MASTERARBEIT | MASTER'S THESIS

Titel | Title

CTMobility: Business Simulation Game For Sustainable Mobility

verfasst von | submitted by

Cristina-Maria Tiutin

angestrebter akademischer Grad | in partial fulfilment of the requirements for the degree of

Master of Science (MSc)

Wien | Vienna, 2024

Studienkennzahl lt. Studienblatt | Degree programme code as it appears on the student record sheet:	UA 066 921
Studienrichtung lt. Studienblatt | Degree programme as it appears on the student record sheet:	Masterstudium Informatik
Betreut von | Supervisor:	Mag. Dipl.-Ing. Dr.techn. Maria Leitner Bakk.

Acknowledgements

My sincere acknowledgement goes to my supervisor, Prof. Maria Leitner. I am grateful for her support and guidance throughout this research process, from the very beginning until the completion of my studies. I would also like to express my appreciation for the entire teaching staff at the University of Vienna, for the experience and knowledge gained within my years at the University, but especially for making life in the pandemic much more interesting.

Furthermore, I want to thank God and then my family, for giving me the right context and possibilities to make my dream of studying in Vienna come true and for not letting me give up. I would not have made it without all of you.

Thank you!

Abstract

Business simulation games are extensively applied for training technical, managerial and problem-solving skills, based on experiential learning standards. Academia, industry and government have embraced games as valuable tools for education, training, advertising and a multitude of objectives outside of "pure" entertainment.

This work proposes a business simulation game for sustainable mobility. Nowadays, there is a multitude of ongoing discussions on the concept of sustainability. In this sense, the United Nations has come up with an agenda for sustainable development. At the base of this agenda stay 17 Sustainabe Development Goals (SDGs), representing a critical demand for action by all countries, in a worldwide partnership. Among these, our attention is directed towards the mobility and sustainable transport goals. These are mainstreamed across a number of SDGs and targets, including those connected to health, food security, economic growth, infrastructure, energy and cities and human settlements.

The objective of this work is to design, implement and evaluate such a business simulation game. Its initial phase aims to survey the applicability and impact of business simulation games within the context of mobility and sustainable transport, to discuss and evaluate existing approaches of applying simulation games as a tool for promoting and encouraging sustainable mobility. Based on the performed research, this work introduces a new proof-of-concept for encouraging sustainable travel and mobility, named CTMobility. The proposal is evaluated through a case study, performed by running the simulation game on thirty people. Results are evaluated via a mixed-method technique, consisting of a survey (quantitative analysis) and interviews (qualitative analysis). The outcome shows that the developed tool was perceived with a positive attitude and has potential in supporting people make sustainable mobility decisions.

Kurzfassung

Wirtschaftssimulationen werden in großem Umfang für das Training von Fach-, Management- und Problemlösungsfähigkeiten auf der Grundlage von Standards für erfahrungsbasiertes Lernen eingesetzt. Wissenschaft, Industrie und Behörden haben Spiele als wertvolle Werkzeuge für Bildung, Training, Werbung und eine Vielzahl von Zielen außerhalb der "reinen" Unterhaltung angenommen.

In dieser Arbeit wird ein Wirtschaftssimulation für nachhaltige Mobilität vorgeschlagen. Heutzutage gibt es eine Vielzahl von laufenden Diskussionen über das Konzept der Nachhaltigkeit. In diesem Sinne haben die Vereinten Nationen eine Agenda für nachhaltige Entwicklung aufgestellt. Die Grundlage dieser Agenda bilden 17 Nachhaltige Entwicklungsziele (SDGs), die eine entscheidende Forderung an alle Länder darstellen, in einer weltweiten Partnerschaft zu handeln. Unsere Aufmerksamkeit richtet sich dabei auf die Ziele für Mobilität und nachhaltigen Verkehr. Diese sind in eine Reihe von SDGs und Zielvorgaben eingebettet, unter anderem in den Bereichen Gesundheit, Ernährungssicherheit, Wirtschaftswachstum, Infrastruktur, Energie sowie Städte und menschliche Siedlungen.

Ziel dieser Arbeit ist es, ein solches Wirtschaftssimulation zu entwerfen, umzusetzen und zu bewerten. In einer ersten Phase sollen die Anwendbarkeit und die Auswirkungen von Wirtschaftssimulationen im Kontext von Mobilität und nachhaltigem Verkehr untersucht und bestehende Ansätze zur Anwendung von Wirtschaftssimulationen als Instrument zur Förderung und Unterstützung nachhaltiger Mobilität diskutiert und bewertet werden. Basierend auf den durchgeführten Untersuchungen wird in dieser Arbeit ein neues Proof-of-Concept zur Förderung von nachhaltigem Reisen und Mobilität mit dem Namen CTMobility vorgestellt. Der Vorschlag wird anhand einer Case Study evaluiert, in der die Wirtschaftssimulation mit dreißig Personen durchgeführt wird. Die Ergebnisse werden mit Hilfe einer gemischten Methode ausgewertet, die aus einer Umfrage (quantitative Analyse) und Interviews (qualitative Analyse) besteht. Das Ergebnis zeigt, dass das entwickelte Tool mit einer positiven Einstellung wahrgenommen wurde und das Potenzial hat, Menschen bei der Entscheidungsfindung für eine nachhaltige Mobilität zu unterstützen.

Contents

List of Tables

List of Figures

1. Introduction

Business games are innovative learning methods, conducted in a risk-free environment to stimulate leadership, problem solving and critical thinking, while encouraging teamwork and decision-making [61]. Participants in simulation games adopt a distinct role and act in varied circumstances held in a simulated environment. Hence, a simulation game is considered a compelling mechanism for detecting stakeholders' behaviour and interactions within organizational action, social change and technical development [30].

The theme that we are pursuing regarding business simulation games concerns sustainable mobility. Given the context of sustainability, the United Nations has come up with an agenda of 17 Sustainabe Development Goals (SDGs), representing a critical demand for action by all countries, in a worldwide cooperation. These admit that putting an end to different deprivations such as poverty has to conform to actions which enhance education and health, diminish inequality, inspire economic progress – all while dealing with climate change, oceans and forest preservation [44]. Mobility and sustainable transport goals are mainstreamed across several SDGs, especially those connected to health, food security, economic growth, infrastructure, energy and cities and human settlements.

The two vital modes of transport for sustainable mobility are walking and cycling. Increasing their use adheres to ecological targets of Sustainable Urban Mobility Plans [4] and strategic EU policy documents ([6], [8], [7]), as it reduces the need for space dedicated to the transport infrastructure, air pollution, energy consumption and noise. Moreover, economic goals are also followed, because mobility by walking and cycling suppose an insignificant cost for the public. Social aspects of sustainability are met as well, as these mobility choices are affordable and can be used by most people without restriction, while also encouraging regular physical activity, thus improving health conditions [57].

Nevertheless, it is noticeable throughout the mobility surveys conducted in recent decades ([21], [3]), that the inclusion of active mobility in daily activities has seen a decrease. Even though cycling has been successfully promoted in metropolitan regions [52], this is not the case of rural regions. Opposed to sports and other physical activities, walking and cycling require less time and motivation [22]. In addition, they can be accommodated without any problem into daily routines and are economically affordable. Thus, it is likely to reach areas of population where individuals may be less willing to engage in outdoor physical activities or cannot manage to do so due to lack of time or financial restrictions [56].

1.1. Relevance of the research topic

The subject matter dealing with business simulation games and sustainable mobility has registered a great interest in the more recent stages. Business games and simulations have become known over the last twenty years and they have distinctive complexity, settings, target and intentions. The on-going studies prove that both researchers and practitioners are devoted to exploring modern and innovative solutions. Many of the proposals focus on creating business simulation games for encouraging sustainable travel and mobility.

The work from [11] dwells into the problem of evolving human mobility towards more sustainable habits, using a gameplay approach. The game plan, definition and highlights have been established with the help of various residents and partners in six European areas. The study contends that the local co-design activities, supported by the local area commitment resolution, have impacted the game definition. The collected player data was supposed to be used for supporting a way centered on citizens, for dealing with equity and mobility justice covered by the metropolitan guidelines.

Moreover, the proposal in [65] describes a gamification model for improving sustainable multi-modal urban travel in contemporary European communities. Within the discussed framework, users are encouraged to consider their current behaviour and adopt more environmentally friendly habits. The techniques approached rely on points accumulation and level achievement. They allow users to record their own behaviour, set objectives, track their evolution and respond to challenges.

The report from [39] highlights an urban gamification strategy for advocating a positive behavioural change of mobility habits. Active players recorded their journeys on sustainable transportation means (i.e. walking, bike, public transport). The user experience impact was evaluated through questionnaires, interviews and game log analysis. According to these, users enjoyed playing the game and showed a change of behaviour towards more sustainable mobility patterns.

Lastly, the authors of [12] investigate the effectiveness of recent app-based tools in changing individual mobility patterns by making sustainable decisions. They focused on testing the capability of a smartphone app designated for local residents. The app presents itself as a game which rewards the most sustainable journeys. The aftermath was encouraging, showing that, to accomplish sustainable mobility, game–based technologies can be efficiently integrated inside urban policy standards.

Nevertheless, the scientific literature hardly focuses on long-distance travel, concerning the decision-making processes [60], trip destination, transport mode alternatives ([35], [45], [59]) and environmental impacts ([1], [14]). Travel comprises the trip to a destination, meanwhile, mobility relates to transportation at a given destination [63]. Particular features of intra-destination mobility are discussed, such as the use of public transportation ([37], [36]), mobility in rural areas ([58], [13]), movement patterns ([41], [66]) or access policy measures [46]. Still, an inspiration for this thesis is provided by the lack of analysis on mobility behaviour, with target on the connection between physical activity routines and mobility patterns in day-to-day life.

1.2. Motivation

Over time, there have been initiatives towards accomplishing a sustainable transport network, due to the CO2 emissions and their impact on air pollution and climate change. Such initiatives imply controlling vehicle use, working on the uptake of public transport and expanding the opportunities for walking and bike riding.

Some general aims that could be achieved in the long run are: reducing noise and air pollution, encouraging traffic well-being, dynamic mobility for individuals (sustainable lifestyle and values), decreasing the use of personal vehicles, reducing traffic jams in the working days. Recently, there has been noticed an interest towards business simulation games approaches in sustainable mobility. One target would be to come up with a system that urges users to consider their actual travel habits and to take part in more environmentally friendly actions, which conduce to the establishment of sustainable mobility patterns in the long run.

Past research has been mostly focused on traffic and its effects in connection to various patterns, such as travel distance, time or means of transport. Nevertheless, it appears that everyday mobility behaviour, together with its link to physical activity habits and mobility patterns, has been hardly investigated. To address this research gap, this thesis applies a mixed-method approach, which examines peoples' mobility choices both at home and on vacation.

This work aims to propose and investigate a business simulation game approach for promoting and strengthening sustainable mobility. In addition to this, our intention is to study mobility and transport patterns of people, both at home and on holiday. To achieve this, the first step assumes conducting a literature review. Based on the information extracted from existing simulation games, we design our own proof-of-concept, taking into account concepts, such as: stories, users, data model. Afterwards, the focus falls on the game implementation, emphasizing the requirements to be integrated. The last step includes an evaluation performed by running the simulation on people residing in urban areas. In this context, a group of people was surveyed about modes of transportation, especially the rationale behind opting for a mean of transport, in the setting of regular and vacation-specific mobility patterns.

1.3. Objectives

Two different objective types can be distinguished as part of the research process: a scientific objective, concentrating on the developed business simulation game, and a management objective.

The research started with the analysis, design and implementation of the game, and later advanced to the use case design, the course of the evaluation and investigation of results (scientific objective). The management objective focused on the organizational work of the research.

With regard to the scientific objective, the direction of the research seeks to create a business simulation game proposal with focus on sustainable mobility, by looking into four different areas: literature review, simulation game design, implementation and evaluation. The aim of each such section is targeted with the help of a research question:

Literature Review

- *RQ1 - What are typical business simulation games for sustainable mobility and their adopted solutions?* By answering this question, we intend to explore the game concepts and goals of the existing contribution, while offering a better comprehension of the existing research proposals.

Simulation Game Design

- *RQ2 - How can the simulation game for sustainable mobility be designed?* The purpose of this question is to focus on the concepts and determine the workflow at the basis of our simulation, by developing and including a number of realistic user-tailored stories.

Implementation

- *RQ3 - How can a simulation game for sustainable mobility be implemented?* By answering this question, we intend to explore the existing data structures and technologies, in order to decide on a suitable data model, frameworks and techniques for the business simulation game.

Evaluation

- *RQ4 - How is such a game perceived by people?* This question aims to determine if our design was successful in supporting the sustained engagement in our mobility game, since our direction is to preserve the behavioural changes of gamification. In other words, we want to establish if seeing the information on sustainable mobility makes people decide differently.

1.4. Contribution

The contributions of this thesis are the followings:

- *A survey on the applicability and impact of business simulation games in the context of mobility and sustainable transport.* A literature review is performed to outline the state-of-the-art, to discuss and evaluate existing approaches of applying simulation games as a technology for promoting and encouraging sustainable mobility. Interesting and useful insights from the existing contribution provide a solid foundation for our own development on business simulation games for sustainable mobility.

- *A proposal of a business simulation game for sustainable mobility.* In continuation to the research process, the proposal is to create a proof-of-concept to encourage sustainable travel and mobility. Its aim would be to introduce a tool called CT-Mobility, which invites participants to ponder on their current travel behaviours and to adhere to more environmentally friendly actions that induce the establishment of sustainable travel habits in the long run.

- *Evaluation conducted on individuals settled in urban neighbourhoods.* Their feedback is considered as a measure of our contribution. We also research if giving information on sustainability has an impact on peoples' mobility choices.

1.5. Structure of the thesis

The thesis is coordinated in six chapters that are detailed in the upcoming paragraphs.

In Chapter 2 we inspect concisely the current related work. We explore relevant development on the business simulation game method with focus on the sustainability topic. The aim is to place our work with respect to the actual research. The Systematic Literature Review (SLR) methodology was implied, due to the fact that it represents an internationally recognized scientifically method of literature review.

Chapter 3 presents background notion on business simulation games and summarizes our proposal, introducing the theoretical concepts, which include: user profiles, activity patterns, mobility options, user response and simulation. Particularities of the game design are emphasised, describing the use case view, the prototype design based on a tool, the data model that covers all theoretical concepts, how profile comparison is performed and the construction of the dashboard.

Details regarding the implementation are provided in Chapter 4, describing how the concepts from the previous chapter were integrated in practice. Technologies and used libraries are specified as well, together with actual representations of the final product.

The setup of the experiments and implied procedures are exposed in Chapter 5. Afterwards, an interpretation of the results is presented. Analysis is performed based on a case study, which investigates the user response obtained in the simulation. Results are evaluated from two perspectives: quantitative, based on a survey given to participants, and qualitative, using interviews. The limitations of the study are also mentioned in this chapter.

Finally, Chapter 6 completes our thesis by gathering the conclusions and encompassing the work with a discussion of future developments.

To sum it up, the purpose of this thesis is to introduce a business simulation game for sustainable mobility, titled CTMobility. To achieve this, we create a proof of concept in order to see how people respond, by developing user-tailored stories. The players' mobility choices for each such story are monitored and analysed towards the sustainability cause. The user responses in the simulation game are gathered to compose a dataset of mobility choices. This dataset is analysed to extract information, interpret results and draw some conclusions.

2. Literature Review On Business Simulation Games

In this chapter, we plan to study concisely the current business simulation game methods with focus on the sustainability topic, in accordance with the existing related work. Given the thesis context, this chapter positions our proposal with regard to the on-going research.

2.1. Systematic Literature Review (SLR)

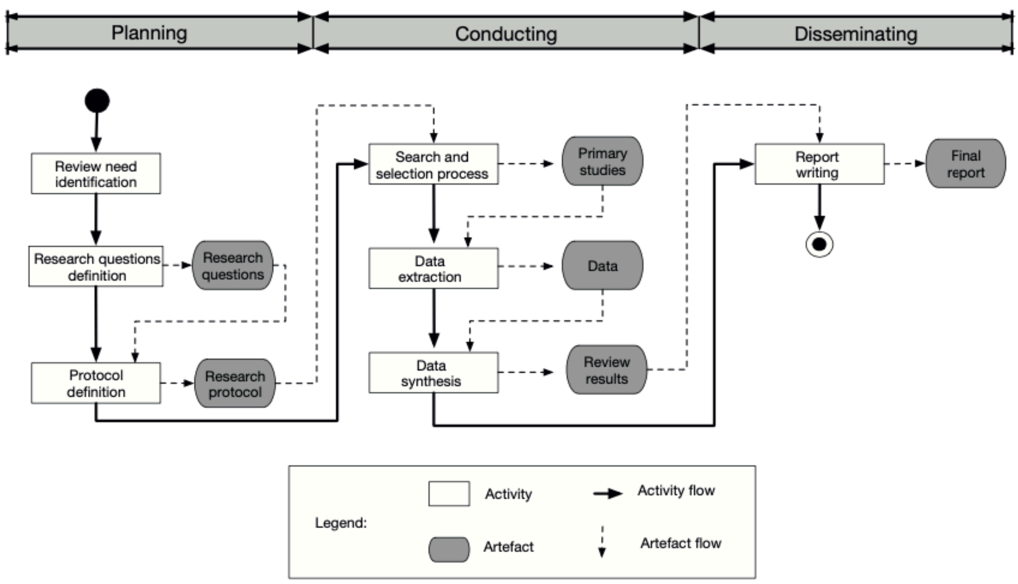


Figure 2.1.: Systematic Literature Review research process (Adapted from "GPU Support for Component-based Development of Embedded Systems" by Gabriel Campeanu, Mälardalen University [5])

To outline the state-of-the-art of business simulation games for sustainable mobility and related work, we resort to the systematic literature review (SLR) approach. The instructions for conducting SLR in software engineering are presented in the work of Kitchenham et al. [29]. They include three notable steps:

1. The first step of an SLR means setting up the process layout, which consists of the next activities: the reasoning for the SLR is described and the research questions

are defined, alongside the instructions for proceeding with the SLR.

2. For the second step, the previously-defined guidelines are enforced, leading to a compilation of primary studies, from which information is obtained.

3. Lastly, the entire extracted information from the SLR is organised as a report.

An overview of the adopted SLR process can be observed in Figure 2.1, as mentioned in the work of Campeanu [5]. Based on the described guidelines, each main step consists of one or more activities.

The next sections detail thoroughly each part of the SLR research process.

2.2. SLR Planning

2.2.1. The need for research investigation

This work portrays a proposition for promoting sustainable mobility values in the business simulation game system. This SLR has the purpose to determine current research which underlines business simulation games that apply one of the various sustainability goals, and to sum up this information. The motives for performing the SLR are:

1. to explore and grasp the actual scientific research on the topics of interest by illustrating the state-of-the-art, and

2. given the background of the thesis, we attempt to study the work that concentrates on the selected topics, while placing ourselves within the on-going research.

2.2.2. Research question definition

The aim of the SLR is targeted by one research question, with a well-defined purpose:

RQ1 - What are typical business simulation games for sustainable mobility and their adopted solutions? By answering this question, our intention is to discover the game concepts and goals of the existing contribution, while offering a valuable understanding of the actual research projects.

2.2.3. Protocol definition

The subsection brings in the actual rules and steps for performing the SLR. There are five components that outline the methodology:

1. the search terms and resources employed to discover primary studies,

2. the selection criteria, applied to exclude or include papers from the systematic literature review,

3. the data extraction process, adopted to extract useful data from the primary studies,

4. the synthesis of the derived information, and
5. the dissemination of the outcome.

2.3. Conducting SLR

2.3.1. Search and selection process

The search and selection method consists of several parts, which plan to discover studies that depict important answers to our research question.

Firstly, we have to establish the databases employed in the search of primary studies, together with the keywords to be used on each database. Results from all databases are merged as part of the second step, leaving out duplicates. Onwards, these studies are filtered based on some predefined criteria, enclosing the third step.

The search and selection process is presented in detail in the upcoming paragraphs.

Step 1. Database search

As shown in Table 2.1, two databases and one indexing system are used in the search process: IEEE Library, ACM Library and SCOPUS. These resources were selected for our study due to their high accessibility to strong research material: conference publications, journal articles, technical standards and other computer science content.

Name	**Type**	**URL**
IEEE Xplore	Electronic database	`http://ieeexplore.ieee.org`
ACM DL	Electronic database	`http://dl.acm.org`
SCOPUS	Indexing system	`http://www.scopus.com`

Table 2.1.: Resources selected for the search process within the Systematic Literature Review methodology

Considering the two elements our research is centered on, business simulation games and sustainable mobility, we mark some proper keywords, corresponding to the primary categories of our study. The category preoccupied with business simulation games includes four keywords, while the one focusing on sustainable mobility aspects comprises one keyword. Table 2.2 presents the five defined keywords, in correspondence to their group.

The defined keywords were connected through a Boolean OR operator between the keywords of a group, and the Boolean AND operator between the two groups. The obtained search string is: (**B1** OR **B2** OR **B3** OR **B4**) AND **S5**.

An advanced search was conducted by applying the search string on all existing fields, from the selected research databases. The string was manually adjusted to fit into the requirements of each electronic library or index system, due to lack of standardization.

Number	Keyword	Group
B1	business simulation	Business aspects
B2	business process	Business aspects
B3	gamification	Business aspects
B4	process mining	Business aspects
S5	sustainable mobility	Sustainability aspects

Table 2.2.: Keywords adopted in the search process within the Systematic Literature Review methodology

Step 2. Merge and duplicate removal

The papers obtained in the database search from step one were merged into a document, with duplicates being excluded. Also, we left out the entries which were not research papers. Since sustainability goals have seen a grown interest more recently, we concentrated on work published between the years 2000 and 2022.

Step 3. Filtering by the selection criteria

A selection criteria is established in order to filter the studies merged in the previous step. Therefore, an entry is considered if it respects the inclusion criteria and eliminated if it adheres to the exclusion criteria.

The inclusion criteria is introduced next. An entry is considered if:

1. full-text can be accessed,

2. it introduces a business simulation or a gamification strategy,

3. it presents solutions that concentrate on sustainable mobility, and

4. it yields an evaluation of the suggested solution and realistic conclusions.

A single exclusion criterion was established:

1. An entry is eliminated if it comprises less than five pages.

Our objective was to select at least ten studies which correspond the most to our thesis proposal. Initially, the selection criteria was applied on thirty studies. Twenty of these studies turned out to respect the specified criteria. Afterwards, a manual filtering was done, helping us reduce the number of studies to ten. The abstract was parsed to determine the studies closest to the field of the thesis, as last step. If the abstract did not offer sufficient data to exclude or include a document, the whole paper was checked. The search ended with ten studies that are in a tight correlation with our proposal.

2.3.2. Data extraction

Ten studies were discovered as useful and significant for our work. Table 2.3 enumerates them, in order of their source type, which is either an electronic library or an indexing system. The purpose of this manually-performed activity is to extract data from the studies, based on the aforementioned research question.

2.4. Data synthesis

The current task contains the inquiry and outline of the obtained information from the preceding point. It briefly surveys the current business simulation game solutions and related work, found in the ten studies which suit better our thesis domain.

Id	Title	Authors	Year
P1	Using gamification to incentivize sustainable urban mobility [27]	Raman Kazhamiakin, Annapaola Marconi, Mirko Perillo, Marco Pistore, Giuseppe Valetto, Luca Piras, Francesco Avesani, Nicola Perri	2015
P2	A Gamification Platform to Analyze and Influence Citizens' Daily Transportation Choices [25]	Raman Kazhamiakin, Enrica Loria, Annapaola Marconi, Mauro Scanagatta	2021
P3	A gamification framework for the long-term engagement of smart citizens [26]	Raman Kazhamiakin, Annapaola Marconi, Alberto Martinelli, Marco Pistore, Giuseppe Valetto	2016
P4	Opportunities for Sustainable Mobility: Rethinking Eco-feedback from a Citizen's Perspective [42]	Johanna Meurer, Dennis Lawo, Christina Pakusch, Peter Tolmie, Volker Wulf	2019
P5	Machine Learning for Personalized Challenges in a Gamified Sustainable Mobility Scenario [28]	Reza Khoshkangini, Annapaola Marconi, Giuseppe Valetto	2017
P6	Choice architecture for environmentally sustainable urban mobility [2]	Efthimios Bothos, Dimitris Apostolou, Gregoris Mentzas	2013
P7	Placemaking for Urban Sustainability: Designing a Gamified App for Long-term, Pro-environmental Participation [49]	Irina Paraschivoiu, Thomas Layer-Wagner	2021
P8	Promoting sustainable mode choice for commuting supported by persuasive strategies [17]	Domokos Esztergár-Kiss, Yuliia Shulha, Attila Aba, Tamás Tettamanti	2021

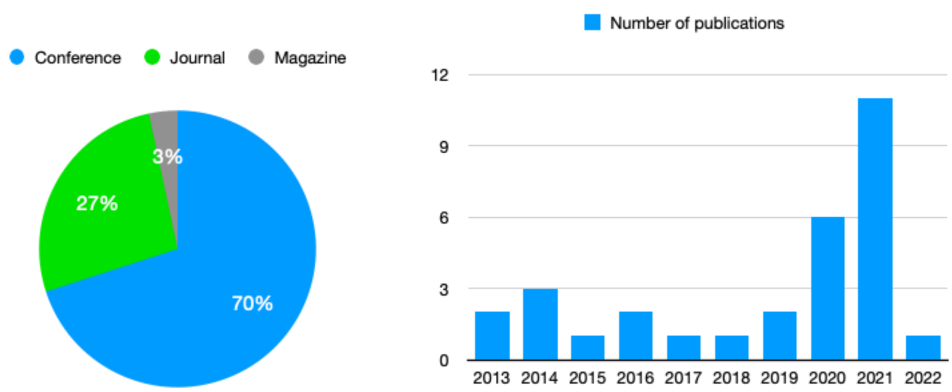
P9	Organizing a sustainable smart urban ecosystem: Perspectives and insights from a bibliometric analysis and literature review [48]	Rocco Palumbo, Mohammad Fakhar Manesh, Massimiliano Matteo Pellegrini, Andrea Caputo, Giulia Flamini	2021
P10	Data collection on Shipper's Preferences Using Simulation Games: A Synchromodality Case Study [31]	Ioanna Kourounioti, Lránt Tavaszzy	2020

Table 2.3.: List of primary studies resulted from the adopted Systematic Literature Review research process

2.4.1. Synthesis overview

Figure 2.2 visually displays our findings. Three categories can be noted, based on the publication type: conferences, journals and magazines. The number of studies for each publication type are shown in Figure 2.2(a). The most common category is represented by the conference studies (21/30), then the journal publications (8/30), and magazine studies (1/30).

The distribution of publications over the time is shown in Figure 2.2(b). It is observable that the concern towards sustainable mobility has gained popularity in 2014, which increased more, later in 2021.



(a) The types of publications

(b) Number of publications per year

Figure 2.2.: The distribution of the publications obtained from the Systematic Literature Review research process, by type and year

2.4.2. Analysis and synthesis

The current subsection addresses a few of the actual business simulation games focused on sustainability, and related contribution in this area. We have selected papers that approach a closely-related problem (see Table 2.3). The paper-based analysis considered various aspects concerning: the objectives of the simulation, used method, complexity of the employed case studies and comparison method with other approaches.

All selected studies were conducted entirely within an academic environment as research setting. Additionally, three fields which approach the sustainability topic were detected in our findings. These are mobility, urban ecosystem and transportation service, as can be deducted from Table 2.4.

Field	**# Studies**	**Studies**
Mobility	8	P1, P2, P3, P4, P5, P6, P7, P8
Urban ecosystem	1	P9
Transportation service	1	P10

Table 2.4.: The sustainability topics found in the primary studies resulted from applying the Systematic Literature Review approach

All of the studies convey some form of result evaluation. Table 2.5 displays various techniques for assessing the effectiveness of the methods discussed in the papers. There are situations when a study combines different evaluation methods, as it is the case for P1 and P3, where both case study and research questions are implied.

Evaluation method	**# Studies**	**Studies**
Case study	5	P1, P3, P5, P7, P8
Research questions	3	P1, P3, P9
Feedback, questionnaire or workshop	2	P3, P7
Guidelines and heuristics	1	P2
Interviews	1	P4
Metrics and running time	2	P5, P6

Table 2.5.: The evaluation methods used in the primary studies resulted from applying the Systematic Literature Review approach

As we are concerned with research aspects referring to business simulation games and sustainable mobility, Table 2.6 presents the proposed solutions that are used to address topics related to these two aspects. First of all, the studies present gamification platforms with different approaches, which include: a service-based method, using a machine learning algorithm or a personalized route planner strategy. The studies also comprise a travel recommender system, a Human-Computer Interaction (HCI) study and a literature review which surveys the topics of interest.

Domain	# Studies	Studies
Service-based Gamification	4	P1, P2, P3, P7
Machine Learning Gamification	1	P5
Recommender System	1	P6
Personalized Route Planner	1	P8
Synchromodal Service	1	P10
HCI Study[1]	1	P4
Literature Review[1]	1	P9

Table 2.6.: Solutions proposed in the primary studies obtained from the Systematic Literature Review research process

The seven main categories of solutions proposed in the primary studies are discussed separately. For each such category, the adherent papers are summarised, emphasising the addressed problem, adopted solution and achieved results.

