.org/10.1016/S0016-3287(03)00159-9.

Mayer, I., Zhou, Q., Lo, J., Abspoel, L., Keijser, X., Olsen, E., Nixon, E., Kannen, A., 2013. Integrated, ecosystem-based Marine spatial planning: design and results of a game-based, quasi-experiment. Ocean Coast Manag. 82, 7–26.

Mildner, P., Mueller, F., 2016. Design of serious Games. Serious Games 57–82. https://doi.org/10.1007/978-3-319-40612-1_3.

Montes, A., Geržinic, N., Veeneman, W., Van Oort, N., Hoogendoorn, S., 2023. Shared micromobility and public transport integration-A mode choice study using stated preference data. Res. Transport. Econ. 99 https://doi.org/10.1016/j.retrec.2023.101302.

Nieuwenhuijsen, M.J., Khreis, H., 2016. Car free cities: Pathway to healthy urban living. Environ. Int. 94, 251–262. https://doi.org/10.1016/J.ENVINT.2016.05.032v.

Peters, V., Van de Westelaken, M., 2014. Simulation Games – a concise introduction to the design process. In: http://www.samenspraakadvies.nl/publicaties/Simulation/20games/20-an/20introduction/20to/20the/20design/20process.pdf.

Petri, G., Gresse, C., Wangenheim, V., Ferreti Borgatto, A., 2018. MEEGA+: A Method for the Evaluation of Educational Games for Computing Education. www.incod.ufsc.br.

Souchère, V., Millair, L., Echeverria, J., Bousquet, F., Le Page, C., Etienne, M., 2010. Co-constructing with stakeholders a role-playing game to initiate collective management of erosive runoff risks at the watershed scale. Environ. Model. Softw. 25, 1359–1370.

Ton, D., Arendsen, K., De Bruyn, M., Severens, V., Van Hagen, M., Van Oort, N., Duives, D., 2022. Teleworking during COVID-19 in The Netherlands: understanding behaviour, attitudes, and future intentions of train travellers. Transport. Res. Pol. Pract. 159, 55–73. https://doi.org/10.1016/j.tra.2022.03.019.

Torabi, F., Araghi, Y., Van Oort, N., Hoogendoorn, S., 2021. Passengers preferences for using emerging modes as first/last mile transport to and from a multimodal hub case study Delft Campus railway station. Case Studies on Transport Policy 10 (1), 300–314. https://doi.org/10.1016/j.cstp.2021.12.011.

Vallat, D., Bayart, C., Bertezene, S., 2016. Serious games in favour of knowledge management and double-loop learning? Knowl. Manag. Res. Pract. 14 (4), 470–477.

Van Bilsen, A., Bekebrede, G., Mayer, I., 2010. Understanding complex Adaptive systems by playing Games. Inf. Educ. 9 (1), 1–18.

Van der Bijl, R., van Oort, N., Bukman, B., 2018. Light Rail Transit Systems: 61 Lessons in Sustainable Urban Development. Elsevier.

Van Marsbergen, A., Ton, D., Nijënstein, S., Annema, J.A., Van Oort, N., 2022. Exploring the role of bicycle sharing programs in relation to urban transit. Case Studies on Transport Policy 10 (1). https://doi.org/10.1016/j.cstp.2022.01.013.

Van Nes, R., 2002. Design of Multimodal Transport Networks: A Hierarchical Approach. Delft University Press. https://repository.tudelft.nl/islandora/object/uuid%3A1da0e395-c39f-4450-b070-06fc5738ad38.

Van Oort, N., vd Bijl, R.A.J., Verhoof, F.C.A., 2017. The wider benefits of high quality public transport for cities. In: European Transport Conference. Barcelona.

Van Oort, N., Yap, M., 2021. Innovations in the appraisal of public transport projects. Advances in Transport Policy and Planning 7, 127–164. https://doi.org/10.1016/BS.ATPP.2020.07.008.

Winn, B.M., 2011. The design, play, and experience framework. Handbook of Research on Effective Electronic Gaming in Education 1010–1024. https://doi.org/10.4018/978-1-59904-808-6.CH058.

Zigmont, J.J., Kappus, L.J., Sudikoff, S.N., 2011. The 3D model of debriefing: Defusing, Discovering, and Deepening. In: Seminars in Perinatology, vol. 35. W.B. Saunders, pp. 52–58. https://doi.org/10.1053/j.semperi.2011.01.003, 2.