Service-based Gamification

The authors in [27] explore whether voluntary behavioural changes can be triggered by gamification systems, towards sustainable mobility arrangements. The created gamification system is a Smart City service platform that works inside the STREETLIFE European venture.

The paper introduces the gap of an application being tightly coupled to the particular business rationale it attempts to gamify. This gap stands in the way of development and reuse. Therefore, this study proposes a generic and extensible gamification structure, built upon the service-oriented architecture. A distinctive quality of this structure is that it lays out a steady and clear connection between programmable city arrangements and systems which boost residents to assist those policies, hidden behind gamification solutions.

The framework is composed of: a Gamification Engine used in the launch and games execution; a wrapping layer to manage interaction between engine and other processes of the Smart City; a game presentation layer which displays the users' progress; an extensible set of gamification modules, denoting common ideas that can be adopted in defining a game and which cover rationale and distinctive features for each concept. As service notions and mechanisms are important in a Smart City, the gamification framework was built in accordance with the principles of the service-oriented model and upon the abstraction of service.

Assessment was performed in 2014, through a case study in an Italian city, Rovereto. The experiment that gathered 40 users was destined to determine the influence of gamification initiatives on the commuters' mobility behaviour, as they have a daily routine of travelling to the city center by car. The presentation of the tool in a reserved trial in

[1] Both studies do not present an implementation solution, but are integrated for completeness reason.

Rovereto has expanded the dependence of game members on transport services provided by the city. Players acknowledged and inclined towards the suggestions offered by these services, to adopt sustainable mobility alternatives in their daily commuting activities.

A similar idea can be found in [26], which is a continuation of the previous paper. The authors propose an extensive software framework addressed to Smart Cities, allowing the design and implementation of gamification solutions. Support is provided on four levels: 1) active and variable Smart City strategies and targets; 2) open-ended integration of heterogeneous services; 3) multi–stakeholder games; 4) games with playable units at levels with different degrees of difficulty and numerous temporal scales.

An open–field case-study was conducted for nine weeks, in the same town, Rovereto. The system was evaluated with the help of a game which encouraged sustainable urban mobility and Volunteer Travel Behavioural Change. During the game, 300 residents enlisted for the Play&Go app on their portable terminals. Results disclose that 110 people effectively played and collected places, tracking around 3,700 itineraries, together with some game activities, like suggesting the game to other people and writing reviews on mobility and user experience. In addition, dynamic participants prevailed in 212 individual challenges and attempted 83 more challenges. However, they did not figure out how to properly overcome in a timely manner.

Following, the work of Kazhamiakin et al. [25] presents a fully-developed Gamification Platform for the design, implementation and execution of game-based sustainable mobility campaigns. On the one hand, game-based sustainable mobility campaigns represent an efficient method to bring issues to light and incite a positive change in residents' way of behaving. On the other hand, they likewise permit to gather point by point information about residents' day-to-day transportation decisions.

The platform is addressed to various categories of stakeholders. First are the mobility administrators and decision-makers, looking to uphold urban sustainable mobility guidelines and launch behavioural change plans, having a target with specific goals. Then, we have the game designers, handling the game ideas and mechanisms provided by the platform. These are used in the development of game-based applications, aligned to the standards and targets of mobility managers. The last category includes the citizens, which take part in behavioural change activities by connecting to the gamified application and experiencing real and virtual initiatives. The system is coordinated in four modules: the Gamification Engine, the Game Management, the Gamified App and the Trip Validation.

The platform is evaluated in contrast to state–of–the–art gameful inquiring and compelling technology rules. Within an iterative design process, the authors strive to recognize usability issues inside an actual design, by setting 28 usability standards on the gameful design topic. The heuristic system depicts intrinsic, extrinsic and context-dependent motivational factors.

To begin with, the intrinsic motivation heuristic is presented. The sustainability of the chosen means of transport influences the received points, expressing the intention that green transportation means are preferred. The framework is capable of automatically adjusting the difficulty of challenges, which caters for a sense of increasing challenge in the case of regular players. Furthermore, new participants begin with a restricted set of challenges and unlock new ones as they advance in the game. This helps ease new players into the system. For experienced users, the framework allows to choose one specific transportation mode, which will constitute the objective for each week's challenge, providing the idea of self-challenge. The structure gives every player a reasonable next objective, permitting them to handle their journey in the gamified framework through moderate objectives. Also, a vast set of badges helps users keep up with their progress. The system integrates multiplayer challenges, which may be cooperative or competitive, to encourage interaction through the greeting system. Moreover, the leaderboard offers participants the occasion to compare their profile with one another.

We proceed to the extrinsic motivation heuristics. The system rewards users with game points for performed activities. Collecting game points leads to a better placement among other competitors. The leaderboard tries to persuade users by awarding external prizes. Because challenges expire at some point, players might lose their position in the leaderboard, assuming they fail to win a challenge.

The context-dependent motivation heuristics are the followings. The system gives prompt input to the player using the notification system. At the beginning of a new week, participants are informed of the last added challenges. User progress is tracked on the homepage. Each week the system offers different challenges, to avoid repetition. Players can be involved in the design process by offering ideas within questionnaires, as part of challenges. The system keeps cheating behaviours under control by automatically validating the trips. Generally, the gamification platform adheres with success to most of the considered heuristics. The result is a context-free mechanism for the pursuit of gamification campaigns to advocate sustainable mobility.

The next study from [49], argues the importance of consolidating standards of gamification and behaviour change with urban participation policies, to keep local residents engaged in the long run. To accomplish this, frameworks should assist stakeholders in the participation process, based on two perspectives: a one-sided type of engagement and a co-production of urban futures. To this end, the proposal is called Smart Citizen: a mechanism which incites players to a collaboration which aims to expand their city's sustainability using both individual and collective means. The connection between conventions from citizen engagement theory and behaviour change, stands at the basis of Smart Citizen. Participants deliberately find out about nearby sustainable services, then engage in sustainability challenges and become a part of discussion and co-design.

The model was tried with 31 users in the city of Salzburg, over a time of fourteen days. Toward the finish of the trial period, they answered a survey focused on technology acceptance constructs, perceived usefulness and motivational effects of the game features. Players also participated in a workshop, in which the discussion was focused on usability and user experience, enhancements, intention to use and platform mechanism. Feedback showed a positive mindset regarding the use of Smart Citizen, particularly for users who shared an interest for the topic, but required help in pursuing vigilant choices.

Machine Learning Gamification

One more gamification approach is introduced in [28], in the light of machine learning: a framework that works by recommending challenges to users, which fit their game background and profile. The proposal can automate the generation of the game subject and employs a recommender system to designate the personalized challenges to every single user. A Machine Learning (ML) component constitutes the basis of the framework. Its purpose is to enhance the challenge selection process. Building the model based on the participant's experience helps to suggest new challenges that fit its predilections within the gamified system.

The proposed framework relies on three different modules: Challenge Generator, Challenge Valuator and Filtering & Sorting (FS). The input set supplied to the ML component includes as features: transportation mean, type of challenge, reward and improvement. These represent the principal parts that can handle the prediction of the output. The training set given to the ML component is composed of the list of user's previous challenges. The model is built using a classification method. The testing set fed to the ML component represents the list of newly generated challenges from the Challenge Valuator Module. Thus, based on the classification approach, the output generated by the ML component represents the probability that the challenge belongs to a particular category, either success or failure. When the prediction is obtained, the module offers an additional parameter, the predicted value, to be processed by the FS module. The FS module works separately for every player, using the challenges listed inside the ML component. The process ends with the tool proposing to each player the K-top challenges, with K being an adjustable value.

Assessment was conducted under the shape of a case study in a city named Trento. To evaluate performance, the metrics selection included: precision, recall and f-measure. Decision Tree, Logistic Regression, Naive Bayes, Bayesian Network and One-R algorithms were enforced on the players' data, with Naive Bayes performing better. The performance comparison of classification techniques was determined by the Area Under the Curve (AUC). The execution time was used to establish the efficiency of the ML module and its value appeared to be promising.

Recommender System

The authors of [2] examine the design of persuasive travel recommender systems which support travellers to adopt green transportation habits. People build their decisions on the choice set attributes and the context of the presented information. Choice architecture task implies designing and integrating small features in the decision-making process, to support people overcome cognitive biases, while emphasizing the preferred options, without restraining their freedom of choice. Research has shown that transport-related attributes, e.g. travel time, costs and CO2 emissions, highly influence the travellers' choices.

The proposed idea is a pre-configured default mixture of alternative paths that contain all possibilities about the transportation modes. During trip planning, users are required to provide their preferences with regard to transportation, to bypass input errors. The recommendation algorithm uses this categorization to filter and display those paths that are very likely to be chosen by the user. The user routing query is matched with some already configured profile parameters, through a query personalization component. In addition to this, a query contextualization component helps to identify the most favourable route set.

Feedback is provided by the recommender system, based on the users' travel behaviour, to remind about their carbon emissions. It also emphasizes those paths which can reduce the number of emissions. Moreover, it is connected to gamification methods, through which users set personal targets to improve their mobility routine, trying to decrease their carbon footprint. The recommender gives feedback within the game and helps users towards accomplishing their objectives.

Personalized Route Planner

A tool to assist commuters is described in [17], in the form of a personalized route planner. The goal is achieved through a utility function, built on four transport options (walking, bike riding, public transport, car) and four attributes (travel time/cost, environmental/health impact). As result, the utility function suggests a transport option.

MoveCit is an application developed in Budapest to study the aim of travel behaviour change. The system indicates the best transport option and demands user feedback. The novelty of the developed application is its capability to determine users' travel preferences, in order to encourage them to make sustainable choices. The obtained results give the positive and negative effect of the various transport modes in terms of the mentioned attributes. Feedback was mostly provided by registered users, as opposed to those who did not create a profile. Almost half of the users went along with the mean of transport offered by the application.

Tunneling guides users by supplying precise settings to discover individual mobility patterns, and creating a ranked list of paths for the different mobility options. Based on the users' settings, suggestion recommends them the most suitable mean for travel. Personalization gives user-tailored content to achieve improved results. The impact of selecting a particular mean of transport is communicated through simulation. Hence, the presented proposal offers a new understanding on the applicability of persuasive technologies, to encourage sustainable mobility. The results affirm that these technologies are promising, as users appear to be open to recommendations.

Synchromodal Service

Finally, the authors of [31] investigate how a simulation game can be applied to achieve an inventive data collection mechanism for decisions on freight transport. A digital simulation game called MasterShipper is used to increase stakeholders' awareness on the benefits offered by synchromodality. The simulation creates the context of an office job: a company employee who works as a logistics planner, selling electronic products.

Participants are given the task of delivering on time various kinds of products received from producers.

A study conveying six gaming sessions was conducted in the Netherlands, in the presence of logistics managers within the logistics sector. The output of the simulation game consists of clean text files which are integrated into one database. In total, the database consisted of 532 observations. For each shipment, the player had to decide on one service: truck, barge or synchromodal. Influential factors of the decisions included: travel time, cost, reliability, workload, shipment priority (low, medium and high), index of the CO2 emissions per type. A Multinomial Logit Model was adopted for defining the player's probability to choose a particular service.

In general, this work investigates the potential of implementing simulation games as survey instruments, in the field of freight transportation. If designed correctly, simulation games can increase the response rate, since it was possible to unfold an informative model for synchromodal services.

HCI Study

Moving on to another domain, the Human-Computer Interaction study includes one paper. The study [42] switches the perspective from that of a designer's to a citizen's. It explores the manner in which eco-feedback tools could be adopted to reinforce sustainable mobility inside the city. In accordance with the literature, the analysis showed that eco-feedback tools which come as strong and normative are likely to be understood as restrained.

To explore this issues, an interview study was performed in a German town, including 14 citizens. An eco-feedback prototype, which records day-to-day exercises, was used to provide a blueprint of users' trips and selected means of transport. The mobility of all interviewees was recorded before the exact interviews. All along, participants were left pondering on both the advantages and constraints of the prototype.

The study displayed very clear that, even though all interviewees sparked an interest towards the positive impact of sustainability, that factor did not represent a key criterion when planning their day-to-day trips. The candidates also discussed other concerns that they had towards eco-feedback tools. The covered issues include: (1) improved information on the way in which sustainable mobility is monitored and measured; (2) consideration for separate mobility choices and circumstances; and (3) maintaining cooperation and responsibility sharing among town services and residents.

The candidates often felt uncertain about the metrics used to estimate sustainable mobility quantitatively. Some interviewees appeared to be insecure when trying to comprehend how the computation of their CO2 balance of daily movement was performed. Another aspect is that, even though sustainability is usually mentioned at a global scale, residents might be eagerly driven by local environmental data, closer to their living areas. The model has to be set in local and concrete experiences that can reassure residents to adopt an eco-friendly behaviour, and to be able to create tangible initiatives in this sense. Also, people perceived well the possibility to evaluate their mobility behaviour through comparison. The developed prototype allowed the comparison between one user's specific data and that of an average user. This feature concluded to be useful in improving the feeling of own input through mobility behaviour.

Many individuals stated that their mobility habits need to suit their own necessities. Therefore, in most cases, sustainable mobility does not fit the life priorities of participants. Some shown worries about the settlement between sustainable mobility and the public transport expense. Precisely, they did not feel like buying tram or bus tickets if they already owned a car. Such an example shows the degree to which personal pressures and predilections impact the sustainable choices. Although, most of the candidates disclosed a positive attitude towards the sustainable mobility cause, they were able to provide the reasoning behind their mobility decisions. This cannot be set aside, as it constitutes a matter of respect.

The findings disclosed that all interviewees had an interest in the sustainable mobility subject. Despite the fact that many of them had difficulties to grasp the abstract aspects of sustainable mobility monitoring, participants showed curiosity about such things. An official model that can be easily perceived and is accessible to everyone, could build trust in the reliability of monitoring. The study was designed to exemplify an assumed learning course on sustainable mobility data. Such learning methods should further be developed in public and social backgrounds (workplaces or schools).

At last, the information showed that sustainable mobility was frequently considered as a shared accomplishment of the individuals from a nearby regional area. Hence, numerous members expressed that it was not their sole obligation to think often about sustainable mobility. A possibility to resolve this concern is to improve eco-feedback tools by offering visual insights. These are capable of promoting challenges, to raise awareness on what can be achieved in a local neighbourhood.

Literature Review

The last domain comprises one paper [48], which represents a bibliometric analysis and an interpretive literature review on the methodologies that could be considered for running a viable smart urban ecosystem. Considering a practical mindset, the review suggests that the progress of a sustainable smart ecosystem in urban places relies upon the tied link between a couple of factors: technological partners and local authorities. The former focuses on the structure of a smart governance, with target on the citizen approval, and the realization of a socially and environmentally sustainable economic development. The latter sets the terms for data and resource distribution, essential to cater the smart processes of urban ecosystems. If an arrangement can be established between such elements, then the capacity of a smart urban ecosystem to lay out a prosperous and self-cultivating shared intelligence can grow, as it represents the foundation of a long-term urban viability.

2.5. Summary

RQ1 - What are typical business simulation games for sustainable mobility and their adopted solutions?

This section presents our findings after exploring the game concepts and goals of the selected primary studies. The examined proposals present various design and implementation solutions that combine notions of business simulation and sustainability. Their goals include promoting and integrating principles of volunteer travel behavioural change with urban participation strategies, raising awareness and inducing a positive shift in residents' behaviour and patterns, but also supporting travellers and commuters in adopting green transportation habits. Regarding implementation, the solutions range from gamification platforms which integrate the principles of service-oriented architecture or machine learning algorithms, to recommender systems and data collection tools. In addition, two studies which do not comprise an implementation solution were reviewed as well, for completeness.

To sum it up, the work discovered within this survey is thorough. The existing contribution provides interesting and useful insights that can supply a solid foundation for future research and development on business simulation games for sustainable mobility.

3. Simulation Game Design

Our proof-of-concept aims to encourage sustainable travel and mobility by providing a method that stimulates players to ponder on their actual travel behaviours and carry out more environmentally friendly actions. The primary goal is to assist sustainable travel behaviours, while admitting that in real life, individuals show a wide range of motivations, which do not always comply with the environmental sustainability goals.

Concerning the intrinsic motivation, we identified the followings: the aim to preserve the environmental system - ecological choice, minor environmental impact - and positive consequences of sustainable mobility on psychological well-being - peace of mind of a low-risk transportation option, reduced traffic-related stress, cleared mind, increasing awareness about how much one moved in sustainable ways. Extrinsic motivation could focus on saving time and money.

In what follows, are presented steps and ideas that were approached in order to reach as closely as possible the mentioned goal of the business simulation game proposal, that we shortly titled CTMobility. In addition, this chapter describes the game concepts which were used in the CTMobility tool.

3.1. Business Simulation Games Background

Business games surfaced as innovative learning methods, aiming to reinforce organizational, entrepreneurial, digital and collaborative abilities, and to support critical thinking, problem solving and leadership [61]. Business simulation games favour teamwork and decision-making inside an environment that does not impose risks. In more detail, players cultivate a holistic view of the business; they have the chance to learn that losses in an early phase might result in a higher profit in a later phase and that sometimes alternatives have to be revisited. Business games and simulations have seen an increase in popularity in the past 20 years, as they appear to differ in complexity, focus, settings and intentions.

Simulation Games represent a growing research technique which deals with the study of complex systems. They are generally defined by [15] as 'a conscious endeavour to reproduce the central characteristics of a system in order to understand, experiment with and/or predict the behaviour of that system'. People who take part in simulation games usually adopt a distinctive role and are placed in a variety of behavioural situations, conducted in a simulated environment [16]. Therefore, a simulation game represents an effective process for analysing stakeholders' reactions within the managerial process, social adjustment and technical progress [30]. Simulation games are adopted in multi-disciplinary research mainly because they are capable of including various data, theories, concepts, perspectives, techniques and tools.

In his work, Duke presents the main features of simulation games, which designate them as suitable for research [15]:

- Comparing to the reality, it is at hand to analyse and investigate a problem inside a simulation game.
- Simulation games provide visibility of certain phenomena, for study and evaluation within an otherwise intricate, chaotic real-world system.
- Through the design of supervised trials, they can provide researchers with elaborate insights on how systems operate.
- Simulation games provide a safe space and background to cultivate laboratory analogues of dangerous phenomena.

Simulation games are acknowledged for their promising potential as a research method and intriguing nature [34]. They can incite participation, support data collection and enable control and manipulation through a researcher [10]. Simulation games help discover awareness in existing systems and, most important of all, contribute to keeping players informed of certain challenges [38], while allowing the observation of player behaviour [62]. However, limitations may appear when these are used for rigour analysis. A certain dynamic emerges when the game is played. Due to some impacting factors, including the expectations, skills and experience of the players, this is hard to be predicted beforehand. The form of game reality developed during the game execution may vary from the meaning given by the game designer and researcher [33].

3.2. Research Design and Analysis

Our proposal represents an inventive method aimed to bring sustainability to mobility and transport. The intention behind CTMobility is to simulate consumption, not production. The plan is to create a simulation in order to see and analyse how people respond, by developing user-tailored stories. The game intends to encourage players to follow the offered sustainable mobility recommendations for each such story.

We strive to design and implement a genuine, substantial game experience which supports the transmission of what can be discovered in the game to the real world. Our framework aims to be usable and responsive. In order to accomplish this, we need to establish very clearly the concepts used throughout the game, specifically the user profiles and stories. We explore what the game would look like for various travels. In the upcoming subsection, we unveil the game design course adopted for the CTMobility business simulation game.

3.2.1. Research question definition

We develop the design of CTMobility by considering a research question:

RQ2 - How can the simulation game for sustainable mobility be designed? The purpose of this question is to focus on the concepts and determine the workflow at the basis of our simulation, by developing and including a number of realistic user-tailored stories.

3.3. Theoretical Concepts

The current section explains the theoretical concepts used for the CTMobility business simulation game.

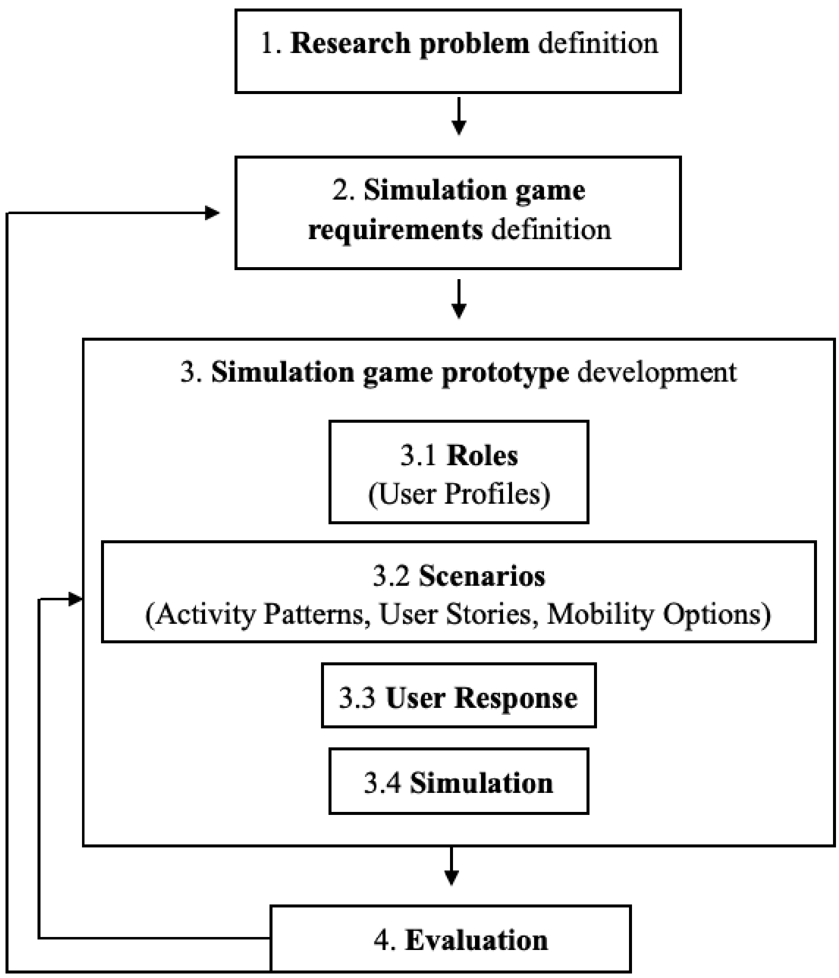


Figure 3.1.: Simulation game design process (Adapted from "Situation Awareness for Socio Technical Systems: A simulation gaming study in intermodal transport operations" by Shalini Kurapati, Delft University of Technology [32])

The game design process is described in Figure 3.1. We have already mentioned the first two sections and, thus, we focus our attention on the third stage of the figure, namely the iterative game prototype development.

The game consists of four main categories:

- roles: user profiles (subsection 3.3.1)
- scenarios: user stories (subsection 3.3.3), including activity patterns (subsection 3.3.2) and mobility options (subsection 3.3.4)
- operating procedures: rules of the game, i.e., the flow of the simulation (subsection 3.3.6)
- an accounting system: scoring schema, i.e., the user response (subsection 3.3.5)

These elements are constructed considering the triadic game design method from [24], which states that a game has to be balanced for reality, by having a real-world representation. In other words, it stands in the scope of the game and play to provide a game that offers interaction, is immersive and captivating. The discussion of the simulation game concepts begins in the next subsection, by explaining the roles of the game, given by user profiles.

3.3.1. User Profiles

When people enter playful settings, they are driven by different motivations. Generally, the question that appears is what reasons individuals and groups have to play. CTMobility will allow both independent profiles (single-person) and family profiles (with different number of family members). Various factors will be taken into account such as age, occupation or gender. The income status was considered as a possible factor. However we decided that it may not be appropriate to ask the user to provide this information.

Predefined Profiles

A study on mobility styles for recreational purposes [43] disclosed different profile types, based on mobility behaviour habits, lifestyle and social status, which we decided to include in our game. Therefore, we opted for five predefined profiles, in which the player will make decisions by considering the characteristics of the selected profile, and a separate option to let players create their own profiles.

The predefined profiles are:

1. "Disadvantaged" (basic education, low income, limited mobility options): unemployed student
   Profile1: 18 years old, unemployed, high-school graduate
2. "Fun-oriented" (young, educated, individualistic fun, risk and technology-oriented, reference to peer groups): employed graduate
   Profile2: 25 years old, Bachelor and Master's Degree, little work experience (between one and two years)

3. “Modern-Exclusive” (professional orientation, discerning, interested in technology): important employee of a company
   Profile3: 35 years old, works in a corporate company and has an important function

4. “Overburdened Family-oriented” (family values, domestic and neighbourly orientation, insufficient demarcation of work, housework and leisure time): family of four
   Profile4: - father: 42 years old, modest income
   - mother: 40 years old, modest income
   - child1: 12 years old, middle school, no income
   - child2: 10 years old, primary school, no income

5. “Traditional Domestic” (above-average age, traditional values, security, durability, reservations concerning modern technologies): elder couple
   Profile5: - grandmother: 64 years old, modest income
   - grandfather: 65 years old, modest income

Figure 3.2 presents an example of predefined profiles data. Each entry in the table corresponds to a user which includes the following information: id corresponding to the profile (i.e. the members of a family profile have all the same profile id), the unique user id, gender, age and occupation (some possible values that suit the gender and age of the user are shown).

ID	UserId	Name	Gender	Age	Occupation
1	1	Hayley	F	18	Student
2	2	Luke	M	25	Software Developer (or Engineer, Teacher, Programmer, Photographer, Writer, Musician, Salesperson, Waiting Staff, Mechanic, Actor, Scientist, Accountant, Flight Attendant)
3	3	Alex	F	35	Professor (or Architect, Physician, Dentist, Lawyer, Doctor, Designer, Technician, Police Officer, Nutrit
4	4	Phil	M	42	Estate Agent (or Consultant, Coach, Engineer, Electrician, Technician, Paramedic, Doctor, Firefighter,
4	5	Claire	F	40	Businessperson (or Hairdresser, Dental Hygienist, Therapist, Social Worker, Economist, Secretary, Ph
4	6	Ben	M	12	Pupil
4	7	Emma	F	10	Pupil
5	8	Jack	M	65	Retirement (or Farmer, Tailor)
5	9	Judy	F	64	Retirement (or Baker)

Figure 3.2.: Example of data from the predefined profiles integrated in the simulation game

Create Own Profile

In addition to the five predefined profiles, generated based on the information mentioned in subsection 3.3.1, players should be allowed to create their own profiles. Some ideas involved in the creation of own user profiles include:

- Allow users to create their own individual (one member) or family profile (more members).
- A family profile is seen as a single entity, not as separate entities for each member of the family.

- A member will include the following information:
  - Name
  - Age (range)
  - Gender
  - Occupation (have a drop-down with choices)
- In case of family profile, it is possible to add more members with this four values.
- List of possible occupation values: Engineer, Architect, Electrician, Pharmacist, Physician, Dentist, Lawyer, Artist, Chef, Scientist, Accountant, Butcher, Designer, Technician, Police Officer, Paramedic, Doctor, Teacher, Psychologist, Actor, Labourer, Firefighter, Student, Gardener, Businessperson, Construction Worker, Mechanic, Software Developer, Waiting Staff, Librarian, Veterinarian, Aviator, Secretary, Journalist, Plumber, Dietitian, Lifeguard, Bartender, Baker, Salesperson, Farmer, Judge, Tailor, Politician, Barber, Economist, Estate Agent, Hairdresser, Cashier, Coach, Cameraman, Nurse, Consultant, Social Worker, Midwife, Mail Carrier, Psychotherapist, Therapist, Radiographer, Editor, Dental Hygienist, Flight Attendant, Jeweller, Musician, Nutritionist, Painter, Photographer, Pilot, Programmer, Professor, Translator, Writer, Pupil, Retirement.

We also considered the possibility of adding more people to an individual profile. However, the decision was to leave this feature as future work. An even better alternative for future work would be to ask the user at the beginning of the simulation if they are travelling alone or with someone (and if so, with how many people). In the case when the user chooses a car or a cab as mobility choice, the CO2 emissions should be split among passengers. Otherwise, it should not have an impact on emissions, as for public transport it is just another additional passenger.

A possible idea left also as future work is to eliminate the concept of family profiles and have only individual profiles. In the profile page there should be a feature which allows the creation of a household (family members, friends) and when travelling the user gets to decide with whom they are travelling.

Administrator User

The admin will be a particular user. Its purpose is not to engage in simulation, but to manage the data and flow of the simulation. A regular user who takes part in a simulation is a non-admin user. Access control will be provided only for admin users, not for all users. Admin users will be manually added in the database, i.e. there will be no option in the interface to register an admin.

First of all, the admin should be able to manage user-related information. There should be a page where the admin can view all regular users; when clicking on such a user, the admin can see the history and progress. Also, the admin can manage information on stories and activity patterns (perform simple add, delete and update operations). Secondly, the admin should have the possibility to visualize data through dashboards, i.e. how many users, how many stories and so on.

3.3.2. Activity Patterns

If the user profiles are equivalent to the roles the participants take in a usual simulation, the activity patterns represent the situations participants react to. An activity pattern is considered to be a fixed scenario, consisting of the following information: descriptions of the activity (a summary one and an explanatory one), the distance needed to travel to the location of the activity, and the mobility options, which are described in more detail in subsection 3.3.4.

A very good approach is to try to be generic in the game's progress. Therefore, we came up with a document to include a number of activity patterns. Figure 3.3 presents an example of activity patterns data. Each entry in the table corresponds to an activity pattern, which includes the following information: id of the activity pattern, a short and a long description, together with the distance, measured in kilometers.

ID	Short Description	Long Description	Distance
1	Go to school or work	It is a new day and you need to get to school, university or work.	3.5 km
2	Study at the library	You need some quiet time to study at the library.	1.5 km
3	Go shopping	You decided to shop for groceries, clothes, books or other supplies.	0.7 km
4	Attend social activities	You would like to attend some social activities or group gatherings.	2.0 km
5	Meet with friends	You go out to meet with friends in different contexts: theatre, opera, cinema, restaurant, bowling or sports match.	2.9 km
6	Extracurricular activities	It is time for some extracurricular activities, such as gym training, sports practice, instrument/ language or driving lessons.	3.4 km
7	Visit relatives	You think it is time to pay a visit to some family members.	12.0 km
8	Get beauty or health services	You decide to pay a visit to the beauty salon or honour your medical appointment.	2.2 km
9	Recreational activities	You need to recreate and try some activities in an amusement park, zoo, spa, aqua park or sports center.	3.0 km
10	Participate in a local event	You are invited to attend a local event such as a wedding, conference, party, festival or sport event.	15.0 km
11	Attend work conference or workshop	You need to attend a work conference/training/workshop or make a visit to client's office.	2.8 km
12	Solve paperwork	Your company asks you to get some paperwork done or you need to deal with personal documents.	3.1 km
13	Perform operations at the bank	Go to the bank for operations regarding account management, credit retrieval, payments.	1.2 km
14	Volunteer work	Do volunteer work.	4.1 km
15	Work-related trip	Leave for trip in another country with work or research purpose.	350 km
16	Competitions or tours	Go and participate in a contest or competition in another city.	152 km
17	Sightseeing abroad	It is time for a well-deserved vacation abroad.	670 km
18	Attend festival in the country	You decided to go to a film festival, camp or music concert/festival in the country.	270 km
19	Nature activities	You need to recreate and try some activities in the nature: rafting, fishing, hunting, horse riding, camping or hiking.	37 km
20	Picknicking	You decide to take a break and go to a picnic in the park.	1.8 km
21	Visit museum or monument	Today you wish to visit a museum or a monument in the city.	4.2 km
22	Go to your friend's house	You go to your friend's house to do homework, play video games or watch a movie.	3.3 km
23	Take a child to the playground	You are taking care of a toddler and you need to take him to the playground.	2.4 km
24	Take a course	The time has come for you to take an art, cooking, dance or photography course.	3.9 km

Figure 3.3.: Example of data from the activity patterns integrated in the simulation game

3.3.3. User Stories

The user stories could represent the simulated environment for observing the behaviour of participants. A story consists of an activity pattern, together with its associated mobility options, and some additional variable properties: day type, weather and accessibility conditions. We decided to include the weather as an influential factor, followed by accessibility conditions, due to the fact that sustainable mobility covers equity in accessibility, with specific consideration offered to the vulnerable population groups.

Regarding the day type, it represents a level achievement mechanism, mentioned in subsection 3.3.6. The two main categories will be regular day and vacation day. Onward, these two will also have two subcategories, in the following way:

- Regular Day
  - Slow
  - Busy
- Vacation Day
  - Labour
  - Vacation

The reason behind integrating these two main classes is that daily mobility generally represents very routine. Therefore, it is necessary to take into account also situations that lie outside the daily routines. Vacations can be thought-out as representatives of such situations. Just like everyday activities, holiday activities heavily depend on mobility and accessibility.

Each story should be built by having in mind a specific set of factors. Some of them are direct parts of the story, some of the activity pattern incorporated in the story and others from the mobility options of the activity pattern. Ideas concerning the integration of this factors in the implementation of the simulation are provided below:

- factors: CO2 emissions, duration and distance of the travel, cost of travel, weather, accessibility
- CO2 emissions:
  - use a tool to compute the emissions for the means of transport (not per person)
- Duration and distance:
  - compute some predefined distances, together with the duration for different means of transport
- Cost:
  - the cost of the travel is computed per profile, not per member (for a family profile, the cost displayed will be for all members of the family, not just one member)
  - do not provide actual cost values (actual values for the cost cannot be displayed because we cannot compute an exact cost of a trip), but rather the cost sources that come with the transport options (tickets, parking fees, fuel)

- Weather:
  - find a dataset which includes the weather forecast for a period of time and randomly select the value for each story from that dataset
- Accessibility:
  - take a 50% chance of introducing an accessibility situation in the story
  - provide more details on the accessibility situation (for example: "you are recovering from surgery" is not enough, as more information about the surgery is needed)
  - create some predefined age-based accessibility situations
  - in case of family profiles, the accessibility situation will be applied only to one member
  - possible accessibility conditions: "You have a broken leg"; "Recovering from eye/hip surgery".

3.3.4. Mobility Options

Transport is not an end in itself, but rather a mean, providing access to a vast variety of services that support the well-being of individuals, such as: jobs, education, markets and goods, social interaction. The mobility options integrated in the activity patterns include:

- walking: the pushing of soft mobility is an easy step to lower emissions and revamp life quality, with predilection to urban neighbourhoods
- ride own bicycle
- rent bicycle
- public transport: promoting the quantity and quality of public transport services is one of the most effective methods to diminish not just emissions, but also congestion
- use own car
- cab
- plane

With regard to the factors implied for a mobility option, we decided on the followings:

- CO2 emissions and green house gases: reveal the values and levels that the users reach in their activities
- time: take into account how much time are the users willing to spend travelling
- cost: consider how much money the user is willing to spend (for example on transport tickets, parking fees, fuel cost, rental of bicycle)

Transport Impact

It is our intention to inform the participants on the impact of the available means of transport, both positive and negative. The possible impact values are enumerated below:

1. Walk/Ride own bicycle: ecological choice, healthy choice, save money
2. Rent bicycle: ecological choice, healthy choice, save money; need to rent bike
3. Public transport: ecological choice, save money, no traffic-related stress, enjoy the view of the trip; need transport from station to destination (in case of trains), need ticket or pass
4. Car: save time, more comfort; traffic, need parking, fuel cost
5. Cab: save time, more comfort; traffic, cost of trip
6. Plane: low-risk transport option; need to be early for check-in, need transport from airport to destination

Before creating the stories, we drew some decisions representing the best transport alternative in different scenarios. Below are presented some of the explored scenarios.

Scenario 1

Stakeholder: student who goes into the city for activities of daily living (university, markets and goods, social interaction and so on)

Alternatives

1. Walking
   - pros: zero cost, zero emissions
   - cons: time (does the distance adjust to the time attribute of the user?), weather (is the user willing to walk in extreme conditions, such as heavy rain/snow, dense fog, strong wind or very low/high temperature?), accessibility (is walking a difficult activity for the user?)
2. Ride own bicycle
   - pros: zero cost, zero emissions
   - cons: time (does the distance adjust to the time attribute of the user?), weather (is the user willing to ride in extreme conditions?), accessibility (is riding a difficult activity for the user?)
3. Rent bicycle
   - pros: low cost (rental), zero emissions
   - cons: time, weather, accessibility
4. Public transport
   - pros: low cost (semester pass), reduction of emissions, time, weather
   - cons: accessibility (is the transport provided with a ramp or special places for disabled people?)
5. Own car
   - pros: accessibility (easier for a disabled person), time, weather
   - cons: high cost (parking and fuel cost), high emissions

6. Get a cab
   - pros: accessibility (easier for a disabled person), time, weather
   - cons: medium cost (cab cost), high emissions

Decisions
Is the user a person with special needs?

- Yes: is public transport accessible?
  - Yes: PUBLIC TRANSPORT
  - No: does the user own a car?
    - Yes: OWN CAR
    - No: GET A CAB
- No: does walking adjust to the time attribute of the user?
  - Yes: is the user willing to walk/ride in the weather conditions?
    - Yes: does the user prefer riding to walking?
      - Yes: does the user own a bike?
      - – Yes: OWN BIKE
      - – No: RENT BIKE
      - No: WALK
    - No: PUBLIC TRANSPORT
  - No: does riding adjust to the time attribute of the user?
    - Yes: does the user own a bike?
      - Yes: OWN BIKE
      - No: RENT BIKE
    - No: PUBLIC TRANSPORT

Scenario 2
Stakeholder: elderly couple coming to the city to visit their nephews
Alternatives

1. Public transport (train)
   - pros: medium cost, reduction of emissions, weather
   - cons: time, accessibility

2. Own car
   - pros: accessibility, weather
   - cons: high cost, high emissions, time

3. Plane
   - pros: accessibility, time
   - cons: high cost, high emissions, weather

Decisions
Is the user a person with special needs or requires some level of comfort (due to age)?

- Yes: is public transport accessible?
  - Yes: does taking the train adjust to the time attribute of the user?
    - Yes: PUBLIC TRANSPORT
    - No: does the user have budget for plane ticket?
      - Yes: PLANE
      - No: does the user own a car?
      - – Yes: OWN CAR (*time)
      - – No: PUBLIC TRANSPORT (*time)
  - No: does the user have budget for plane ticket?
    - Yes: PLANE
    - No: does the user own a car?
      - Yes: OWN CAR (*time)
      - No: PUBLIC TRANSPORT (*time, accessibility)
- No: does the user have budget for plane ticket?
  - Yes: PLANE
  - No: does the user own a car?
    - Yes: OWN CAR
    - No: PUBLIC TRANSPORT (*accessibility)

3.3.5. User Response

Since our plan was to see how people respond through these stories, we could ask the users to provide an explanation, regarding why they made a particular choice of transport. At this point, we may present to the users the impact of their given options, both their choice and the remaining ones.

Every time the players begin a simulation, the session will be saved with an identifier of the simulation and the profile id of the participants. Each mobility choice made by the user for a story will be recorded as user response and saved with the following information:

- id of the user story
- id of the selected transport option
- id of the simulation
- explanation for the mobility choice

The information provided by the user response is very important since one of our intentions with this business simulation game is to extract this data, analyse it and draw mobility conclusions based on the choices made by participants. Thus, the user response can be seen as a link between all the other presented theoretical concepts: simulation, user profile, mobility option, activity pattern and user story.

3.3.6. Simulation

After investigating the existing literature, we decided to use a level achievement technique. Therefore, the simulation will consist of two different levels, each having another two classes: regular day type, which may be slow or busy, and vacation day type, with its divisions, labour and vacation.

Our aim for a simulation is that, given a set of alternative travel plans, which include a range of different mobility options and are ranked based on CO2 emissions, players will select and complete a journey that has lower emissions than one with higher emissions. However, while travellers may try to be environmentally sustainable, they cannot always keep all aspects of the journey in control (for example business journeys by taxi, that run against personal travel preferences, hence reward the more sustainable journeys, not punish the less sustainable). The path will be shown considering the several types of movement: walk, ride bike, public transport and so on. Every such option will be accompanied by economic and environmental cost, time and impact. The game inspires individuals to revise their practices with the help of "intrinsic motivation" as well, by offering information on costs or carbon footprint. Even though commuters don't appear to be delicate to weather circumstances than non-commuters, the approach includes the climate scene too, beside the accessibility conditions.

The complete workflow of a simulation consists of the following actions: the player selects one of regular day type (slow or busy) and vacation day type (labour or vacation). Based on the chosen day type, the screen will display a list of activity patterns that people (regardless of profile) are most likely to engage in for that type of day. The player should select between 2 and 4 activity patterns, after which the user stories will be created based on these choices. For each story, the screen will display one by one the following information: a short description, the distance that is to be travelled and the mobility options, which include details such as time required, cost and CO2 emissions ([23]). For each simulation, we consider including "special" activity patterns, which should incorporate the additional factors: the weather (the player must take into account the weather conditions when making choices) or accessibility (there may be cases when the user broke a leg or simply its mobility is affected by an accessibility situation). If none of these factors are specified, it means that we suppose by default that the weather is favourable for doing any activities and no accessibility conditions are needed. The players should choose the preferred transportation. Afterwards, they will be requested to provide an explanation for their option. At this step, we would also display information regarding the impact that the given mobility options have. The user's response is recorded and the simulation continues with the next selected activity pattern. When the users finish with a specific day type, they can try another one and go through the same steps again. At the end of each type of day, some progress information about the user's evaluation (CO2 index) will be available.

In what follows, are presented some of the activity patterns and their mobility choices, that were thought for each day type. For each pattern it is shown the entire information that will be included in the screen. Regarding the cost, an approximate cost was computed, considering factors such as: rental cost, parking ticket, taxi cost. CO2 emissions were obtained using a tool, namely [23].

- Go to school/university/work
  Distance: 3.5 km
  Options: walking: time: 45min / cost: 0€ / emissions: 0
  ride own bicycle: time: 15min / cost: 0€ / emissions: 0
  rent bicycle: time: 20min / cost: 1€ / emissions: 0
  public transport: time: 22min / cost: 2€ / emissions: 0.4kg
  car: time: 20min / cost: 5€ / emissions: 0.9kg
  cab: time: 20min / cost: 7€ / emissions: 0.9kg

- Go to study at the library
  Distance: 1.5 km
  Options: walking: time: 18min / cost: 0€ / emissions: 0
  ride own bicycle: time: 3min / cost: 0€ / emissions: 0
  rent bicycle: time: 5min / cost: 1€ / emissions: 0
  public transport: time: 13min / cost: 2€ / emissions: 0.2kg
  car: time: 20min / cost: 5€ / emissions: 0.4kg
  cab: time: 20min / cost: 8€ / emissions: 0.4kg

- Shop for groceries, clothes, books or other supplies
  Distance: 0.7 km
  Options: walking: time: 10min / cost: 0€ / emissions: 0
  ride own bicycle: time: 3min / cost: 0€ / emissions: 0
  rent bicycle: time: 5min / cost: 1€ / emissions: 0
  public transport: time: 8min / cost: 2€ / emissions: 0.1kg
  car: time: 4min / cost: 1€ / emissions: 0.2kg

- Go to the gym for training
  Distance: 3.0 km
  Options: walking: time: 35min / cost: 0€ / emissions: 0
  ride own bicycle: time: 9min / cost: 0€ / emissions: 0
  rent bicycle: time: 10min / cost: 1€ / emissions: 0
  public transport: time: 21min / cost: 2€ / emissions: 0.3kg
  car: time: 15min / cost: 2€ / emissions: 0.8kg
  cab: time: 15min / cost: 6€ / emissions: 0.8kg

- Attend social activities or group gatherings
  Distance: 2.0 km
  Options: walking: time: 25min / cost: 0€ / emissions: 0
  ride own bicycle: time: 8min / cost: 0€ / emissions: 0
  rent bicycle: time: 10min / cost: 1€ / emissions: 0
  public transport: time: 14min / cost: 2€ / emissions: 0.2kg
  car: time: 12min / cost: 2€ / emissions: 0.5kg
  cab: time: 12min / cost: 4€ / emissions: 0.5kg

- Meet with friends in different contexts (theatre, opera, cinema, restaurant, bowling, sports match)
  Distance: 2.9 km
  Options: walking: time: 21min / cost: 0€ / emissions: 0
  ride own bicycle: time: 5min / cost: 0€ / emissions: 0
  rent bicycle: time: 7min / cost: 1€ / emissions: 0
  public transport: time: 10min / cost: 2€ / emissions: 0.3kg
  car: time: 18min / cost: 5€ / emissions: 0.8kg
  cab: time: 18min / cost: 7€ / emissions: 0.8kg

- Go to the hairdresser's or beauty salon
  Distance: 2.2 km
  Options: walking: time: 20min / cost: 0€ / emissions: 0
  ride own bicycle: time: 6min / cost: 0€ / emissions: 0
  rent bicycle: time: 7min / cost: 1€ / emissions: 0
  public transport: time: 16min / cost: 2€ / emissions: 0.2kg
  car: time: 12min / cost: 5€ / emissions: 0.7kg
  cab: time: 12min / cost: 4€ / emissions: 0.7kg

- Go to your children's place to take care of the nephews
  Distance: 12.0 km
  Options: ride own bicycle: time: 42min / cost: 0€ / emissions: 0
  rent bicycle: time: 45min / cost: 1€ / emissions: 0
  public transport: time: 34min / cost: 2€ / emissions: 1.3kg
  car: time: 30min / cost: 4€/ emissions: 3.1kg
  cab: time: 30min / cost: 14€ / emissions: 3.1kg
- Attend sports practice, instrument/language lessons or driving lessons
  Distance: 3.4 km
  Options: walking: time: 42min / cost: 0€ / emissions: 0
  ride own bicycle: time: 14min / cost: 0€ / emissions: 0
  rent bicycle: time: 15min / cost: 1€ / emissions: 0
  public transport: time: 23min / cost: 2€ / emissions: 0.4kg
  car: time: 12min / cost: 5€/ emissions: 0.9kg
  cab: time: 12min / cost: 7€ / emissions: 0.9kg

3.4. Design Development

This section considers various activities concerning the design phase, emphasizing the design of the: use case view, prototype, data model, profile comparison and dashboard.

3.4.1. Use Case View

The use case view presents different actions actors are able to do within the system.

Figure 3.4.: Use case diagram of the system's general workflow

Use Case	
Actor	User
Brief Description	The general workflow of the system
Pre-Conditions	-
Post-Conditions	The user has successfully reached the end of the simulation.
Main Success Scenario	1. User selects an existing profile. 2. User chooses a day type, between regular slow day, regular busy day, vacation labour day and vacation day. 3. User selects activity patterns from the displayed list, based on the previously chosen day type. 4. User takes part in the simulation (which may last as long as the user wants). 5. Evaluation of the user's progress is shown.

Figure 3.5.: Use case view of the system's general workflow

First, Figures 3.4 and 3.5 present the general workflow of the system that the user goes through, when taking part in the game, as a single use case. Afterwards, we describe a single simulation step more detailed in a second use case (Figures 3.6 and 3.7). The second use case may repeat as many times as the user wants, as part of the simulation from the first use case.

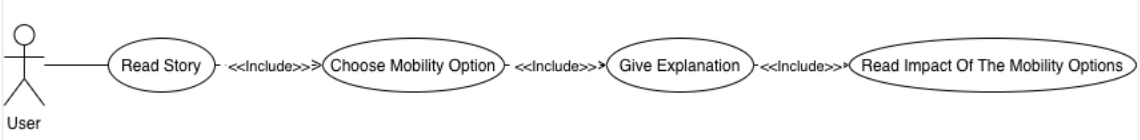


Figure 3.6.: Use case diagram of the simulation workflow

Use Case	
Actor	User
Brief Description	The simulation part of the system, based on the selected activity patterns
Pre-Conditions	Profile was selected, day type was chosen, as well as activity patterns
Post-Conditions	The user has successfully reached the end of the simulation.
Main Success Scenario	1. User reads the story based on the selected activity pattern. 2. User decides on one mobility options. 3. User inputs an explanation for the performed choice. 4. The impact of each involved mobility option is shown.

Figure 3.7.: Use case view of the simulation workflow

3.4.2. Prototype Design

Based on the research done and the decisions taken, a first design of the prototype was established, as depicted in the images below. Prior to the actual implementation of the CTMobility business simulation game, an improved version is to be realised. The tool called Figma [19] was used for the realisation of the screen prototype.

The screens that were built for the prototype include: profile selection, reveal and creation, day selection, activity pattern selection, story presentation (with mobility decision), question (for the choice) and evaluation of the achieved progress.

The Profile Choice Screen in Figure 3.8 shows the available options for a profile. By clicking on a profile, the player is redirected to the next screen. The View Profile Screen in Figure 3.9 displays the details of the selected profile: for each member (either one for individual profile or more for family profile), the name, age, a description and income are displayed. The Create Profile Screen (Figure 3.10) allows the player to create its own profile by giving the same information. At any time, the profile of the user would be included on the screen.

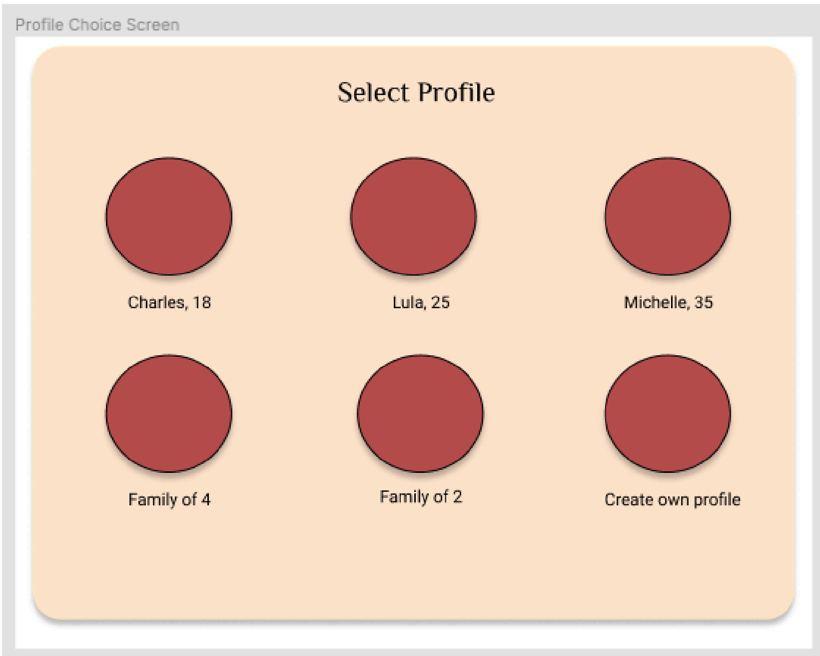


Figure 3.8.: Prototype design of the profile selection screen

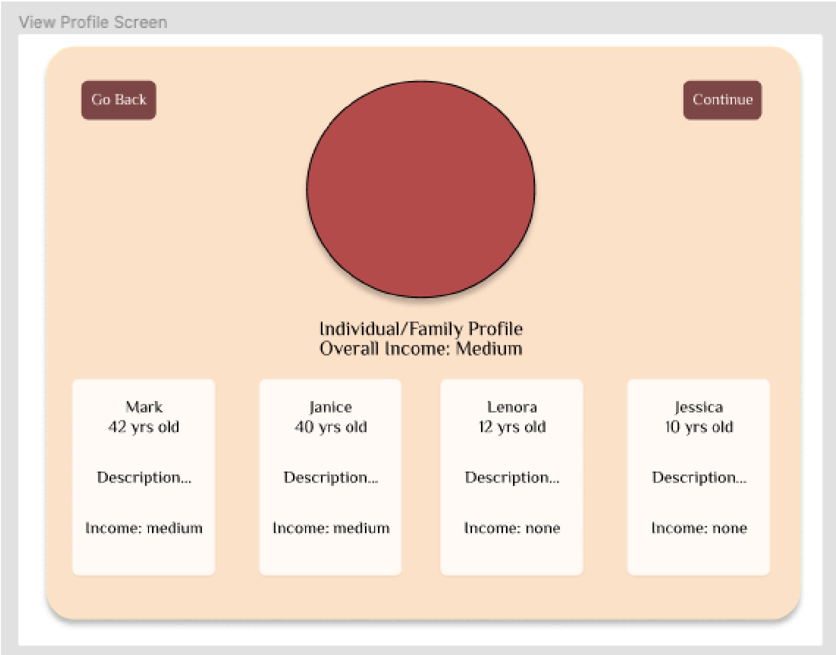


Figure 3.9.: Prototype design of the profile reveal screen

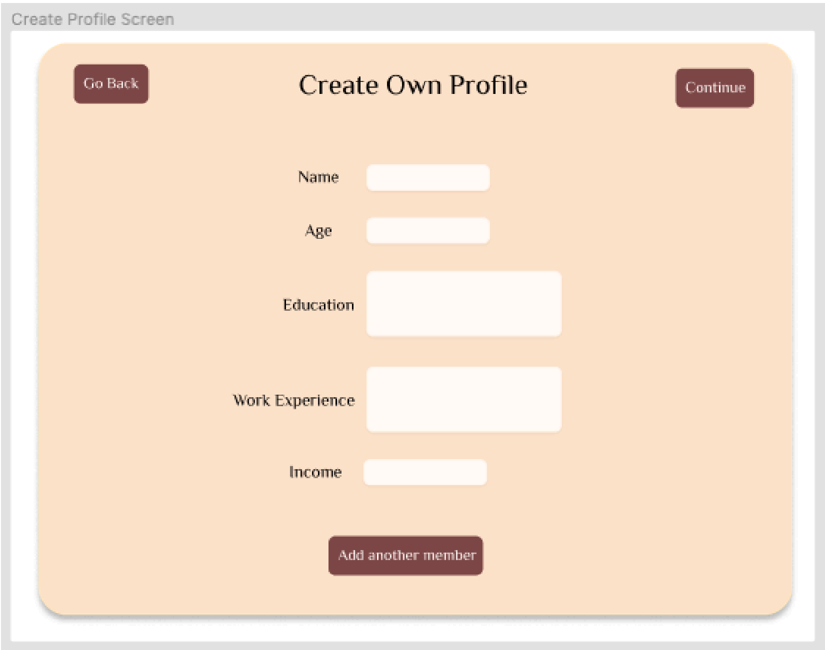


Figure 3.10.: Prototype design of the profile creation screen

The simulation begins with the level choice in Levels Screen (Figure 3.11). The Level Details screen in Figure 3.12 informs the user on how to play the game. The activity patterns screen was added, as seen in Figure 3.13, which allows participants to select from a list. The Simulation Screen shows the story with factors and transport options, as depicted in Figure 3.14. The player keeps going through these stories, selecting the preferred options, until the end is reached. There is also an explanation screen (where the impact of the transport is displayed this time), shown in Figure 3.15. The user is asked here to mention the reason behind a mobility decision. In the Evaluation Screen from Figure 3.16, the user can see the course of the game, with the accumulated points and computed CO_2 index. In the simulation part we added the option to view your profile at any time.

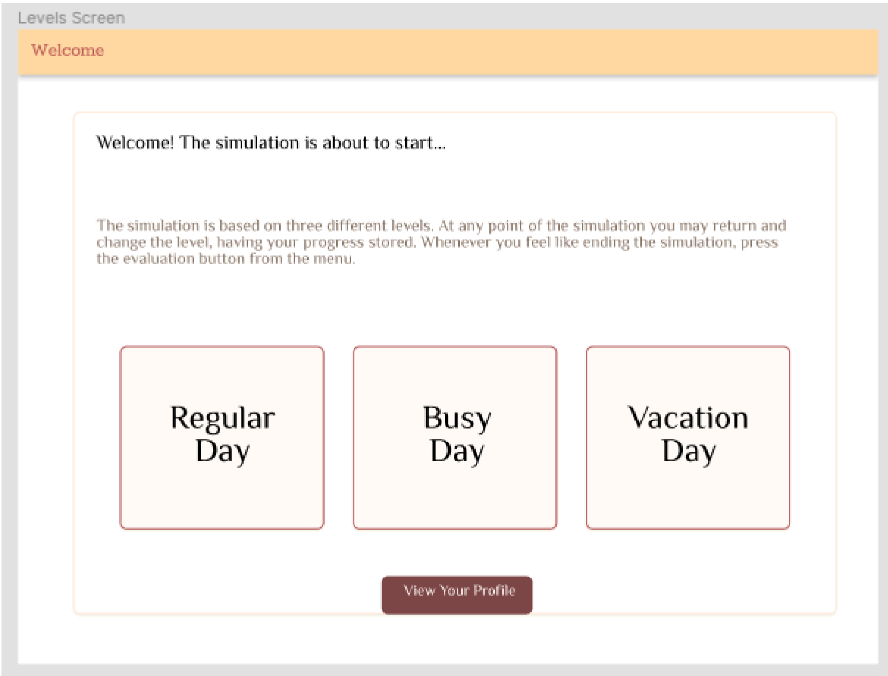


Figure 3.11.: Prototype design of the day selection screen

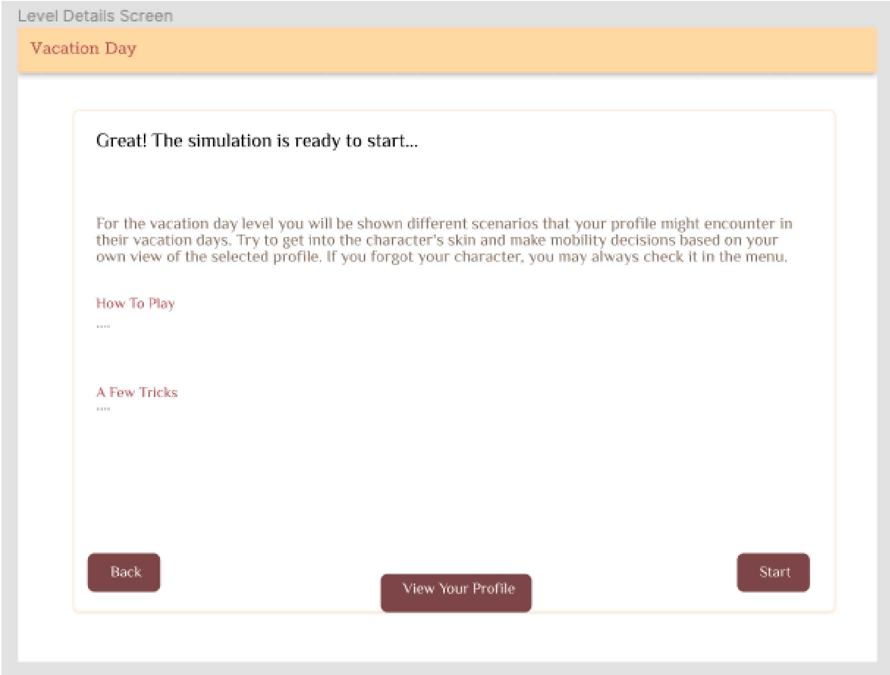


Figure 3.12.: Prototype design of the selected day screen

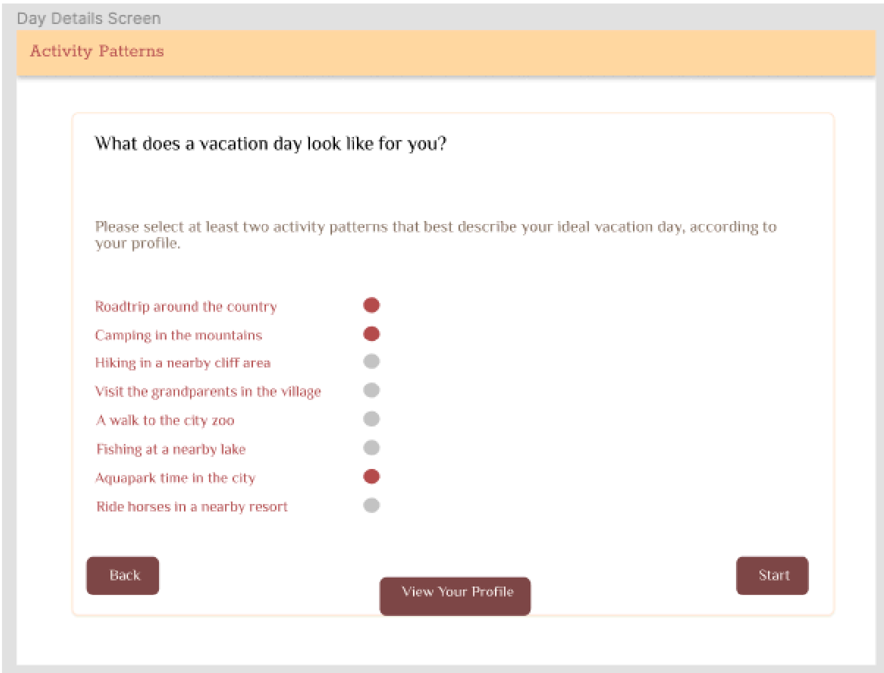


Figure 3.13.: Prototype design of the activity pattern selection screen

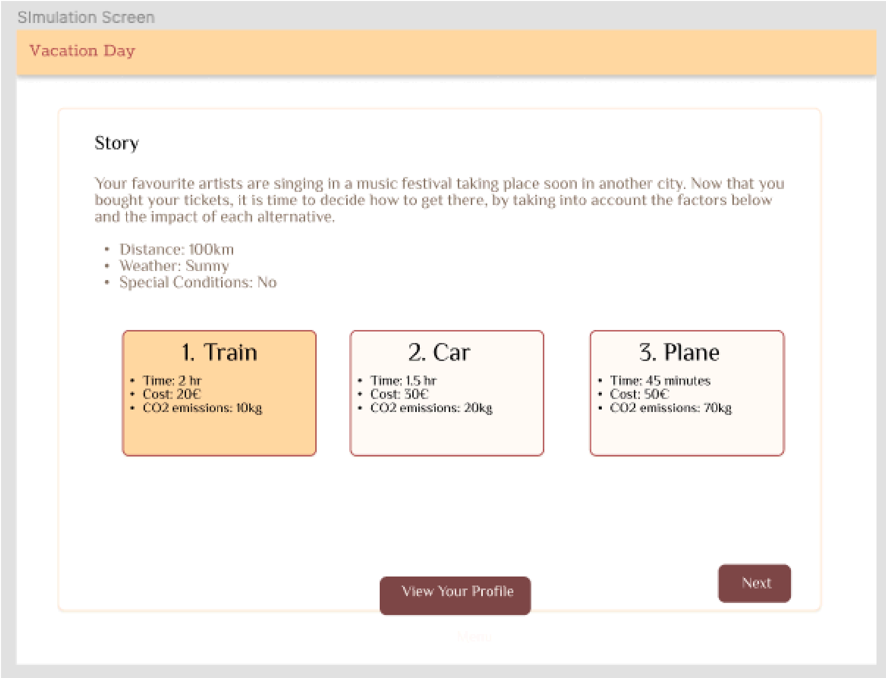


Figure 3.14.: Prototype design of the story screen

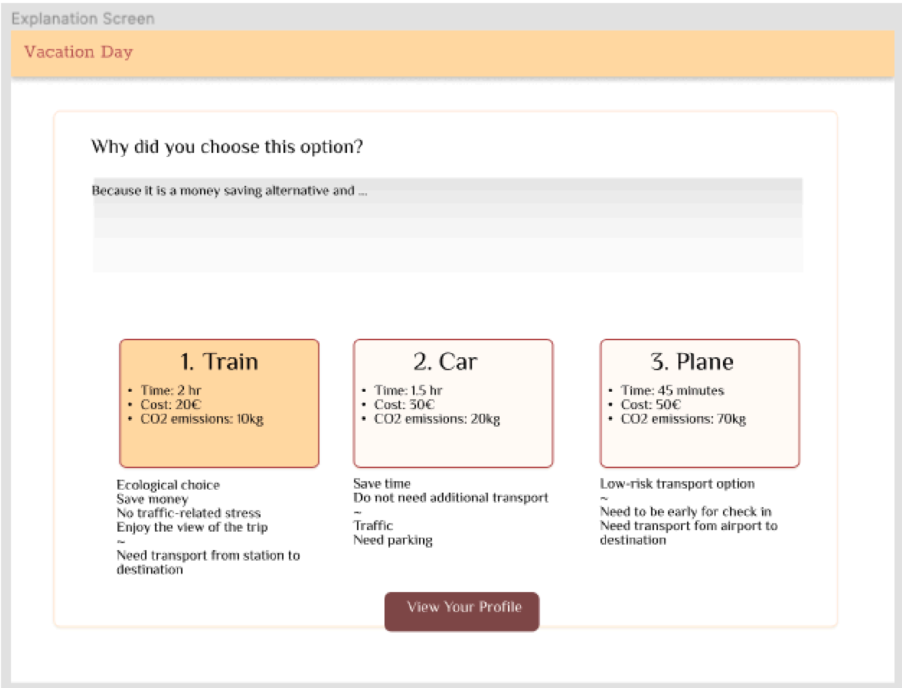


Figure 3.15.: Prototype design of the question screen

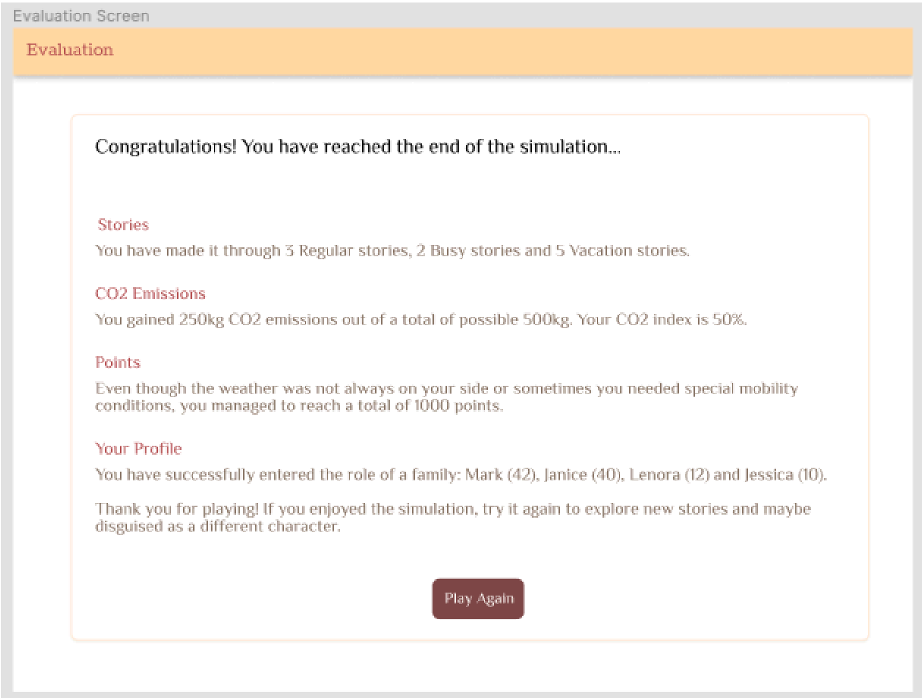


Figure 3.16.: Prototype design of the evaluation screen

3.4.3. Data Model

The design of the data model was performed as a database diagram format. Figure 3.17 presents the tables with their corresponding fields and relationships between them. These are further described in more details.

- Member:
  - id
  - name
  - age
  - gender
  - occupation
  - profileId (a member belongs to a profile)

- Profile:
  - id (a profile has one or more members)
  - isPredefined (boolean value)
  - numberOfMembers
  - username
  - password (for admin)

- Activity:
  - id
  - description
  - distance

- Story:
  - id
  - weather
  - accessibility
  - activityId (a story is created from the fixed information of an activity pattern, by adding variable factors)

- Transport:
  - id
  - name
  - duration
  - cost
  - emission
  - activityId (the transport is linked to activity, not story; the transport options depend on the fixed information from activity, not on weather or accessibility)

- Impact: predefined impact values;
  - id
  - value

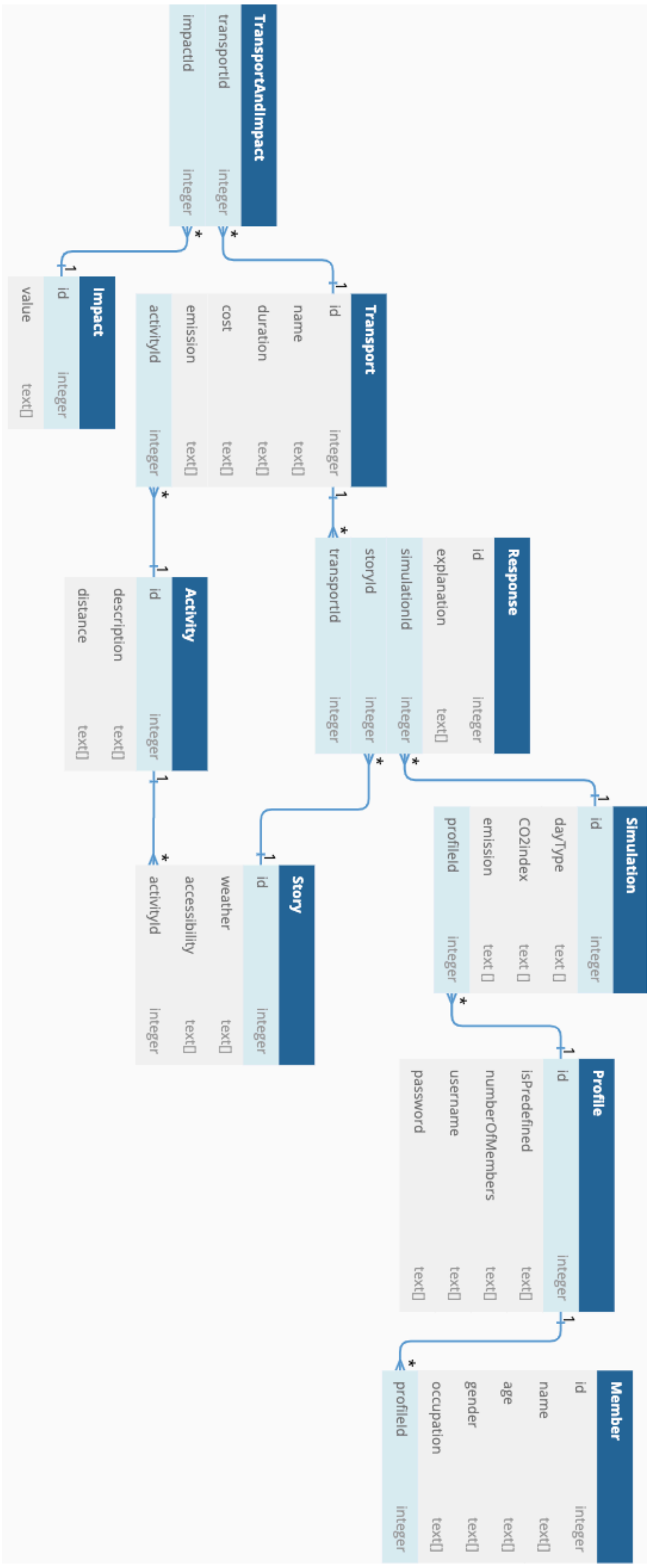


Figure 3.17.: Overview of the data model

- TransportAndImpact: link table between transport and impact (a transport can have more impact values, whereas an impact can appear in more transports);
  - transportId
  - impactId
- Response: records the user's response in the simulation;
  - id
  - explanation (of the transport choice)
  - simulationId (id of the session)
  - storyId (we need the varying and fixed information)
  - transportId (the choice of the user)
- Simulation: save every session;
  - id
  - profileId (of the user)
  - storyId (we need the varying and fixed information)
  - transportId
  - dayType (this information is fixed and is chosen once for each simulation, thus it depends on the session, not on the story or actitvity patterns)

To simplify this information, Figure 3.18 presents the data model organised on layers matching the corresponding logic.

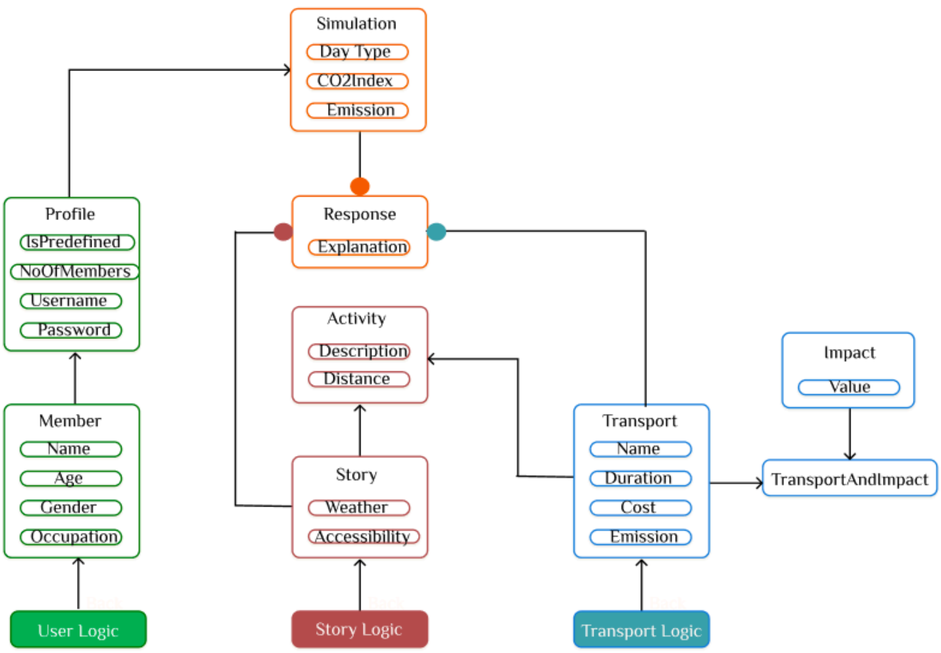


Figure 3.18.: Simulation Model Data Structure

3.4.4. Profile Comparison

The aim of the profile comparison is to strengthen the evolution of participants with regard to the sustainability goals. Our intention is to allow users to compare their progress, especially their achieved CO2 index, but also time or distance travelled, with other user profiles in order to help them improve their own index and real-life decisions.

There are two types of profiles: predefined profiles and own profiles. Further, both these categories are split between individual profiles, with only one member, and family profiles, having at least two members. Regarding the predefined profiles, some of the information is already fixed, as mentioned before in 3.3.1. We denote the five predefined profiles (three individual ones and two families) in the following way:

1. S (student): age=18, occupation=Student
2. G (graduate): age=25, occupation=Software Developer etc.
3. W (worker): age=35, occupation=Professor etc.
4. F (family of 4):
    a) father: gender=M, age=42, occupation=Estate Agent etc.
    b) mother: gender=F, age=40, occupation=Businessperson etc.
    c) first child: age=12, occupation=Pupil
    d) second child: age=10, occupation=Pupil
5. E (elderly couple):
    a) grandfather: gender=M, age=65, occupation=Retirement
    b) grandmother: gender=F, age=64, occupation=Retirement

Own Created Profiles

Concerning the own profiles, none of the information is fixed. Thus, the own profiles can vary in respect to the features: different number of members, each one with its own characteristics. Own created profiles are denoted as:

O (own created profile)

To create a comparison link between predefined profiles and own created profiles, we can find an equivalent predefined profile for each created one, like this:

- O: individual created profile, age less than 22 <=> S (student)
- O: individual created profile, age between 22 and 30 <=> G (graduate)

- O: individual created profile, age greater than 30 <=> W (worker)
- O: family created profile, has at least a child (age less than 18) <=> F (family of 4)
- O: family created profile, with no children <=> E (elderly couple)

However, considering that a user profile consists of various features (different number of members, each with its own characteristics), we wondered if there exists the possibility to define such different characteristics in the own created profiles, that deviate very strongly from the five predefined ones. This lead us to consider an average profile across everyone, together with a min/max and a median of some of these predefined profiles.

This is something that is very interesting because it allows you, as a player, to see how you performed in the simulation game and then to compare yourself to others. In this case, we don't want to go for some real profiles that have been executed, we rather prefer to seek an average mean or other calculations, as previously mentioned. Considering that we have defined these five fixed-term profiles, we can calculate an average for each one of them. The player(s) who will complete the game can then see their results compared to all these predefined profiles. However, it makes sense to have an additional one, which represents the average user and shows the mean across all user profiles. Moreover, it is important to have other values as well, not just CO2, like the average time and distance travelled.

Furthermore, as we mentioned, we have an average user, which covers all profiles (predefined and own ones). Thus, the average user includes the five fake-aggregated predefined profiles in it as well. This is just fine, but it could be even more appropriate to just calculate one average own user (including only the own created profiles). The intuition behind this idea is that we know what people are actually using independently and not only from the predefined profiles, because we assume it is easier for them to make the mobility choices. Therefore, we should have two average users (one for all profiles, one for just the own profiles), because the predefined profiles rely on assumptions that we took, which is not the case for the own profiles, where players invent or use their own situations.

The composition of the own profile is something players decide: what it looks like, if they have two kids and so on. Given this situation, it would be of great benefit to see what the average profile is actually here as well. Our interest is not just in the average usage, but also the average profile (for example average age, average number of members). We establish the average profile of the own created profiles and then have a list of statistics: the percent of men and women among players, the average age and so on. This information may not be interesting for the end users, but rather for the administrators.

Figure 3.19 presents a sketch, which makes easier to understand what would be the result of such a dashboard. It allows me, as a player, to see a bit of how others performed. In this example, it is noticeable that my profile is close to the family one and my response is not so far away, but the individuals are very far away for some reason. One explanation might be that families take trains or (shared) cars, while individuals are likely to take the car alone. The result of the profile comparison should be available in the dashboard and at the end of the game. Next subsection introduces the design of the dashboard.

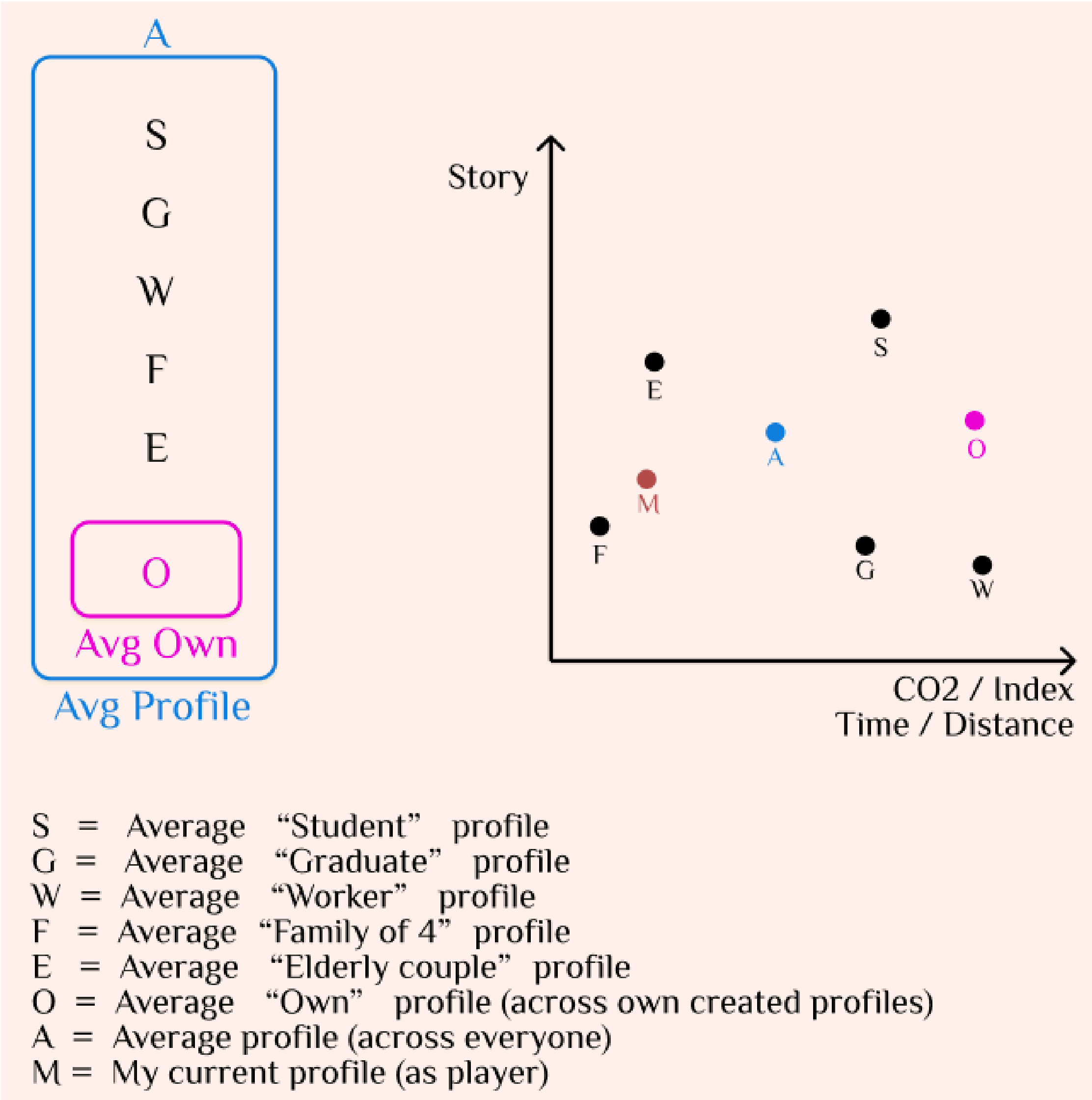


Figure 3.19.: Schema of the profile comparison approach from the prototype

3.4.5. Dashboard Design

In general, a dashboard represents a glimpse of all the data through visual display and can be used for a variety of reasons. However, its main goal is to supply information at-a-glance. We also resort to the help of dashboards for visualizing user-related data, regarding sustainability and game progress. Figure 3.20 represents a prototype for the dashboard design.

The initial design concerns the dashboard for non-admin users, which are participants in the simulation. In our design, we considered different ideas and perspectives for the dashboard with respect to the information that we want to display and how it is displayed. First, we include information for dashboard such as stories played, travelled distance, accumulated CO2 emissions and index. Secondly, we add a variety of visualisations (graphs and charts) for dashboard, on the CO2 emissions, travelled distance and CO2 index. Lastly, we use tables with information on completed stories and selected mobility options, for the dashboard.

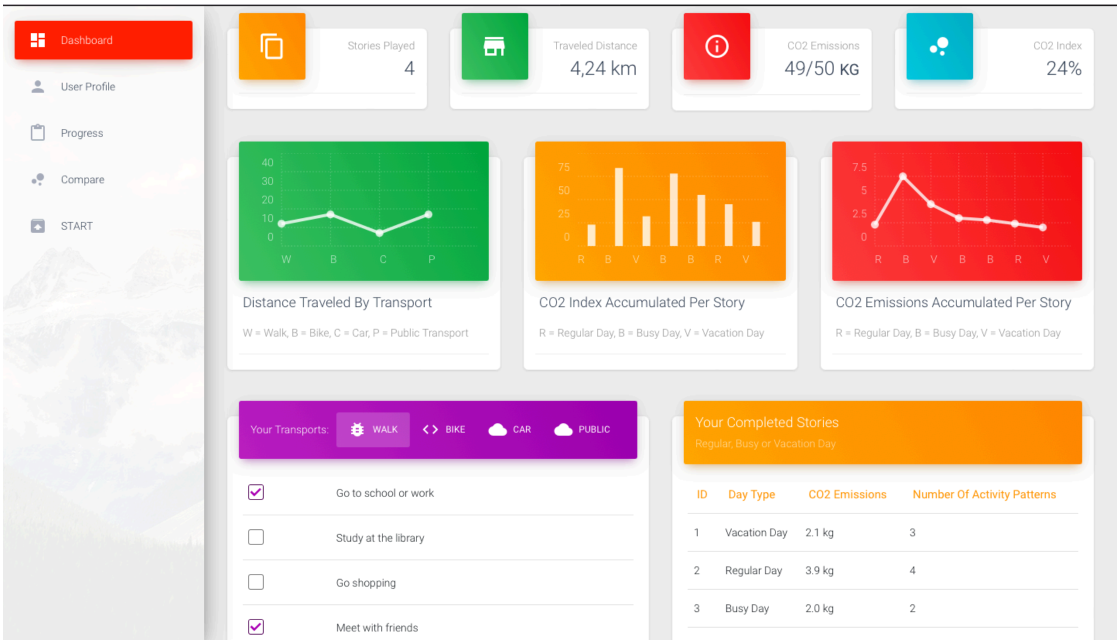


Figure 3.20.: Design of the dashboard screen

3.5. Summary

RQ2 - How can the simulation game for sustainable mobility be designed?

Building on the previously performed research in chapter 2, this section presents our own ideas for the design phase, concerning the concepts and workflow of the simulation. Their concrete implementation is addressed in the next chapter 4.

A simulation game is intended to mirror a simplified adaptation of reality. However, it is a reliable setting to conduct experiments in [50]. This statement is valid for the CTMobility business simulation game. This chapter has introduced and discussed simulation gaming as an exploration issue and strategy testing research technique. Games have the ability to serve as dynamic scenarios, allowing stakeholders to build not just individual, but also team awareness, which is perceived as an essential condition for rewarding choices ([18], [40]). In our business simulation game design, we keep participants informed of the consequences of certain mobility decisions in various daily activities.

From the game design process, we focused on the development of the simulation game prototype and identified four stages. We have separately described each one of them: roles (user profiles, which can be individual or family profiles), scenarios (user stories, which consist of some variable information, such as the weather or accessibility conditions, and an activity pattern, which further comprises mobility options), accounting schema (the user response) and operating procedure (the simulation itself).

As part of the design development, we also considered the use case view, prototype design of the simulation workflow using a tool, the data model, including a database diagram format, profile comparison based on two average profiles (one across everyone and one across own profiles) and dashboard design for the visual display of data.

4. Implementation

This practical chapter uncovers an intricate display of the way in which the previously-introduced theoretical ideas are consolidated and implemented, with respect to the business simulation game for sustainable mobility.

4.1. Requirements

The first step in the direction of successfully implementing such a tool, is to identify what the implementation needs. The functional requirements are prioritized based on their necessity, by using three goals: need-to-have, nice-to-have, not-to-have. Requirements titled as "Need to have" are essential for the current delivery time-box in order for it to be successful. Requirements named as "Nice to have" are desirable, but not critical, and could improve the user experience for a light development cost. Requirements called as "Not to have", have been decided as not appropriate at the time.

Code	Summary	Goal
R01	Create five predefined profiles, based on mobility behaviour habits, lifestyle and social status.	Need to have
R02	Allow user to create its own profile.	Need to have
R03	Allow user to see the selected profile at any time.	Need to have
R04	The levels page should let the user choose the simulation type: regular day (slow / busy) and vacation day (labour / vacation).	Need to have
R05	Provide a help page which describes the steps of the simulation	Nice to have
R06	Allow the user to decide the activity patterns for the selected day type.	Need to have
R07	The system should let the user choose between two and four activity patterns.	Need to have
R08	The simulation will provide one by one the selected activity patterns.	Need to have
R09	For each activity pattern, display some information and the mobility options.	Need to have
R10	Allow the user to select only one mobility option in each story.	Need to have
R11	Provide a method for users to explain in each story their choice.	Need to have
R12	After going through all selected activity patterns, allow the user to either change the day type, go to the profile page or end the simulation.	Need to have

R13	Provide a points score system.	Not to have
R14	Save the user's actions in CSV format.	Nice to have
R15	Create a data structure for the user response.	Need to have
R16	Create a dataset out of the user's saved actions.	Need to have
R17	Include a "Profile Comparison" page, which displays a comparison between user profiles (in order to see how other user profiles performed in the simulations). For the current player, compare one's present results with separate results obtained from each of the five generated user profiles, results from the own created user profiles, but also results extracted from all user profiles at once.	Need to have
R18	In the "Profile Comparison" page, have an option for day types, in order to determine how other users (and also all users) performed in the selected day type, in terms of distance, time and CO2 level.	Need to have
R19	Include a "Progress" page, which displays the user's history in simulation (selected activity patterns, mobility choices).	Nice to have
R20	Include information for dashboard, such as: stories played, travelled distance, accumulated CO2 emissions and index.	Need to have
R21	Include a variety of visualisations (graphs and charts) for dashboard, on the CO2 emissions, travelled distance, time and CO2 index.	Need to have
R22	Include a table with information on completed stories, for dashboard.	Need to have
R23	Include a table with information on selected mobility options, for dashboard.	Need to have
R24	Create a graphical user interface for the admin.	Nice to have
R25	Provide dashboard for admin to visualise important data related to sustainability, such as CO2 emissions and index of the users.	Nice to have
R26	Provide access control (login) for admin.	Nice to have
R27	Provide access control (login) for regular users.	Not to have
R28	Allow the admin to add/modify/delete activity patterns.	Nice to have
R29	Allow the admin to export data, such as user response.	Nice to have
R30	Allow the admin to view all users; when clicking on a user, the admin can see the user's history and progress.	Nice to have
R31	Allow the admin to view statistics, such as: how many users entered the system, how many activity patterns are in the system, how many simulations were played, how much a user has travelled, how much CO2 a user has consumed.	Nice to have

Table 4.1.: Requirements prioritization for the CTMobility tool

Depicted in Table 4.1, the functional requirements are prioritized based on the three mentioned goals.

The fundamental functions ("need-to-have" ones) are related to profiles, activity patterns and dashboard. For the profiles, the focus is on creating five predefined profiles, based on mobility behaviour habits, lifestyle and social status, while also allowing the user to create its own profile. Regarding the activity patterns, the intention is to let the user decide on activity patterns for different day types (regular day: slow or busy, vacation day: labour or vacation). Every activity pattern will have displayed some information and the mobility options for the player. Moreover, we want to integrate a dashboard concerning various statistics, such as: comparison between different users, monitoring the progress of current user (selected activity patterns, mobility choices), visualisations on the CO2 emissions, travelled distance and CO2 index.

With regard to what we want to pursue with this project, an idea would be to gather all the information from users taking part in the simulation and create a dataset focusing on mobility choices. Following, we can analyse this dataset, extract information from it, interpret results and draw some conclusions. Therefore, it is of utmost importance to come up with a data model for the user response.

Afterwards, an important part of the implementation is given by the dashboard design. In general, a dashboard is a visual illustration of all of the data. While it can be used in all kinds of different ways, its main purpose is to offer information at-a-glance. We also resort to the help of dashboards for visualizing user-related data, regarding sustainability and game progress.

4.1.1. Research question definition

We perform the implementation of our simulation game based on one research question:

RQ3 - How can a simulation game for sustainable mobility be implemented? By answering this question, we intend to explore the existing data structures and technologies, in order to decide on a suitable data model, frameworks and techniques for the business simulation game.

4.2. Technologies and Libraries

The CTMobility tool is built as a web application. The implementation consists of two integrating parts: the front-end, which players get to experience, and the back-end, which constitutes the structure hidden from users that makes the front-end possible. In our case, the back-end comprises the model architecture and database operations, while the front-end is centered on the graphical user interface.

The proposed business simulation game for sustainable mobility is developed entirely in Python as part of the back-end side, while the front-end is realised using the Angular framework for web applications. The rationale for selecting Python to be the base programming language is given by the significant number of libraries it provides, to support vast operations. External libraries are not used within this work, only Python-related ones. For the data management, our employed PostgreSQL database adapter is Psycopg2 [54], whereas Flask [20] is used for server requests, assisting the correlation between front-end and back-end. To achieve our research and testing objectives, a user-friendly graphical interface is created. The application incorporates as well an administrator interface with access control. We adhere to PostgreSQL [53] relational database management system, through the development platform pgAdmin [51].

It is necessary to point out the settings which created a suitable environment for our application to be developed and tested. The configurations of the system are:

- Operating system: macOS Monterey 12.3.1
- Processor: 1,8 GHz Dual-Core Intel Core i5

In order to achieve a proper game execution, the project expects the following software:

- PostgreSQL database (recommended platform: pgAdmin 4)
- Python 3.11 (recommended IDE: PyCharm 2021.2.2 - Professional Edition [55])
- Angular CLI (recommended IDE: WebStorm 2018.3.1 [64])

The Python incorporated-libraries that are worth mentioning are:

- Psycopg2 [54]: PostgreSQL database connector for the Python programming language
- Flask [20]: micro web framework designed in Python, used as an API

4.3. Model Architecture

Integrated within the back-end component, the model includes separate classes for:

- Member (id, name, age, gender, occupation, profile id - identifier of the profile it belongs to)
- Profile (id, is predefined - value used for checking if the profile is predefined or own created, number of members, username and password - both for admin)
- Simulation (id, day type, CO2 index, emission, profile id - identifier of the profile used to participate in the simulation)
- Response (id, explanation, simulation id - identifier of the simulation in which the response was given, story id - identifier of the story for which the response was given, transport id - identifier of the selected mobility choice)
- Story (id, weather, accessibility conditions, activity id - identifier of the activity pattern on which the story was built)
- ActivityPattern (id, description, distance)
- Transport (id, name, duration, cost, emissions, activity id - identifier of the activity pattern for which the transport is a mobility option)
- Impact (id, value)
- TransportAndImpact (transport id, impact id - both identifiers of selected mobility choice and its corresponding impact value).

A better visualisation is depicted inside the class diagram from Figure 4.1.

The stories are all initialized with specific weather and accessibility conditions, assigned randomly. The values for weather include: sunny, cloudy, rainy, windy, snowy, foggy, stormy, partly sunny and partly cloudy. Accessibility conditions vary between none and 'You have a broken leg'. The Impact consists of values for each transport, representing both the positive and negative impact of using that mean of transport. The Response class is used for saving the user response and progress throughout the played simulations into a CSV file.

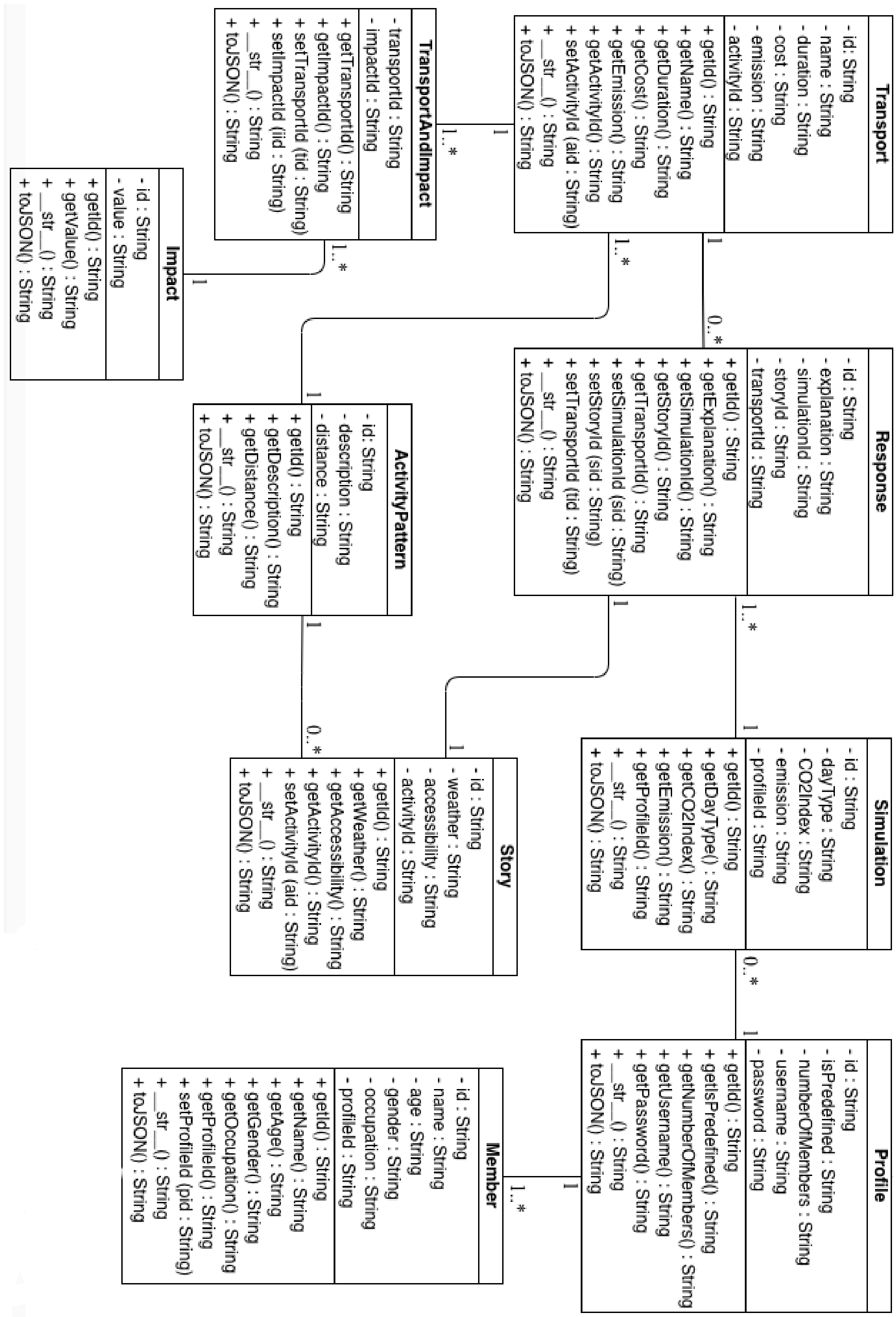


Figure 4.1.: Class diagram denoting the structure of the CTMobility system

4.4. User Interface Functions

In what follows, the functionalities of CTMobility are presented, based on the user role, accompanied by figures denoting parts of the project interface.

To begin with, Figure 4.2, shows the first screen of the web application, where the user can choose to proceed to the simulation as a participant (i.e. regular user) or login as an administrator. The administrator user interfaces are described first, followed by the participant interfaces.

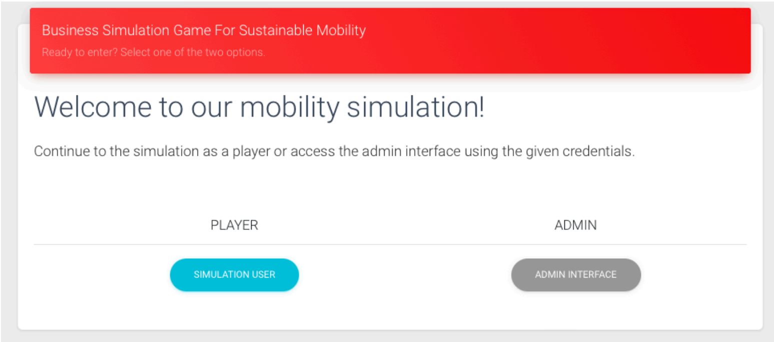


Figure 4.2.: CTMobility: Homepage

4.4.1. Administrator User Interfaces

The administrator can login using already provided credentials. As an overview, the admin is granted access to these interfaces: admin dashboard, profiles management, activity patterns management, reports and statistics with profile comparison. The following paragraphs describe in more details the main functionalities that an administrator is provided with.

4.4.1.1. Admin Dashboard

Further, in Figures 4.3, 4.4 we can view the dashboard of the admin user. On the first row, we can see fixed information such as: number of profiles and members, activity patterns, simulations played, responses, overall CO2 emissions and average CO2 index achieved. The second row provides visualizations of the distance travelled by each mean of transport, gained CO2 index in last 10 simulations and accumulated emissions in the last 10 simulations. The tables on the bottom provide information on the transport impact (positive and negative for each mean of transport) and completed simulations so far, by their type.

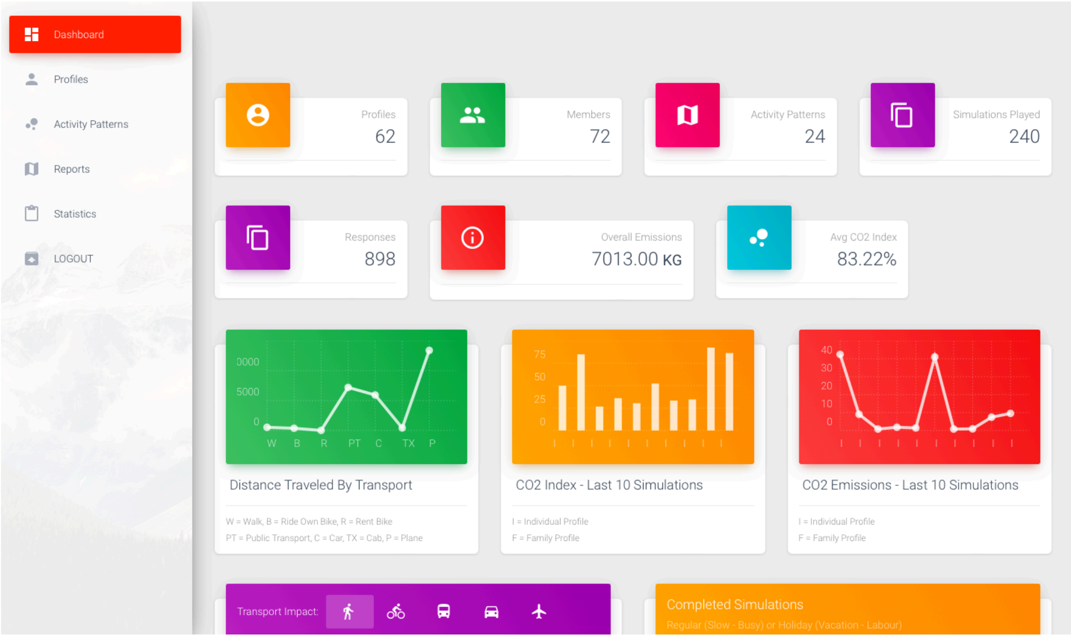


Figure 4.3.: CTMobility: Admin dashboard (1)

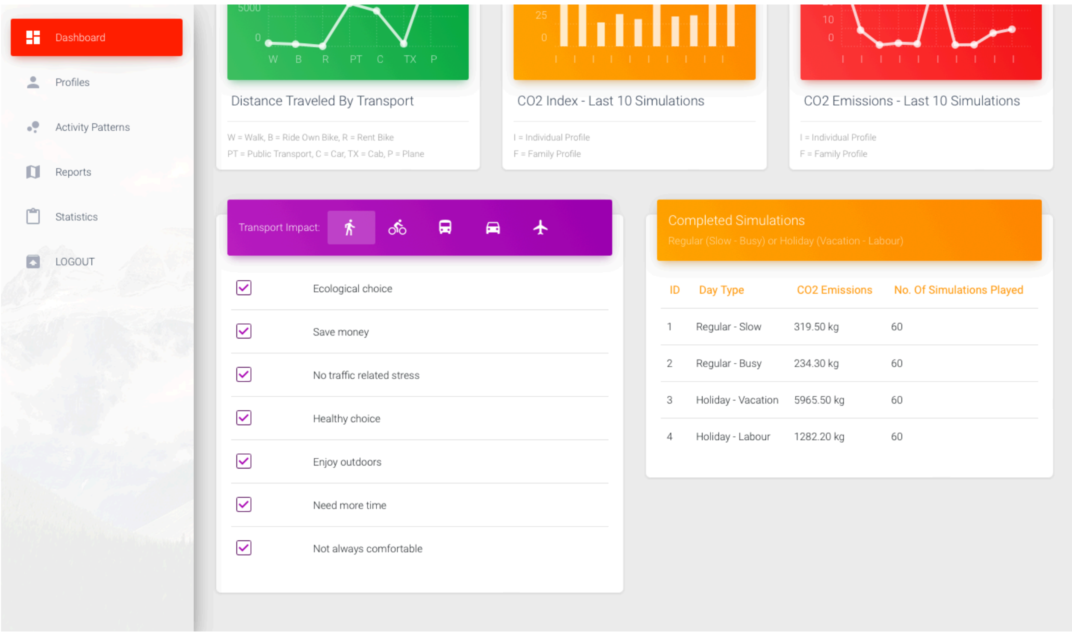
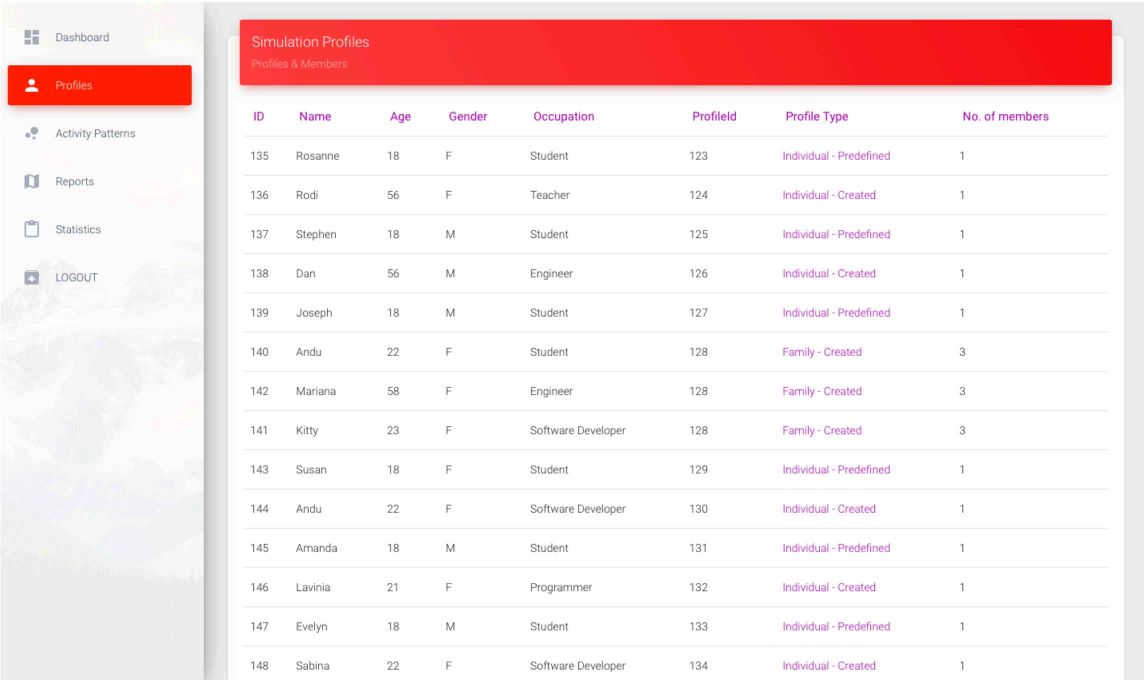


Figure 4.4.: CTMobility: Admin dashboard (2)

4.4.1.2. Profiles Management

The profiles option in the menu from Figure 4.5 is meant to help administrators manage the simulation users. They can view users, together with their profile and members, including their progress and responses so far. Update operation can be performed there as well.



ID	Name	Age	Gender	Occupation	ProfileId	Profile Type	No. of members
135	Rosanne	18	F	Student	123	Individual - Predefined	1
136	Rodi	56	F	Teacher	124	Individual - Created	1
137	Stephen	18	M	Student	125	Individual - Predefined	1
138	Dan	56	M	Engineer	126	Individual - Created	1
139	Joseph	18	M	Student	127	Individual - Predefined	1
140	Andu	22	F	Student	128	Family - Created	3
142	Mariana	58	F	Engineer	128	Family - Created	3
141	Kitty	23	F	Software Developer	128	Family - Created	3
143	Susan	18	F	Student	129	Individual - Predefined	1
144	Andu	22	F	Software Developer	130	Individual - Created	1
145	Amanda	18	M	Student	131	Individual - Predefined	1
146	Lavinia	21	F	Programmer	132	Individual - Created	1
147	Evelyn	18	M	Student	133	Individual - Predefined	1
148	Sabina	22	F	Software Developer	134	Individual - Created	1

Figure 4.5.: CTMobility: Admin - Profiles list

Figure 4.6 shows a selected family profile. The information of the players can be edited. In the lower part of the screen, the simulation progress is visible, with the selected activity patterns and mobility choices.

4.4.1.3. Activity Patterns Management

The activity patterns option is also meant to help with the management of activity patterns. The list of items is displayed, having the option to add more patterns. For each one, the transports available can be retrieved as in Figure 4.7. Update operation can be performed as shown in Figure 4.8.

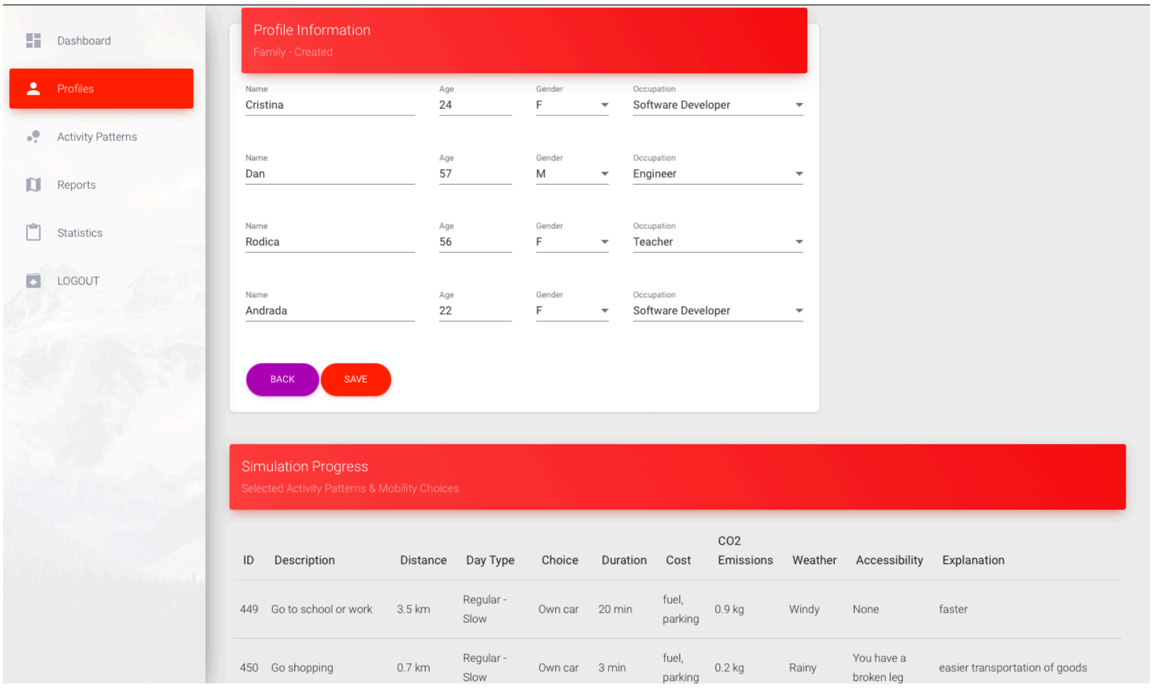


Figure 4.6.: CTMobility: Admin - Profile view and update

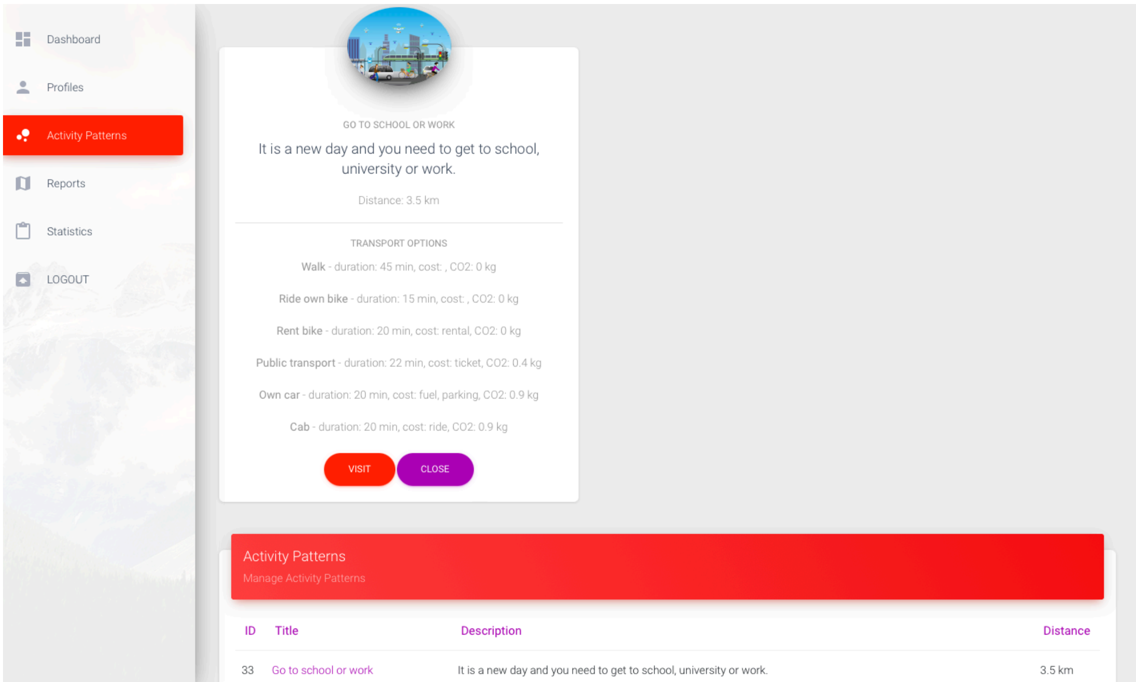


Figure 4.7.: CTMobility: Admin - Activity pattern view

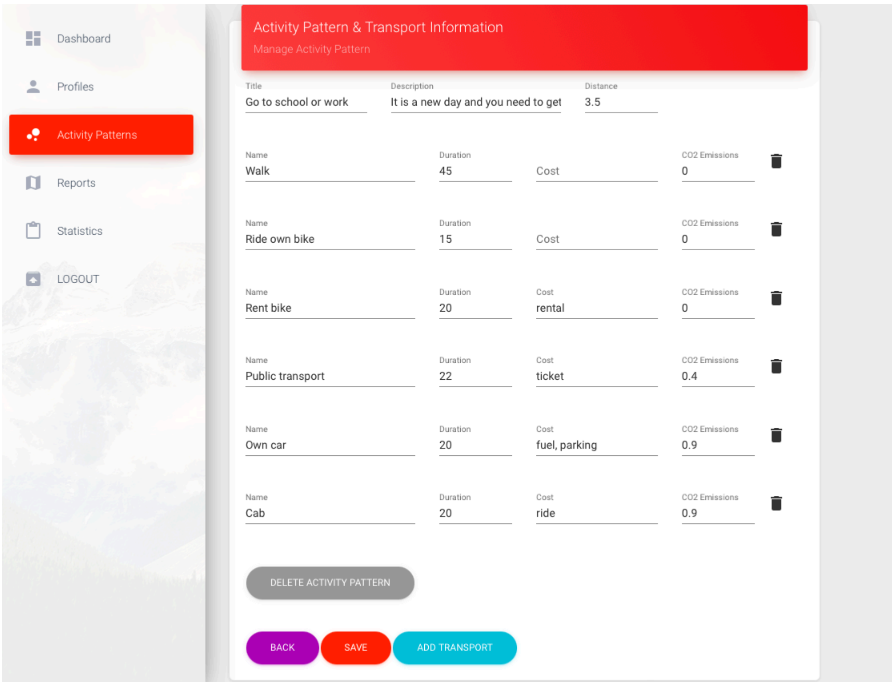


Figure 4.8.: CTMobility: Admin - Activity pattern setup

4.4.1.4. Reports

The reports page allows the retrieval of users as a top, sorted by their CO2 index (the smaller the value, the better). Three types of reports can be generated in CSV format. Figure 4.9 presents this admin interface.

The Profile report (Figure 4.10) concerns user profiles and gathers information on profile type, number of members, name, age, gender, occupation and number of simulations played. Each entry in the table corresponds to a member of the profile.

The Response report focuses on the responses given for stories in the simulation. It records the information of the profile giving the response (type, number of members, name, age, gender, occupation), the information of the story for which the response was given (activity pattern, distance, weather, special conditions, day type) and the actual response information (selected transport, duration, cost, CO2 emissions and explanation). Each entry in the table corresponds to a simulation response (who responded, the context and the actual response). Figure 4.11 shows the response specific data from the report.

The Simulation report includes the simulation details: information of the profile taking part in the simulation (type, number of members, name, age, gender, occupation), the day type, number of activity patterns in the simulation and their description, CO2 emissions gathered in the simulation and accumulated CO2 index. Each entry in the table corresponds to a simulation. Figure 4.12 displays the report, showing only the columns with simulation-specific data.

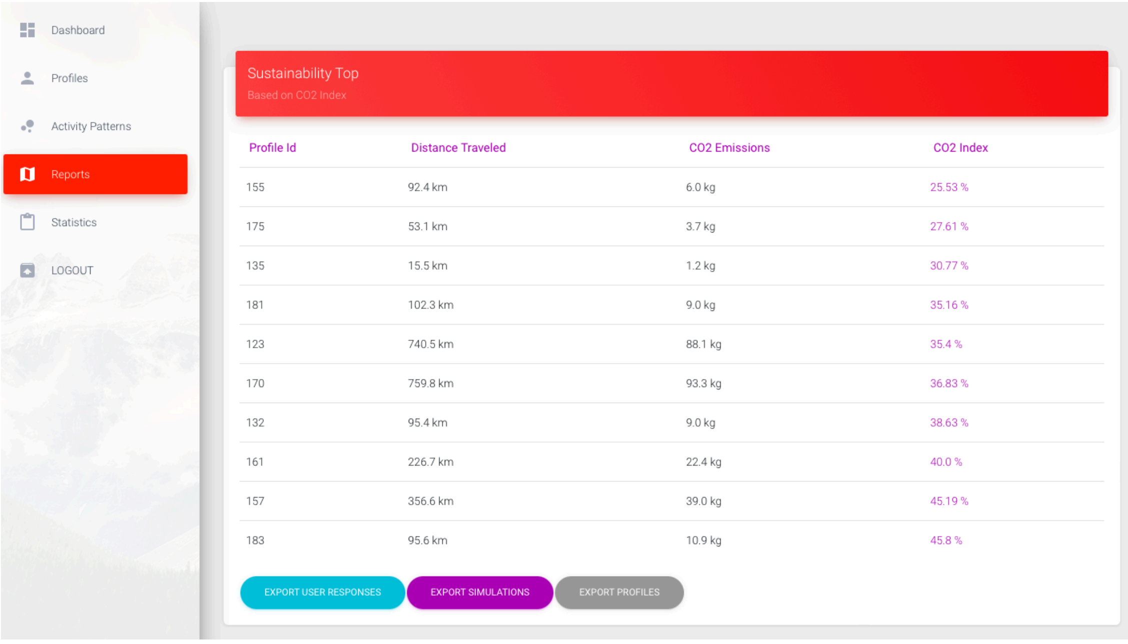


Figure 4.9.: CTMobility: Admin - Reports

No.	Profile ID	Member ID	Profile Type	Members	Name	Age	Gender	Occupation	Simulations Played
1	101	94	Family - Created	2	Andu	22	F	Actor	4
2	101	95	Family - Created	2	Kitty	23	F	Accountant	4
3	103	97	Individual - Predefined	1	Toney	18	F	Student	0
4	104	98	Individual - Predefined	1	Eugene	25	M	Engineer	3
5	105	99	Individual - Created	1	Brunette	30	F	Nurse	1
6	106	100	Family - Predefined	4	Tony	42	M	Engineer	4
7	106	101	Family - Predefined	4	Ethel	40	F	Secretary	4
8	106	102	Family - Predefined	4	Barbara	12	M	Pupil	4
9	106	103	Family - Predefined	4	Joe	10	F	Pupil	4

Figure 4.10.: Illustration of the profile report

The difference between these two reports resides in the fact that one simulation comprises more responses. Therefore, the simulation report is concerned with the data achieved from all travels performed within a day. Meanwhile, the response report is focused on each separate travel.

No.	Activity Pattern	Distance	Day Type	Selected Transport	Duration	Cost	CO2 Emissions	Explanation
1	Sightseeing abroad	670 km	Holiday - Vacation	Plane	80 min	ticket	231.0 kg	Comfortable
2	Nature activities	37 km	Holiday - Vacation	Own car	34 min	fuel, parking	9.0 kg	Flexible
3	Visit museum or monument	4.2 km	Holiday - Vacation	Walk	50 min		0 kg	Healthy
4	Go to school or work	3.5 km	Regular - Busy	Own car	20 min	fuel, parking	0.9 kg	I own a car
5	Study at the library	1.5 km	Regular - Busy	Walk	18 min		0 kg	Relaxing
6	Go shopping	0.7 km	Regular - Busy	Own car	3 min	fuel, parking	0.2 kg	I own a car
7	Attend social activities	2.0 km	Regular - Busy	Own car	20 min	fuel, parking	0.5 kg	I own a car

Figure 4.11.: Illustration of the response report

No.	Simulation ID	Day Type	No. Patterns	Activity Patterns	CO2 Emissions	CO2 Index
1	55	Holiday - Vacation	3	Sightseeing abroad; Nature activities; Visit museum or monument;	240.00 kg	99.59%
2	56	Regular - Busy	4	Go to school or work; Study at the library; Go shopping; Attend social activities;	1.60 kg	80.00%
3	57	Regular - Slow	3	Study at the library; Attend social activities; Recreational activities;	0.40 kg	25.00%
4	58	Holiday - Labour	3	Work-related trip; Attend festival in the country; Go to your friend's house;	75.80 kg	50.60%
5	60	Regular - Slow	3	Go shopping; Extracurricular activities; Visit relatives;	3.40 kg	82.93%
6	61	Holiday - Labour	2	Study at the library; Extracurricular activities;	0.00 kg	0.00%
7	59	Holiday - Vacation	1	Recreational activities;	0.70 kg	100.00%
8	62	Regular - Busy	2	Go shopping; Meet with friends;	0.30 kg	30.00%
9	63	Holiday - Labour	4	Attend work conference or workshop; Solve paperwork; Perform operations at th	84.30 kg	98.25%
10	64	Holiday - Vacation	4	Get beauty or health services; Picknicking; Visit museum or monument; Go to yo	1.30 kg	46.43%
11	65	Regular - Slow	4	Go to school or work; Study at the library; Go shopping; Attend social activities;	0.20 kg	10.00%
12	66	Regular - Busy	2	Go to school or work; Visit relatives;	3.40 kg	87.18%

Figure 4.12.: Illustration of the simulation report

4.4.1.5. Statistics with Profile Comparison

The statistics entry corresponds to the Profile Comparison subsection described in 3.4.4 and integrates two parts: the average user and visualisations of the average profiles. The first part includes the number of each type of predefined profile, followed by information on the own created profiles: the percentage of male and female members, their occupations, average age and number of members for the own created profiles, as in Figure 4.13.

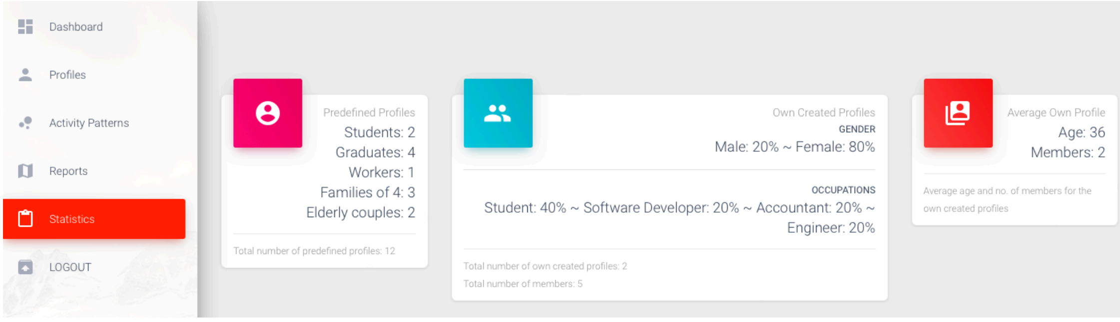


Figure 4.13.: CTMobility: Excerpt of the admin statistics showing the average user

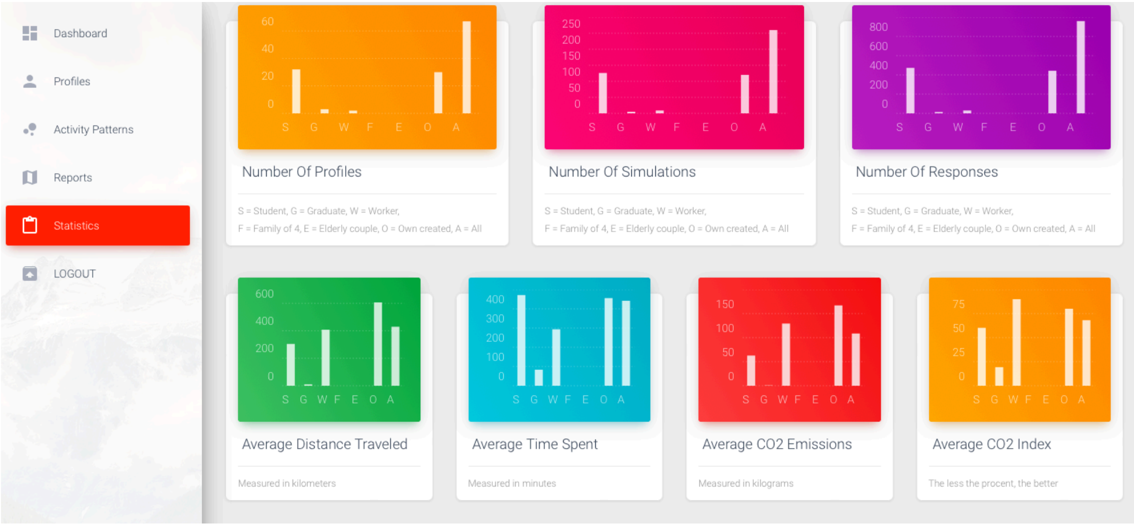


Figure 4.14.: CTMobility: Excerpt of the admin statistics charts (profile comparison)

The second part contains visualisations of the different types of profiles: average of students, graduates, workers, families of four, elderly couples, own created profiles and all profiles. The charts focus on the number of profiles, simulations, responses and average distance, time, CO2 emissions and CO2 index, just like in Figure 4.14. A drop-down allows the administrator to select one of the four day types, in order to draw graphs of the data points corresponding to the seven average types of profiles (Figures 4.15 and 4.16). Below each such graph, the actual values of the seven entries are shown. The interpretation of these graphs is presented in a detailed manner as part of the Participant Interfaces 4.4.2.3.

Lastly, the admin is provided with the possibility to logout and be redirected back to the initial homepage.

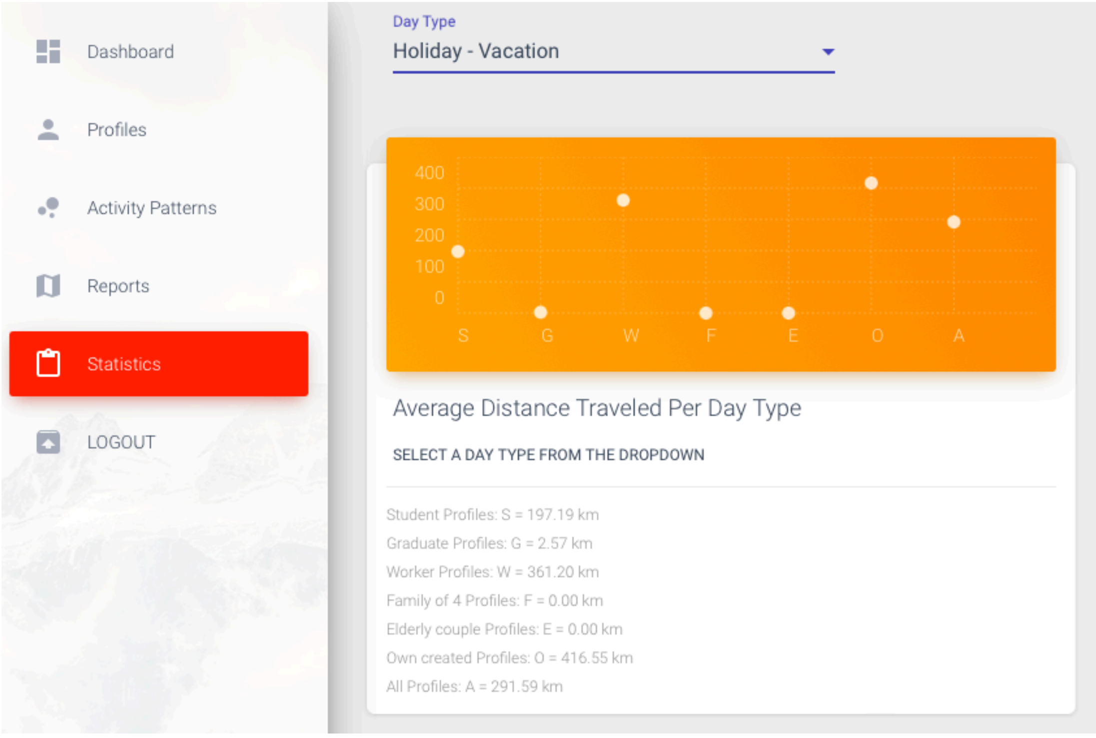


Figure 4.15.: CTMobility: Excerpt of the admin statistics graphs (profile comparison) (1)

Figure 4.16.: CTMobility: Excerpt of the admin statistics graphs (profile comparison) (2)

4.4.2. Participant Interfaces

The following paragraphs describe the main functionalities that a simulation user has access to. As an overview, they include: profile creation, participant dashboard, profile comparison and simulation start.

4.4.2.1. Profile Creation

As a simulation user, you have the option to choose from a range of predefined profiles, or create your own. In the Select profile screen presented in Figure 4.17, the user can choose between five predefined profiles (only the names of the characters are randomly generated every time the user wants to change the profile) or may create an own profile. The five predefined profiles are split according to the default profiles from 3.3.1: three individual profiles (of ages 18, 25 and 35) and two family profiles (a family of 4 - parents and two children, and an elderly couple).

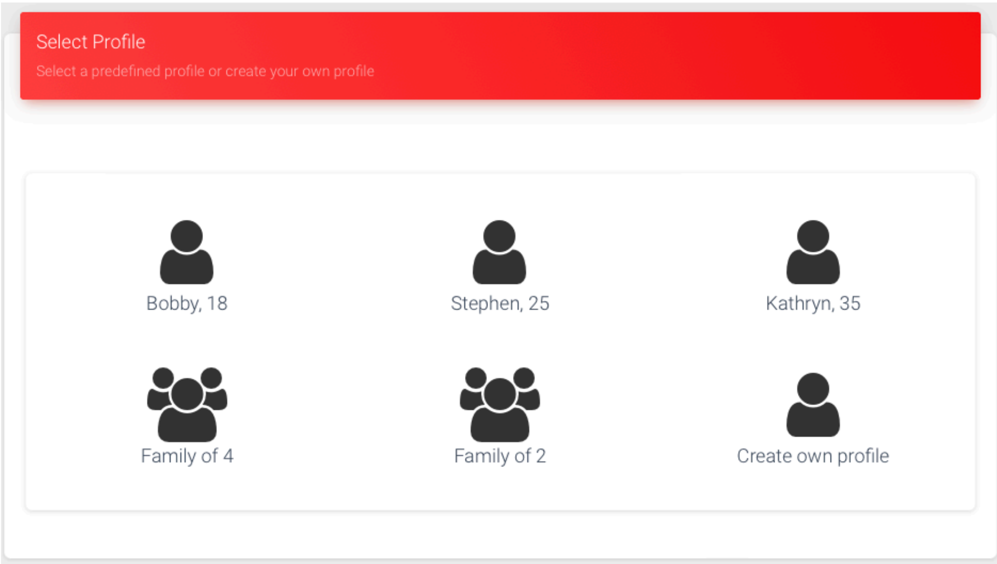


Figure 4.17.: CTMobility: Participant - Profile selection screen

If instead of a predefined profile the player decides to create their own profile, the number of members for the profile is required. Afterwards, you can finish the profile by adding the required information for each member, as depicted in Figure 4.18.

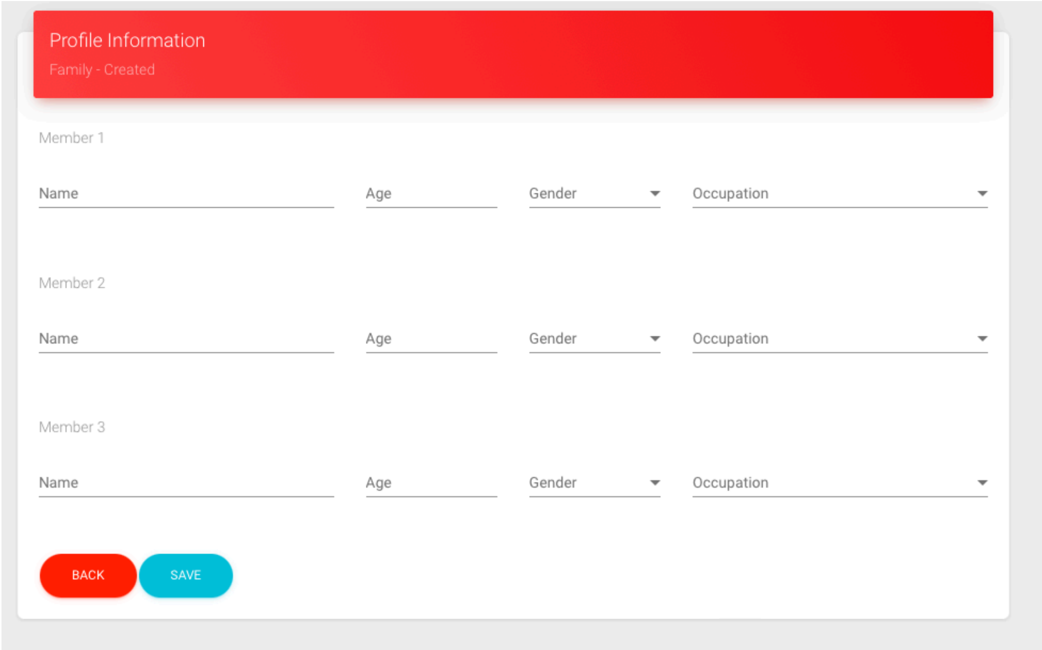


Figure 4.18.: CTMobility: Participant - Save user operation

4.4.2.2. Participant Dashboard

Further, in Figures 4.19, 4.20 we can see the dashboard of the user. On the first section, we can see fixed information such as: number of simulations played, travelled distance, overall CO_2 emissions and achieved CO_2 index. In addition, the daily average widget presents the average distance and time per story. The second section provides visualizations of the distance travelled by current profile on each mean of transport, gained CO_2 index in last simulations, considering the day type, and accumulated emissions in the last simulations. The tables on the bottom provide information on the given explanations for selected transports and completed simulations so far.

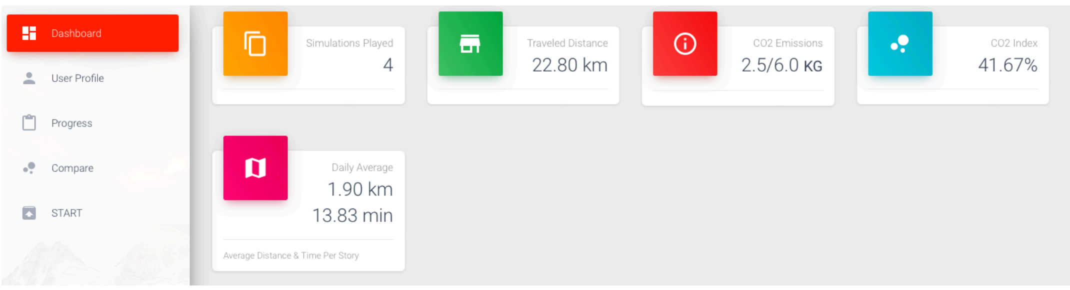


Figure 4.19.: CTMobility: Excerpt of the fixed information from the participant dashboard

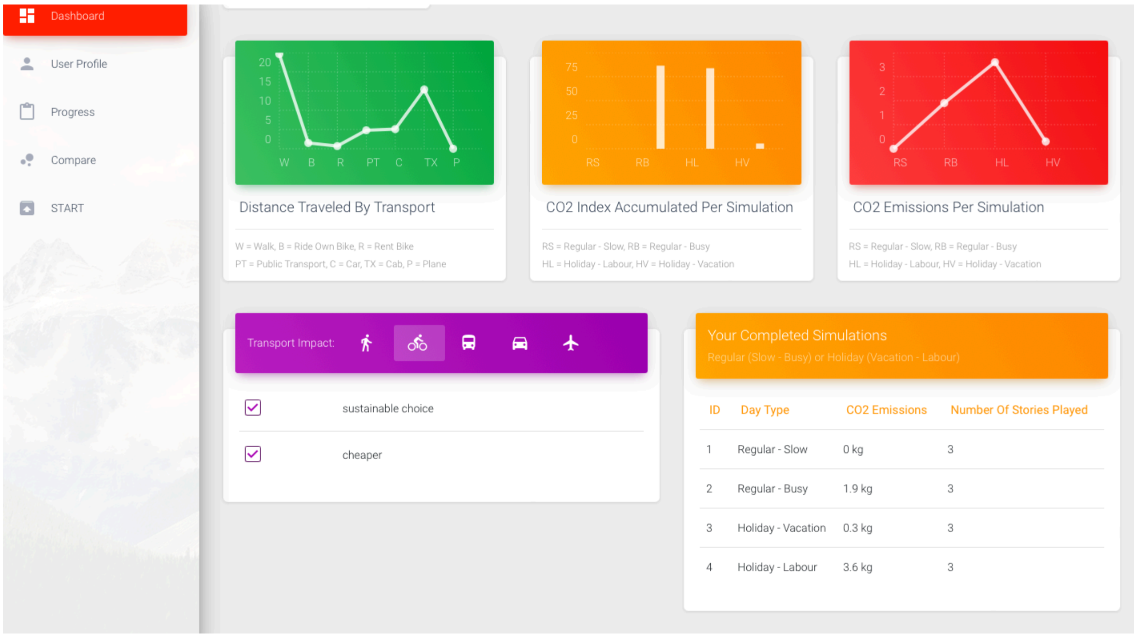


Figure 4.20.: CTMobility: Excerpt of the participant dashboard

The user profile option allows current user to see and update the information corresponding to their profile. As part of the user's progress, the activity patterns selected so far and the responses to them are displayed. This is similar to the information shown in Figure 4.6.

4.4.2.3. Profile Comparison

The Comparison entry (subsection 3.4.4) includes three parts: an explanation of the profile types, the visualisations of the average profiles and an explanation of the results. To facilitate the participant's understanding of the different profile types, this data is presented in a clear manner, as in Figure 4.21.

The second part focuses on visualisations of the different types of profiles: average of students, graduates, workers, families of four, elderly couples, own created profiles, all profiles and my profile (the current profile of the participating user). The charts focus on average values of the travelled distance, time spent, accumulated CO2 emissions and achieved CO2 index, from a general perspective, just like in Figure 4.22. A drop-down lets the player choose between the four day types, in order to draw graphs of the data points corresponding to the eight average profile types. Below each such graph, the actual values of the eight entries are shown. These graphs are addressed separately in what follows.

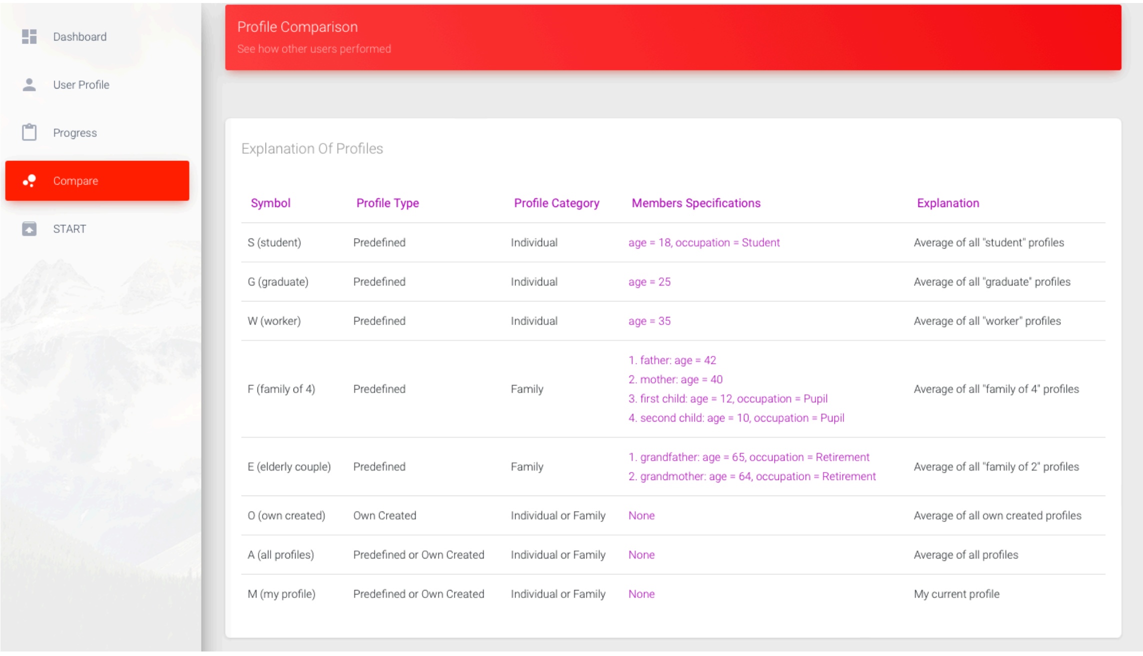


Figure 4.21.: CTMobility: Participant - Profile comparison (profile type explanation)

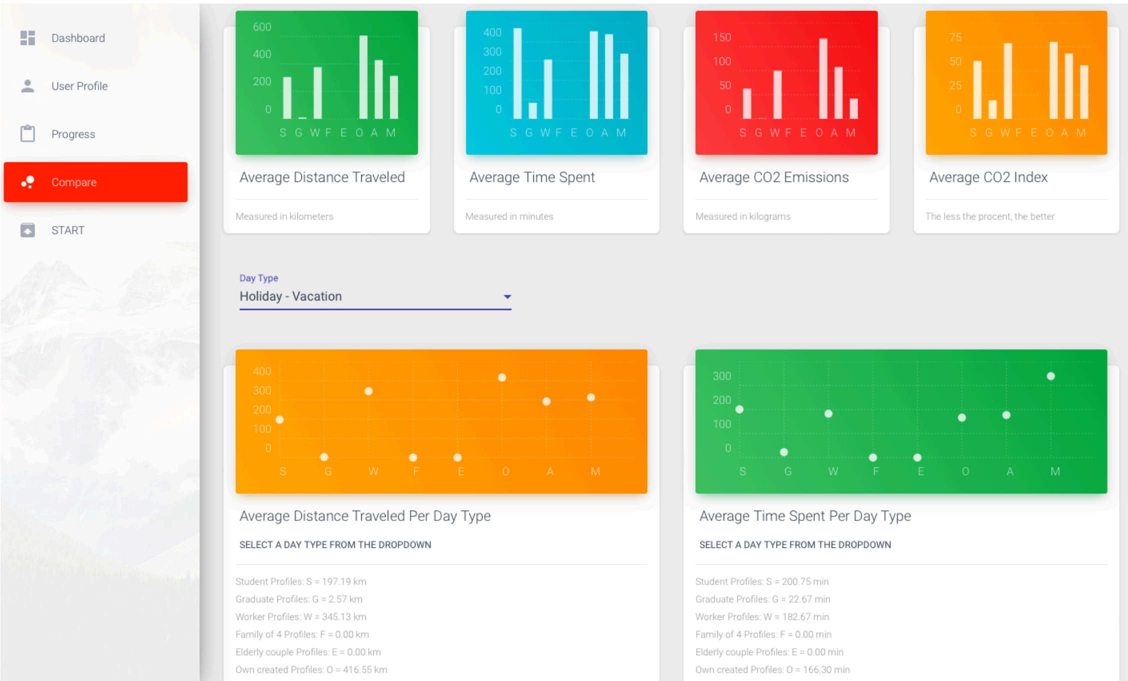


Figure 4.22.: CTMobility: Participant - Profile comparison (charts)

The first graph (Figure 4.23) shows the data points corresponding to the average distance recorded for the eight profile types, during the selected day type. It can be noticed that for the current day type, the average student (S) has travelled 197.19 km, the average graduate (G) 2.57 km, the average worker (W) 345.13 km, the average family of four (F) 0 km, the average elderly couples (E) 0 km, the average own profile (O) 416.55 km, the average user (A) 291.91 km, whereas the actual player (M) 313 km.

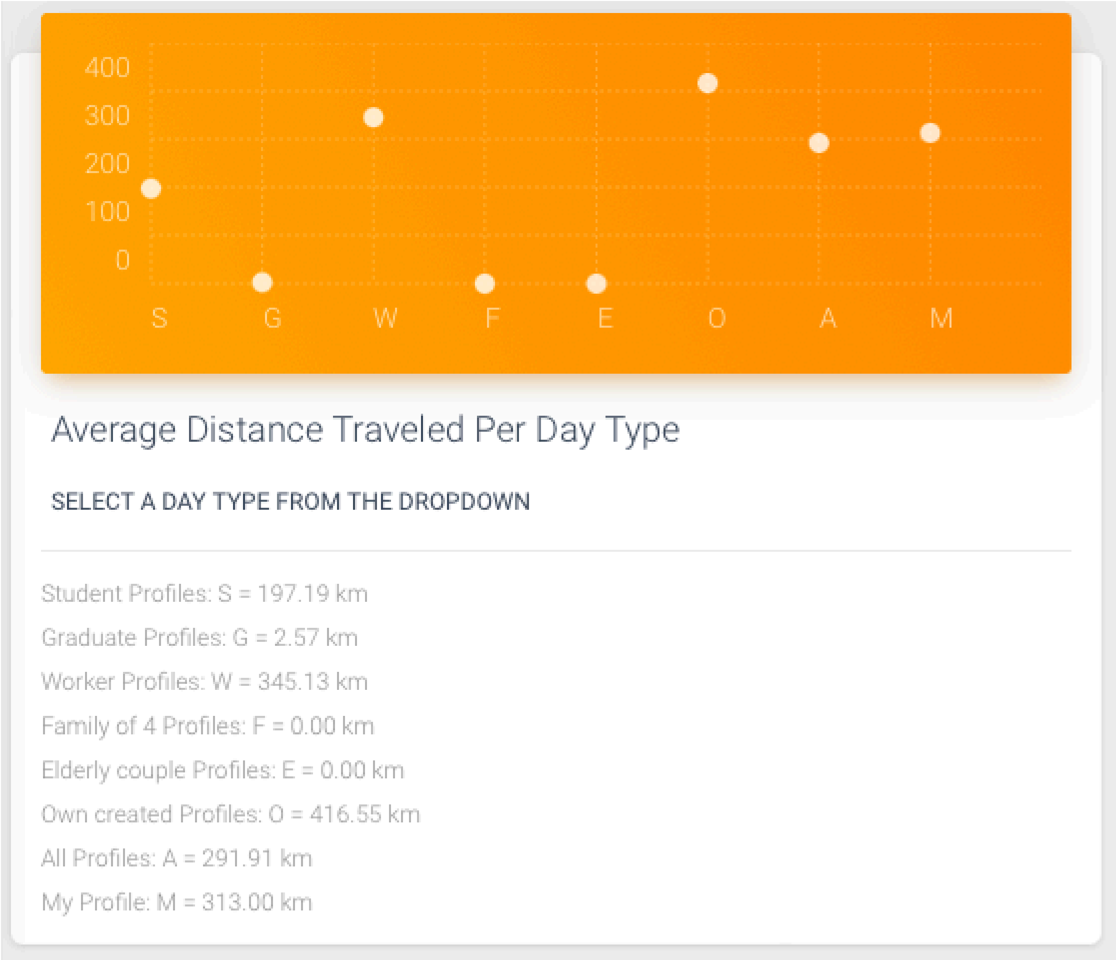


Figure 4.23.: CTMobility: Participant - Profile comparison (average distance graph)

The second graph (Figure 4.24) shows the data points corresponding to the average time recorded for the eight profile types, during the selected day type. It can be noticed that for the current day type, the average student (S) has spent 200 minutes, the average graduate (G) 22 minutes, the average worker (W) 182 minutes, the average family of four (F) 0 minutes, the average elderly couples (E) 0 minutes, the average own profile (O) 166 minutes, the average user (A) 176 minutes, whereas the actual player (M) 339 minutes.

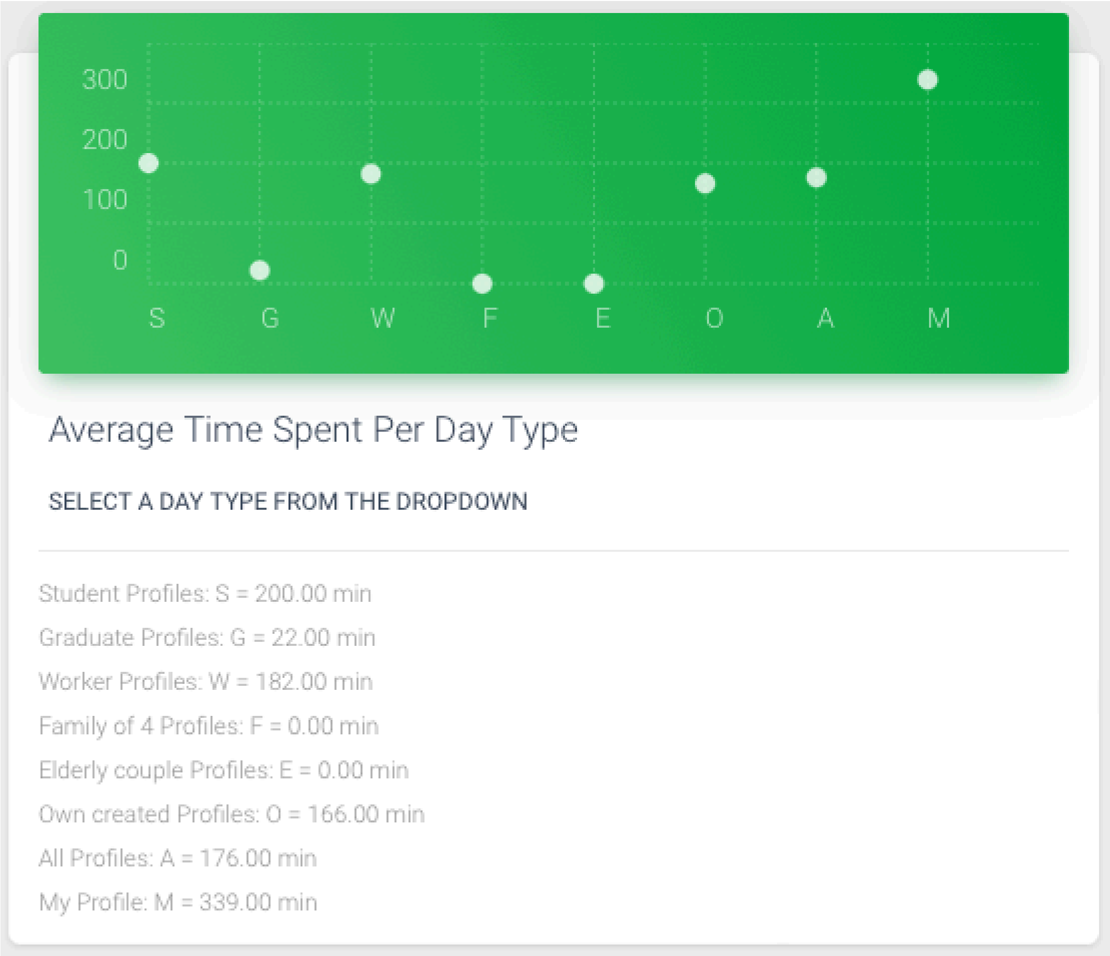


Figure 4.24.: CTMobility: Participant - Profile comparison (average time graph)

The third graph (Figure 4.25) shows the data points corresponding to the average CO2 emissions achieved for the eight profile types, during the selected day type. It is visible that for the current day type, the average student (S) has consumed 41.22 kg, the average graduate (G) 0.07 kg, the average worker (W) 94.33 kg, the average family of four (F) 0 kg, the average elderly couples (E) 0 kg, the average own profile (O) 129.45 kg, the average user (A) 80.67 kg, whereas the actual player (M) 42 kg.

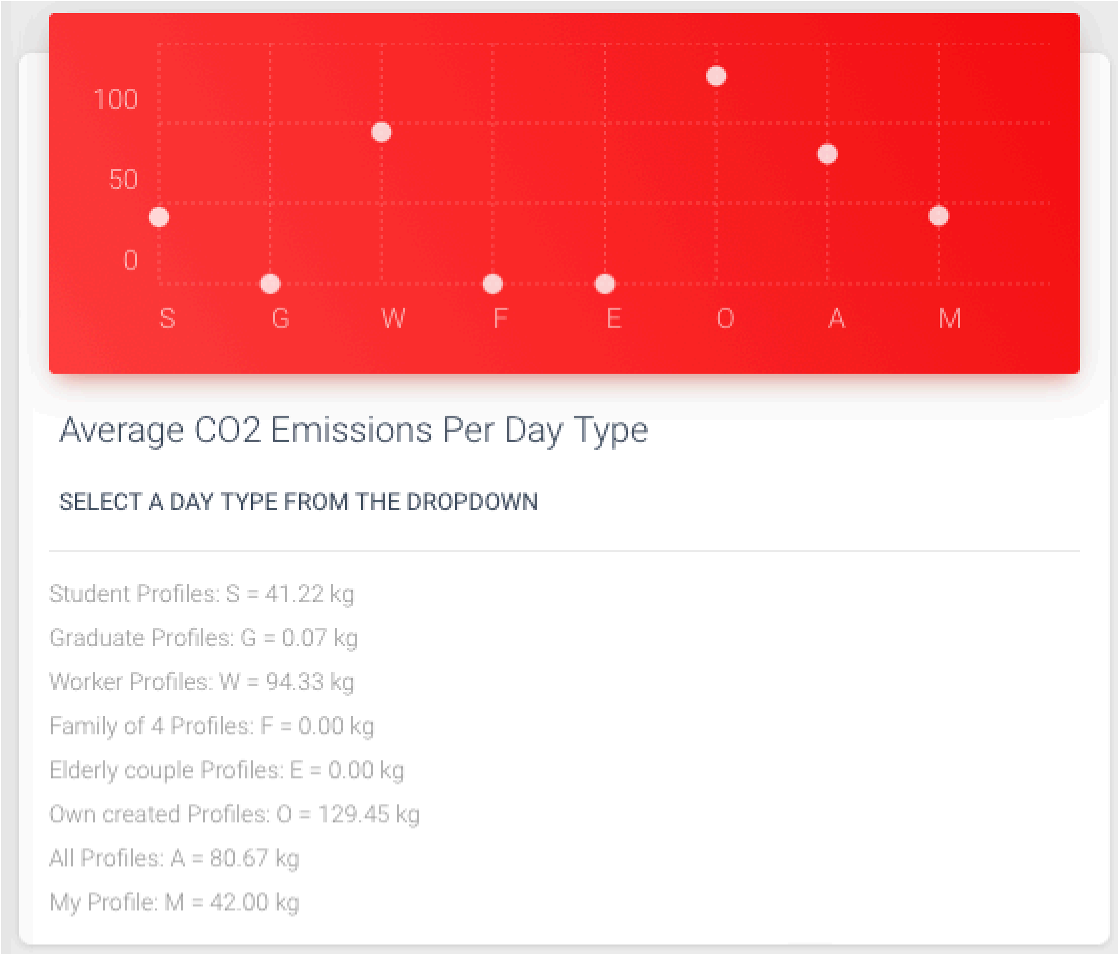


Figure 4.25.: CTMobility: Participant - Profile comparison (average CO2 emissions graph)

The fourth graph (Figure 4.26) shows the data points corresponding to the average CO2 index obtained for the eight profile types, over all day types. It can be observed that in total, the average student (S) has reached 60.24%, the average graduate (G) 19.28%, the average worker (W) 78.59%, the average family of four (F) 0%, the average elderly couples (E) 0%, the average own profile (O) 80.04%, the average user (A) 67.98%, whereas the actual player (M) 55.70%.

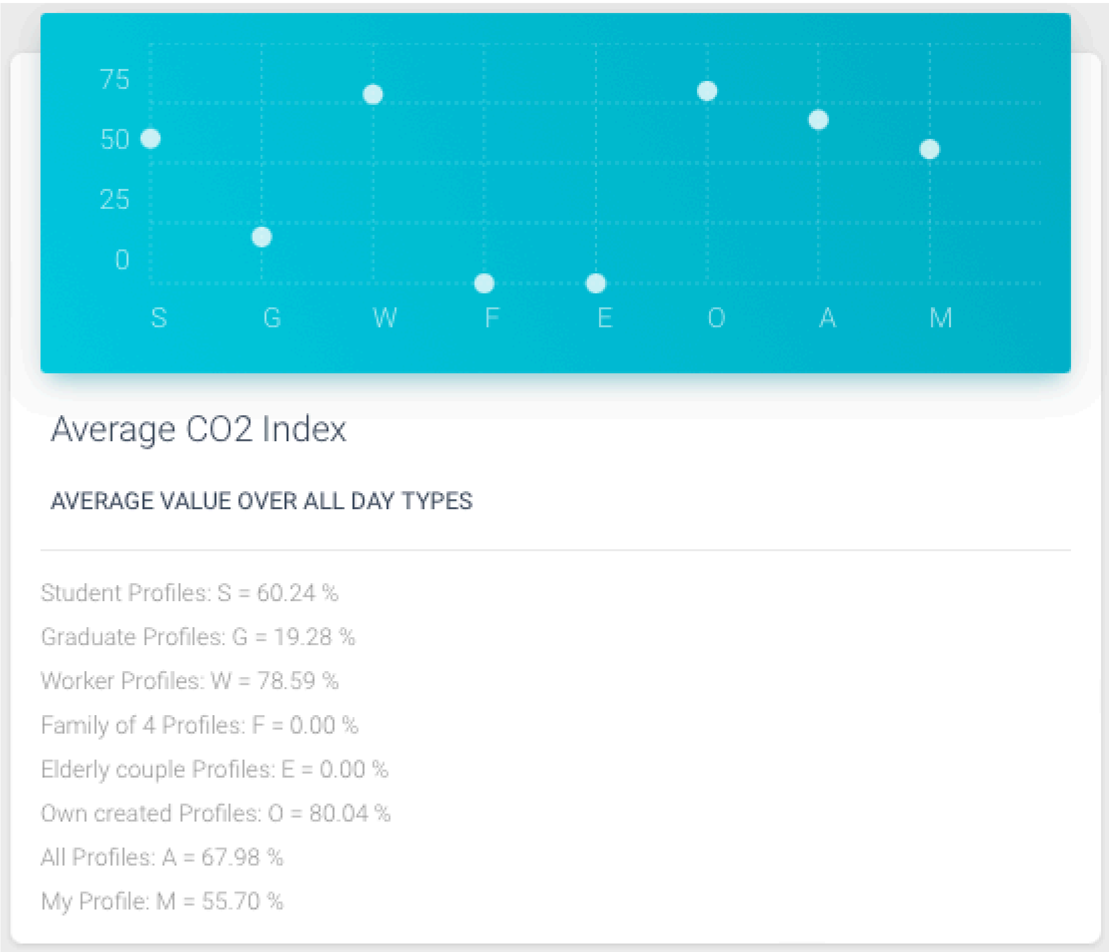


Figure 4.26.: CTMobility: Participant - Profile comparison (average CO2 index graph)

Lastly, this feature includes an explanation of results section, which details the closest and the furthest profile type for the current one, in terms of distance and time travelled, overall CO2 emissions and index.

For example, in Figure 4.27 we can see that our user profile is closest to the "student" profile, from three perspectives: distance, CO2 emissions and index, and closest to the "worker" profile, regarding the time. However, in terms of CO2 emissions it is furthest from the "own created" profiles, whereas in terms of distance, time and CO2 index it is furthest from "family of 2" profiles.

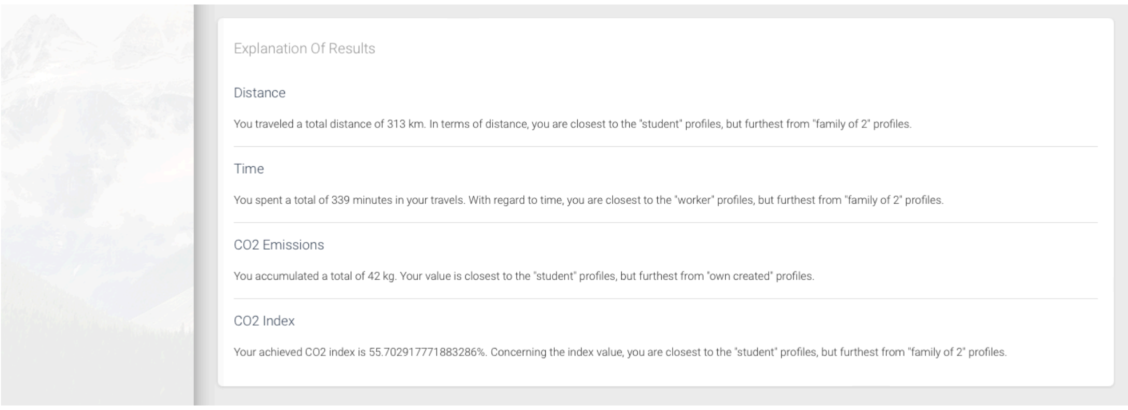


Figure 4.27.: CTMobility: Participant - Profile comparison (result explanation)

4.4.2.4. Simulation START

At last, the simulation can begin from the start option in the menu (Figure 4.28). A status of the already completed simulations is shown, based on the value of the CO2 index. If the index is below 50%, it is an accepted value, otherwise it is a value to be corrected through the user's future behaviour. In addition, the logout option is included, redirecting the player to the initial homepage.

The simulation starts with the player being asked to choose between a regular day (slow or busy) and a holiday (labour or vacation), while displaying the information of the selected profile. Some brief instructions and the purpose of the simulation are presented beforehand to the users.

Afterwards, players are required to choose between different activity patterns, according to the selected day type. In Figure 4.29, the user decided on four activity patterns that best describe a regular - slow day for its profile. Moving on, for each selected activity pattern we have a Story screen (Figure 4.30) and an Explanation screen (Figure 4.31). The Story screen presents the story of the selected activity pattern, together with the distance, weather and special conditions. The available mobility options are shown with the following information: time, cost and CO2 emissions.

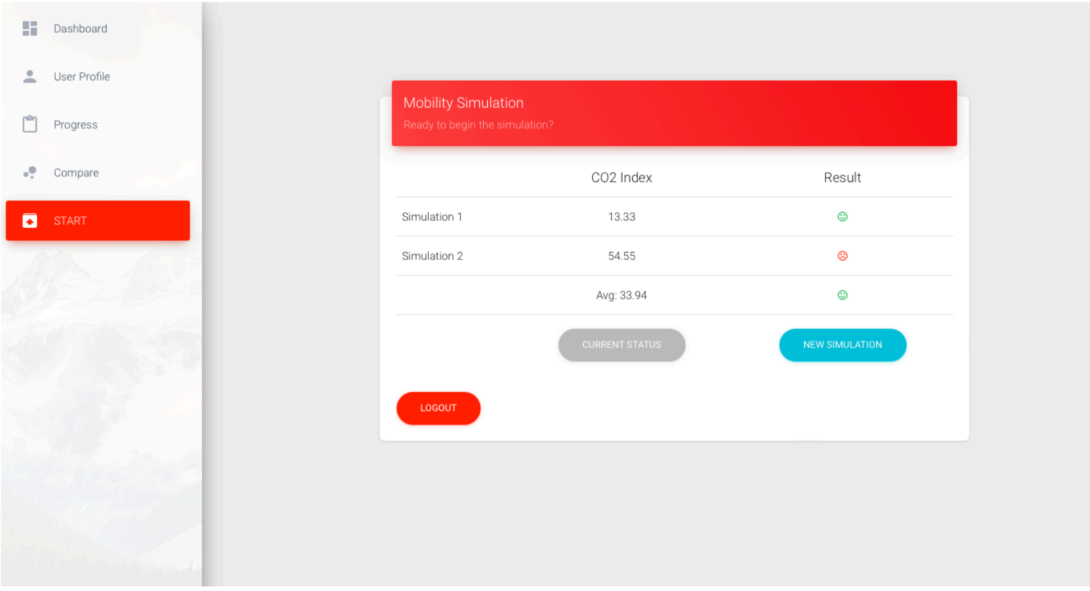


Figure 4.28.: CTMobility: Participant - Simulation start

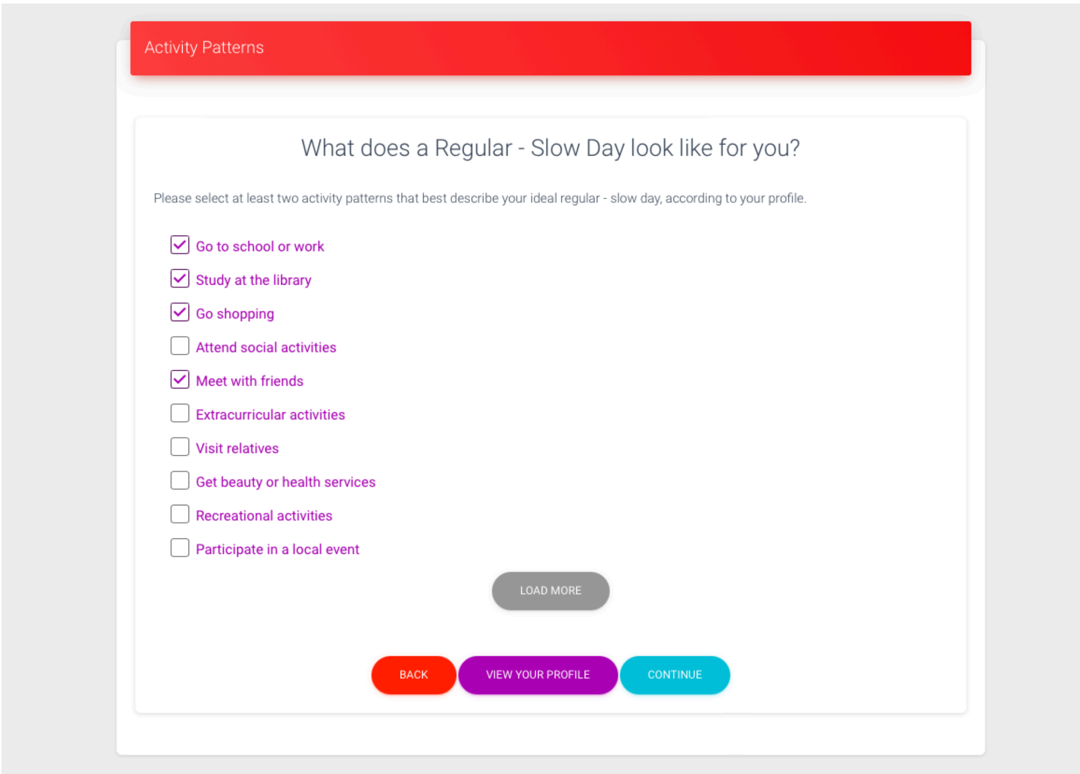


Figure 4.29.: CTMobility: Participant - Activity pattern selection

After deciding on one option, the user may advance to the next screen. An open question is defined here: "Why did you choose this option?". The user is asked to briefly explain in a text-box the reason behind their mobility decision. Also, impact values for the available transports can be observed at this point. The end of the simulation redirects players to the dashboard, where they can analyse their updated information and choose to take part in the simulation once again.

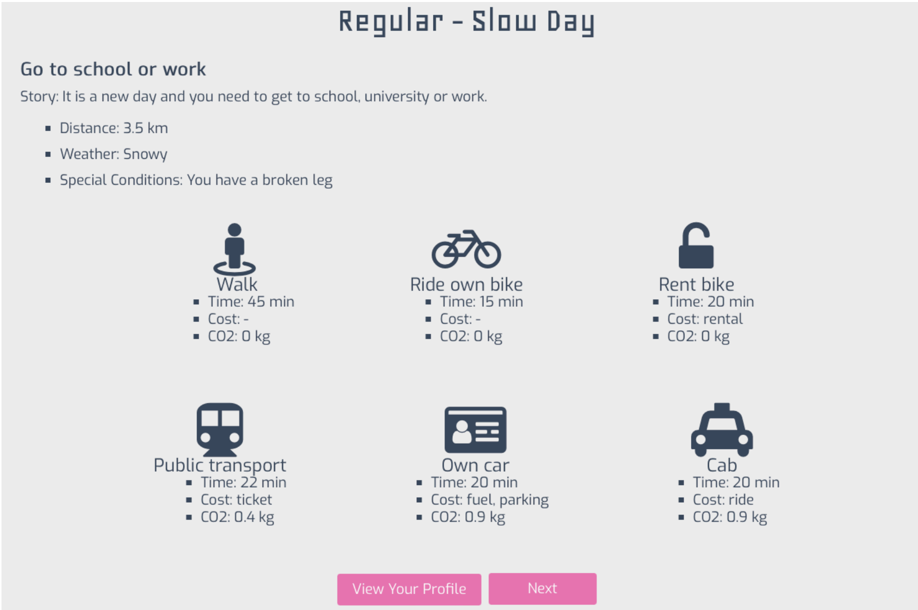


Figure 4.30.: CTMobility: Participant - Story presentation and mobility choice selection

Figure 4.31.: CTMobility: Participant - Explanation for the decided mobility option

4.5. Summary

RQ3 - How can a simulation game for sustainable mobility be implemented?

This chapter builds on the previous one 4, by integrating all the discussed theoretical concepts and presenting the detailed implementation of the addressed approach. The next chapter 5 focuses on a real-life evaluation of the business simulation game.

The first step that we took before proceeding with the implementation of the tool was identifying and prioritizing the functional requirements, in relation with the theoretical concepts, such as profiles, activity patterns, dashboard and so on.

Afterwards, we resorted to building the business simulation game as a web application, using a divided implementation approach, with two principal components: the back-end and the front-end. The back-end comprises the model architecture and operations performed on the database, while the front-end is focused on the graphical user interface.

As mentioned in the current chapter, the implementation of the project was realised using Python for the back-end component and Angular framework for the front-end component. The front-end communicates with the back-end through Flask, a micro web framework written in Python. Regarding the database management, PostgreSQL was chosen as object-relational database.

Operations exposed to the end-user differ based on the role of the user, which can be administrator or simulation user. The administrator, which has access control, manages entities such as profiles and members, activity patterns and transports, while also being able to view statistics and export results from the user response in the simulation. The simulation user, as the name suggests, has the option to take part in the simulation, but also to visualize statistics through dashboards. Its current progress is stored in a local session.

The resulted CTMobility tool facilitates the purpose of the business simulation game for sustainable mobility, to encourage sustainable travel and mobility through a new proof-of-concept. The tool-based experiments and interpretation of the results are specified in the following chapter 5.

5. Evaluation

Seeking to properly evaluate our contribution, the analysis of a case study was performed, to determine the impact of gamification tools and incentives on the mobility patterns of a group of people. Our primary intention was to discover what impression these people have about the game.

5.1. Methodology

In order to achieve a more varied evaluation, we conducted one case study (5.2) and evaluated the results via a mixed-method technique [47], consisting of a survey (quantitative analysis 5.3) and interviews (qualitative analysis 5.4). The evaluation plan implies running the simulation with individuals settled in urban neighbourhoods. We are interested to find out if seeing more information on sustainable mobility helps individuals in their choices and shifts their opinion. Moreover, we want to know if players liked the game, if they consider features such as stories and profiles to be realistic and what other improvements can be made.

5.1.1. Research question definition for evaluation

We target our experimental results to supply an answer to the following research question:

RQ4 - How is such a game perceived by people? This question aims to determine if our design was successful in supporting the sustained engagement in our mobility game, since our direction is to preserve the behavioural changes of gamification. In other words, we want to establish if seeing the information on sustainable mobility, makes people decide differently.

An overview of the evaluation process reveals that 30 people interacted with our CTMobility game, during the case study. All of them completed the questionnaire offered during the quantitative analysis. However, only 10 people took part in the interviews from the qualitative analysis. The next sections describe in detail how evaluation was conducted and the captured results.

5.2. Case Study

We implemented the proposed business simulation game with the purpose to evaluate the power of gamification in influencing the players' habits, to use sustainable transport alternatives. The study at hand took place between October 2023 and December 2023.

Any kind of participation happened on a voluntary basis, with no financial reward being offered.

The study was conducted inside a Romanian city, Cluj-Napoca, and its suburban regions, including commuters. Situated in the North-West of Romania, Cluj-Napoca is a growing city of about 303K inhabitants. Due to its increasing development in the last decade, the city faces a critical traffic pressure, especially in the centre. Parking places in central neighbourhoods are occupied with a value of 90%, leading to even more traffic caused by vehicles searching for a parking spot. Thus, the city has put substantial effort and allocated resources to improve the mobility conditions. An example in this sense is that Cluj-Napoca is the first Romanian city to integrate electric buses for public transportation. In addition, the city has inaugurated a new bike sharing system with 50 self-service rental stations.

5.2.1. Participants

The application was tested with 30 users, selected from various backgrounds, including the university network in Cluj-Napoca and an IT company. The median age reached 25, expressing a high proportion of university graduates and current employees, of whom 14 male and 16 female. All participants hold a University degree, most of them being from the fields of Computer Science, Engineering and Economic Studies. Every person expressed an intermediate or advanced knowledge of technology and online tools. However, none of the players had previous experience with simulation games. Regarding the sustainability goals, most participants revealed a moderate interest towards these issues. None of the participants received any form of compensation for their contribution.

The group of participants played and used our CTMobility tool in a span of nine weeks, starting from the 23rd of October 2023, until the 23rd of December 2023. A number of 22 players spent one hour or more exploring the simulation game and its features. From the remaining players, 6 spent between 30 and 45 minutes, one between 45 and 60 minutes, and one between 20 and 30 minutes.

5.2.2. Procedure

At the beginning of the case study, we interacted with the participants one by one in convenient places, such as the university, their workplace or home. We explained to them beforehand the aim of this software and then offered instructions on how to properly use locally our business simulation game for sustainable mobility.

Our intention was for them to understand, but also to test this software. Therefore, we gave them concrete tasks and observed their interaction with the system during this whole time. The tasks consisted of:

1. Register in the simulation with the Student predefined profile

    - observe the available features (dashboard with mobility tracking, user details, user progress on activity patterns and profile comparison)

- complete the simulation four times, by selecting between 2-4 activity patterns each time:
  (1) regular - slow, (2) regular - busy, (3) vacation - labour, (4) vacation - vacation
- after each completed simulation, explore the updated dashboard (to see the travelled distance, CO2 emissions and index, daily average, improved charts, provided responses and simulations finished so far)
- at the end of the four simulations, perform a profile comparison, to position yourself among the results achieved by other profiles

2. Register in the simulation with your own created profile
   - it is not necessary to observe the available features once again, because they are the same as for the predefined profile
   - complete the simulation four times, by selecting between 2-4 activity patterns each time:
     (1) regular - slow, (2) regular - busy, (3) vacation - labour, (4) vacation - vacation
   - after each completed simulation, explore the updated dashboard (to see the travelled distance, CO2 emissions and index, daily average, improved charts, provided responses and simulations finished so far)
   - at the end of the four simulations, perform a profile comparison, to position yourself among the results achieved by other profiles

We decided to ask participants to use the same predefined profile in order to get more data points for the same profile. The Student profile was considered to be the most appropriate one, since it is a common one to all participants, from different perspectives: some of the players are still students or recent graduates, while others, even though they were students many years ago, they either work with students or are relatives of students.

5.2.3. Results

As a result of the tasks completed by the 30 participants in the CTMobility tool, a total of 898 responses obtained from 60 profiles was received. We gathered all the recorded information and investigated the mobility behaviours. Inspecting the profile situation from the perspective of profile members, 53 profiles were individual ones, while 7 were family ones.

In what follows, we present a two-fold analysis of the user response, concerning mobility choices and user feedback. The mobility choices analysis focuses on participants' decisions (i.e. what mobility option they selected for an activity pattern, on a specific day type). The user feedback analysis relates to the participants' reasoning behind decisions (i.e. why they decided on a particular mobility option for a given activity pattern).

5.2.3.1. Mobility choices

The situations proposed by the activity patterns in the simulation captured both daily mobility and mobility on vacation categories. Seven transport mode categories were distinguished: walk, ride own bike, rent bike, public transport (bus, tram, metro or train), own car, cab and plane. From the pile of results, it can be revealed that the preferred mobility choice for vacation days is the public transport (29.2%), followed by walking (28.9%) and own car (22.4%). A similar overview is obtained for the mobility options in regular days. Using public transport (36.5%) and walking (29.2%) are most common, followed by taking own car (23%). Figure 5.1 visually shows the percentage of the travels performed in total for the seven offered transport modes. Total trips refers to regular and vacation days added together. The low percentage registered for the cab is due to the fact that most participants either have a car they can use or would rather take the public transport. Regarding the small percentage of users inclined towards taking the bike (their own or rental), this is due to the city missing a well-established cycling infrastructure. The plane option has also a small percentage, mainly because the user stories were more predominantly about shorter distances, for which the plane was not an alternative.

The absolute numbers of the travels made by participants in the case study can be checked in Appendix A.3.

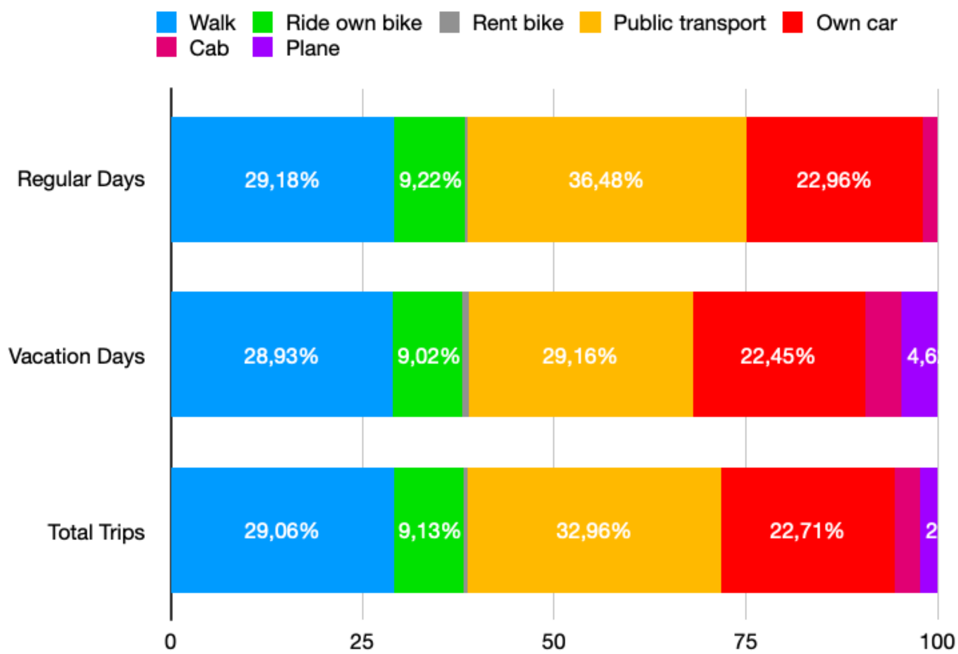


Figure 5.1.: Percentage of travels made for each mode of transport by the participants in the case study

Furthermore, we looked into more detail, separately at each day category - regular and vacation. For regular days, results show that the preferred mobility choice for slow days is walking (35.5%), followed by public transport (32.0%), own car (21.3%) and riding own bike (8.4%). A slightly different overview is obtained for the mobility options in busy days. Using public transport (40.6%) and taking own car (24.5%) are most common, followed by walking (23.2%) and riding own bike (10.0%). Figure 5.2 visually shows the relative share of the travels performed in regular days for the six available transport modes. Total Regular trips refers to regular - slow and regular - busy days added together.

The absolute numbers of the regular-day travels made by participants in the simulation can be verified in Appendix A.4.

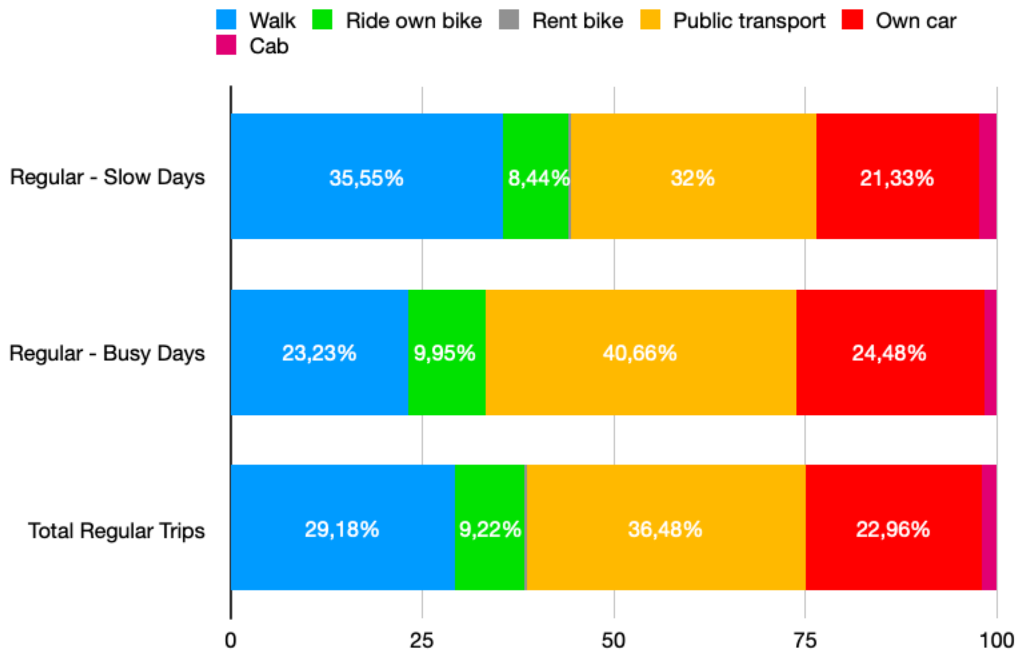


Figure 5.2.: Percentage of regular-day travels made for each mode of transport by the participants in the case study

Afterwards, for vacation days, results show that the preferred mobility choice for labour days is the own car (29.5%), followed by public transport (26.4%), walking (26.0%) and riding own bike (11.3%). A somewhat different overview is obtained for the mobility options in vacation days. Using public transport and walking are most common (both 31.8%), followed by taking own car (15.9%) and riding own bike (6.8%). Figure 5.3 visually shows the relative share of the travels performed in vacation days for the seven available transport modes. Total Vacation trips refers to vacation - labour and vacation - vacation days added together.

The absolute numbers of the vacation-day travels made by participants in the case study can be reviewed in Appendix A.5.

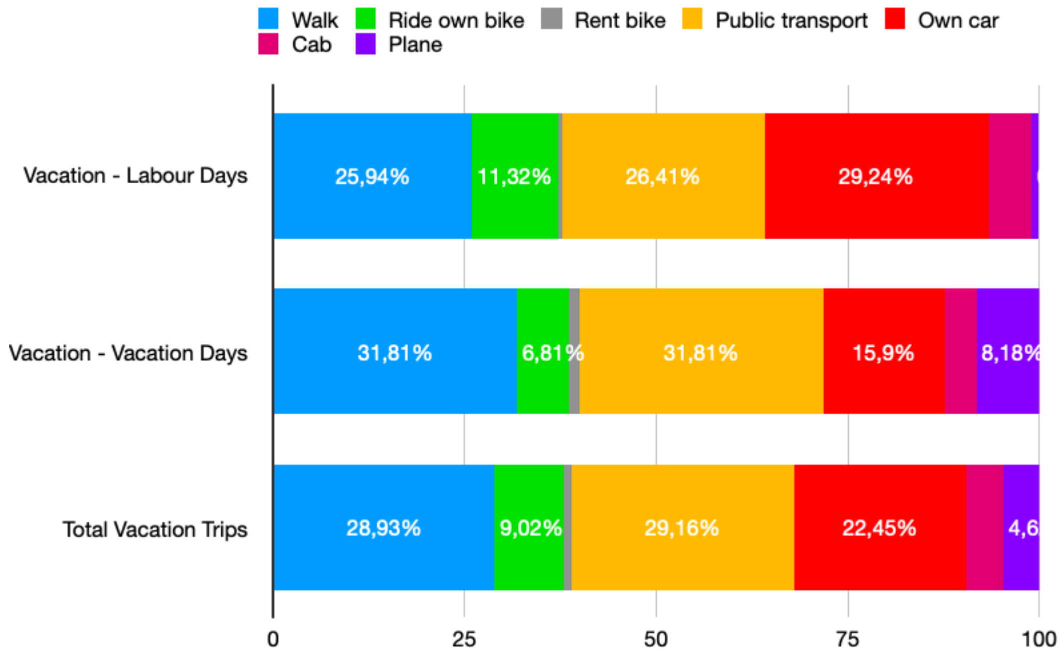


Figure 5.3.: Percentage of vacation-day travels made for each mode of transport by the participants in the case study

5.2.3.2. User Feedback

Looking to influence and uphold the conscious decision of players, the impact of each mobility choice is observed based on the following attributes: travel distance and duration, implied travel costs, environmental effect and additional impact values concerning physical health, well-being and comfort. The application evaluates the result of a completed story seeing the environmental effect. The CO2 emissions reach the highest values in the situation of own car or cab, while the lowest ones - zero - are for walking and cycling.

After deciding on a mobility option for a given story, the player is asked through an open question to provide an explanation or give feedback for the choice made (as shown in Figure 4.31). From the total number of 898 generated stories, the users provided a total of 882 relevant feedback information.

As we are granted access to the reasoning behind choosing a particular mode of transport, our intention is to analyse the players' attitude towards sustainable mobility too. The provided feedback was classified in seven categories, each one representing a different type of reasoning for a selected mobility option:

- cost
- time
- distance (abbreviated as dist in Table 5.1)

- environmental impact (abbreviated as env in Table 5.1)
- physical health
- well-being
- comfort (or convenience)

Table 5.1 depicts the results of the provided user feedback, for each mobility choice. In the first column, the "ride own bike" option is shortened as "own bike", while "public transport" is shortened as "public tran". Each relevant explanation given by a user was categorized based on the seven impact classes. If one response fitted more than one category, it was taken into consideration for all of them. The table discloses the necessity of the conditions that should be considered in order to encourage players to adhere to environment-friendly modes of transport, both on regular and vacation days. Even though players seemed to be opened towards making a positive contribution on sustainable mobility, a great number of responses showed that they are not willing to compromise on comfort and convenience.

The absolute numbers of the game responses of participants at the case study can be checked in Appendix A.6. In what follows, we discuss separately the feedback obtained for each mobility choice.

	Cost	**Time**	**Dist**	**Env**	**Health**	**Well-being**	**Comfort**
Walk	2.40%	5.50%	22.10%	1.20%	16.20%	50.60%	2.00%
Own bike	10.60%	3.50%	1.20%	-	41.15%	35.30%	8.25%
Rent bike	14.30%	14.30%	-	-	14.30%	57.10%	-
Public tran	32.20%	18.10%	4.35%	0.70%	-	4.05%	40.60%
Own car	2.55%	19.90%	12.75%	-	-	2.05%	62.75%
Cab	2.95%	29.40%	14.70%	-	-	-	52.95%
Plane	-	38.10%	4.75%	-	-	-	57.15%

Table 5.1.: Results of the user feedback for selected mobility options, extracted from the game responses of participants at the case study from the conducted evaluation

Walk

Around half of the responses for walking as a mobility choice belong to the well-being category. Feedback provided by players describes walking as a relaxing or chilling activity, which can help achieve a clear mind, while enjoying fresh air and the outdoors. Four responses declare walking to be a great way to appreciate the view of the surroundings during a vacation-day trip. Thirty responses reveal that people prefer to walk in order to avoid the drawbacks of other means of transport, which are: crowds in public transport, the trouble of finding a parking place for the car and the stress caused by traffic. In addition to this, fourteen responses state that walking is an occasion to socialise with the people who accompany your travel.

Moreover, 22% of the responses correspond to the distance category, with the reasoning that walking is preferred for short distances. A percentage not much lower comes from the health category. Besides the health benefits, six responses mentioned walking as an opportunity to move and stretch your body or achieve daily steps goal.

Time was pointed out to be a factor on holidays and slow days, with 5% of responses indicating that people prefer walking rather than other transport, as they have more free time. The cost factor did not seem to be important, with only 2% of the feedback stating that walking is a way of saving money. The same percentage describes walking as convenient. Less than 2% of the responses reveal that walking is an eco choice, a choice made by a good environment conscious citizen.

Ride own bike

The most answers (41%) focus on the physical health benefits (healthy choice, daily motion). Not very far behind is the well-being impact class (35%). Eighteen responses show that players view riding the bike as a refreshing activity for enjoying the outdoors and nature. At the same time, it avoids traffic and congestion (9 responses). Therefore, no traffic-related stress is implied.

10% of the feedback presents this mobility choice as free, with no costs being involved, especially if you don't want to pay for public transport ticket every day. 8% of the answers promote that riding the bike is convenient and easy if you own one. The fewest responses concern the time indicator - 3% claim to be a faster choice - and the distance, with few people choosing this for short distances. The environmental impact was not a determining factor to ride your own bike.

Rent bike

More than half of the responses resort to the well-being category (57%), with reasoning such as: relaxing activity, opportunity to enjoy outdoors and nature, no traffic-related stress. The remaining percentage is split equally between cost (cheap transport), time (arrive fast at the destination) and health (healthy activity). Just like in the case of riding your own bike, the environmental impact is missing.

Public transport

Comfort appears to be the dominant category for public transport (40%). Explanations given by players depict public transport as convenient, easy, comfortable and accessible. Four responses disclose that public transport was chosen to avoid difficult weather conditions. Two responses mention public transport when you have to carry various things. In addition to this, three answers view public transport as a safe alternative when staying late.

Moreover, 32% of the responses belong to the cost category, with the reasoning that public transport is affordable and budget-friendly, while in two situations the tickets are paid by school or employer. A percentage somewhat lower comes from the time category. Players mentioned public transport as a way to save time, emphasising that it is a faster option when in rush.

Distance was pointed out to be a factor for commuters, with 4% of responses indicating that they prefer public transport. The same goes for long distances or for a distance which is too long to walk. Well-being is included with a similar result, with reasons such as: enjoying the view (of the city or of the trip), avoiding (car) traffic or the need for parking. One person even mentioned that using public transport allows them to have an occasional drink. The environmental factor did not seem to be of interest, with only few responses revealing that public transport is an ecological choice, an alternative which leads to less pollution.

Own car

Results show comfort to be the predominant category for using the own car (40%). Players' feedback describes this alternative as convenient, easy, flexible and accessible. In addition, it offers an easy transportation of goods (i.e. materials, products, groceries). Six responses claim that it is a comfortable choice, which does not restrict your wardrobe. Another six responses unveil your own car to be reliable, avoiding to depend on a specific timetable, and a safe option at late hours. Using your own car also prevails difficult conditions such as sickness, age or bad weather (seven responses). One person mentioned that a member of their family drives well, so taking the own car is the most convenient option.

Less than the comfort, players are interested in the time factor (19%). Responses present the car to be a fast alternative, which can also be used for different activities. On top of that, it is reliable in order to avoid being late or especially in emergencies or urgent situations, when you need the fastest alternative. The distance factor achieved a somewhat similar percentage, with the main reasoning being the long distance, strengthened by the commute for people living in the countryside.

Lastly, the same value of 2% is shared for both cost and well-being. Regarding the cost category, feedback shows that own car can be an affordable and better alternative for a family, but also convenient for people who have a parking place. With concern to well-being, two responses find long-distance driving to be relaxing, while one person claims they deserve to use their own car during vacation days.

Cab

Similar to the own car alternative, in the case of cab, comfort is the most important factor (52%). Responses reveal the cab to have the strong point of offering 24/7 service, together with flexibility, convenience, comfort and no wardrobe restriction. The cab was also selected for its easy transportation of goods and avoidance of adverse weather conditions.

29% of the responses describe this alternative to be fast and useful, especially in emergencies. Following, 14% of the answers support the use of cab for long distances. Less important is the cost factor, one response mentioning that it is not an expensive option for a family.

Plane

The plane is mostly preferred for its comfort (57%), which is detailed as: comfortable, convenient, easy and flexible. Time is an important impact (38%), as the plane is fast and saves time. The remaining percentage goes to the distance, having one response stating that this alternative offers the possibility to travel far away.

The analysis performed on the user feedback strengthens the relevance of the business simulation technique, having the users informed about different aspects of their mobility decisions. Thus, they have the occasion to leave feedback on their choices.

As part of the next two sections, the performed case study is evaluated from two perspectives: a quantitative one 5.3, including all previous participants, and a qualitative one 5.4, consisting of only a third of them.

5.2.4. Main results of user feedback

This subsection addresses a summary of the user feedback results shown in Table 5.1 (with Appendix A.6) and described in the previous subsection. Each mode of transport is briefly mentioned again, this time together with the highest-ranked categories of response. These responses were provided as part of the user stories, by all 30 participants at the case study.

- **Walk**: mostly preferred for well-being (128 responses), distance (56 responses) and health reasons (41 responses)
- **Ride own bike**: selected for health (35 responses) and well-being purposes (30 responses)
- **Rent bike**: used in cases of well-being (4 responses)
- **Public transport**: taken due to provided comfort (121 responses), cost (96 responses) and time (54 responses)
- **Own car**: preferred for comfort (123 responses)
- **Cab**: selected for comfort (18 responses)
- **Plane**: mostly used for its comfort (12 responses)

5.3. Quantitative Analysis

The first part of the mixed-method evaluation is represented by the quantitative analysis. It aims to weigh in on the use and components of the CTMobility tool, via a questionnaire based on the conducted case study.

5.3.1. Participants and Procedure

All 30 participants who joined the case study, took part in the survey as well (16 of them were female; 14 were male). The minimum and maximum age reached 21 years and 58 years, leading to an average age of approximately 29 years. In addition to this, the median age approached 25 years.

The procedure employed considered the guidelines provided in [9]. As part of the quantitative analysis, we used an online questionnaire to conduct a survey. A link was sent to each participant shortly after the interaction with the system. Every person of the participating 30 completed the questionnaire. The survey contained two pages and filling the survey lasted about ten minutes. It incorporated two parts. The first part collected data concerning technology acceptance constructs and comprised ten statements. The second part focused on features and motivational effects of game-based elements and included four statements. Participants were asked to state their extent of agreement with the survey statements. Received answers were measured on the 5-point Likert scale.

Table 5.2 shows all the statements in the survey, associated with the corresponding construct. Perceived usefulness reflects the user's perception on whether our CTMobility tool could improve their mobility habits. This construct is measured through two items, statements **I.1** and **I.2**. Perceived ease of use indicates the player's view whether the tool can be easily used and demands minimal effort. This construct is measured through two items, statements **I.3** and **I.4**.

Perceived enjoyment shows the degree to which the user finds the activity of using the CTMobility tool to be enjoyable. This construct comprises two items, statements **I.5** and **I.6**. Attitude points out the user's opinion on whether the use of our tool is beneficial to them. This construct is analysed based on one item, statement **I.7**.

Behavioural intention of use expresses the player's intention to recommend our CTMobility tool to other people. This construct is evaluted through one item, statement **I.8**. Behaviour change asserts the user's perception on whether the CTMobility tool can lead to a reconsideration of mobility habits. This construct includes two items, statements **I.9** and **I.10**.

The second part denotes the player's perception on the usefulness of the following game features: stories, mobility tracking, dashboard and profile comparison. Each feature is measured through one statement: **II.1** for stories, **II.2** for mobility tracking, **II.3** for the dashboard and **II.4** for the profile comparison.

Construct	**Wording**
Perceived usefulness	**I.1.** Using CTMobility helps me become aware of my decisions and their impact.
Perceived usefulness	**I.2.** I find CTMobility useful in my mobility choices.
Perceived ease of use	**I.3.** Learning to use CTMobility has been easy for me.
Perceived ease of use	**I.4.** My interaction with CTMobility is clear and understandable.
Perceived enjoyment	**I.5.** I find using CTMobility to be enjoyable.
Perceived enjoyment	**I.6.** The actual process of using CTMobility is pleasant.
Attitude	**I.7.** I have a positive feeling towards the use of CTMobility.
Behavioural intention of use	**I.8.** I would recommend others to use CTMobility for their mobility habits.
Behaviour change	**I.9.** CTMobility helps me understand my CO2 emissions.
Behaviour change	**I.10.** CTMobility determines me to reconsider my mobility behaviour.
Stories	**II.1.** Please rate how useful you found the features of the game software.
Mobility tracking	**II.2.** Please rate how useful you found the features of the game software.
Dashboard	**II.3.** Please rate how useful you found the features of the game software.
Profile comparison	**II.4.** Please rate how useful you found the features of the game software.

Table 5.2.: Definition of the survey questions used for the quantitative analysis of the conducted evaluation

The 5-point Likert scale is used in the questionnaire, in two ways: for the first part 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree, while for the second one 1 = very useless, 2 = useless, 3 = neutral, 4 = useful, 5 = very useful. The full survey sent to participants can be found in Appendix A.1.

5.3.2. Results

Each individual statement in the questionnaire gathered 30 responses. The results obtained in the survey are mentioned in what follows.
I.1. Using CTMobility helps me become aware of my decisions and their impact.

- Neutral: 9 responses
- Agree: 8 responses
- Strongly Agree: 13 responses

I.2. I find CTMobility useful in my mobility choices.

- Neutral: 10 responses
- Agree: 12 responses
- Strongly Agree: 8 responses

I.3. Learning to use CTMobility has been easy for me.

- Neutral: 1 response
- Agree: 12 responses
- Strongly Agree: 17 responses

I.4. My interaction with CTMobility is clear and understandable.

- Neutral: 2 responses
- Agree: 14 responses
- Strongly Agree: 14 responses

I.5. I find using CTMobility to be enjoyable.

- Disagree: 1 response
- Neutral: 5 responses
- Agree: 14 responses
- Strongly Agree: 10 responses

I.6. The actual process of using CTMobility is pleasant.

- Disagree: 1 response
- Neutral: 3 responses
- Agree: 12 responses
- Strongly Agree: 14 responses

I.7. I have a positive feeling towards the use of CTMobility.

- Disagree: 1 response
- Neutral: 3 responses
- Agree: 11 responses
- Strongly Agree: 15 responses

I.8. I would recommend others to use CTMobility for their mobility habits.

- Neutral: 9 responses
- Agree: 10 responses
- Strongly Agree: 11 responses

I.9. CTMobility helps me understand my CO2 emissions.

- Neutral: 6 responses
- Agree: 14 responses
- Strongly Agree: 10 responses

I.10. CTMobility determines me to reconsider my mobility behaviour.

- Neutral: 11 responses
- Agree: 9 responses
- Strongly Agree: 10 responses

Please rate how useful you found the features of the game software.

II.1. Stories

- Neutral: 5 responses
- Useful: 14 responses
- Very Useful: 11 responses

II.2. Mobility tracking

- Useless: 1 response
- Neutral: 4 responses
- Useful: 11 responses
- Very Useful: 14 responses

II.3. Dashboard

- Useless: 1 response
- Neutral: 3 responses
- Useful: 11 responses
- Very Useful: 15 responses

II.4. Profile comparison

- Useless: 1 response
- Neutral: 9 responses
- Useful: 8 responses
- Very Useful: 12 responses

Responses received in the survey can be reviewed in Appendix A.4.

We evaluated six technology acceptance constructs, to comprehend the general level of interest that participants have towards our gamification framework. Tables 5.3 and 5.4 illustrate the obtained results for the two used metrics: mean and standard deviation. The *"behaviour change"* construct surveyed perceived effects of the business simulation game in adopting more sustainable habits. In general, the ratings received from users were positive, with the highest scores being registered for the *"perceived ease of use"* construct, followed by *"attitude"* (towards the game). The lowest ranking construct was *"perceived usefulness"*, which also appeared to have a larger fluctuation in responses (SD = 0.822). Participants also evaluated the gamification components and features of the business simulation game. These received positive ratings as well, with the highest values being accomplished for the dashboard.

Technology acceptance constructs	**Mean**	**SD**
Perceived usefulness	4.03	0.822
Perceived ease of use	4.46	0.595
Perceived enjoyment	4.20	0.798
Attitude	4.33	0.802
Behavioural intention of use	4.06	0.827
Behaviour change	4.05	0.790

Table 5.3.: Results of the quantitative analysis: technology acceptance

Features and gamification	**Mean**	**SD**
Stories	4.20	0.714
Mobility tracking	4.26	0.827
Dashboard	4.33	0.802
Profile comparison	4.03	0.927

Table 5.4.: Results of the quantitative analysis: features and gamification

Technology acceptance constructs

Analyzing the received responses, we observe that our design is not difficult to be understood, while the interaction with the system is clear. Most of the participants have shown a positive attitude towards this game. However, based on the mean metric, lower (and similar) rankings were established for the constructs concerning the behaviour impact and usefulness. Out of the 150 responses obtained for the five statements, 45 of them, representing a percentage of 30%, were classified as neutral. On a positive note, the remaining 70% of responses classified this statements as agree or strongly agree. This is encouraging, meaning that our simulation game can help understand a person's CO2 emissions and mobility decisions.

Features and gamification

From the collected responses on the game features, the mean metric discloses the dashboard feature as the highest ranked. This result emphasises the importance of including some form of visualisation of the user progress, which was realised in our game through the dashboard. Our dashboard aims at displaying to the player its progress, the CO2 information and travels, in a way that is much easier to understand. The lowest ranked feature, the profile comparison has the purpose of displaying the user's results, in comparison with other profile types. A third of the responses, classified this feature as useless or neutral, still the remaining ratings labelled it as useful or very useful. Therefore, this feature cannot be considered unnecessary, taking into account that a greater percentage of the participants found it essential to the game.

5.4. Qualitative Analysis

The second part of the mixed-method evaluation is represented by the qualitative analysis. It focuses on the validation of results obtained from the quantitative analysis survey through interviews, and also dwells into the use of our business simulation game. The interview participants were selected on a convenience sample.

5.4.1. Participants and Procedure

As part of the qualitative analysis, a set of semi-structured interviews were organised, right after the completion of the survey. A questionnaire served as guidance for the interviews. The discussions conducted with participants at the interview were recorded and lasted about 10 minutes each. In total, we interviewed 10 individuals out of the 30 initial participants, giving them the opportunity to provide qualitative feedback about their interaction with the game. The adopted strategy was to focus the interviews on people who were directly in charge of the mobility decisions within their household. This means that they either live alone or are the primary income source of their family (i.e. parents of a family with children). A wide range was considered, with concern to age, gender, type of household, rural or urban place of domicile and favoured mobility options. Table 5.5 shows a precise overview of the selected participants.

Two predefined questions served as guideline for these interviews. Each question takes on a different perspective, which can supply more awareness on the impact of our sustainable mobility game, as well as the understanding players show towards gamification as a persuasive mechanism. We are interested to see if taking part in the simulation helped people consider a change in their mobility choices. We cannot measure if they really made a change afterwards, but even just considering can already be seen as a success.

Therefore, the questionnaire - which can be found in Appendix A.2 - contained three distinct parts. The purpose and the goals behind the interview were mentioned as part of the first section. Our interest was to obtain an in-depth look into the game impact - if seeing more information on sustainable mobility helps individuals in their choices and

No.	Age	Gender	Household	Area	Walk	Bike	Public tran	Car
1.	23	F	FH	urban	X			X
2.	22	F	FH	urban	X	X	X	X
3.	55	F	FH+2	urban	X	X		X
4.	56	M	FH+2	urban		X	X	
5.	57	F	SH	urban				X
6.	22	F	SA	rural	X		X	X
7.	21	F	SA	urban			X	X
8.	24	M	SA	rural			X	
9.	24	F	SH	rural	X		X	X
10.	23	M	SA	rural		X		X

Table 5.5.: Overview of the interview participants, as part of the qualitative analysis from the evaluation process. SH = single household; FH = family household no children; FH+n = family household with n children; SA = shared apartment

shifts their opinion - and into players' attitude - their opinion on the game experience and suggestions for improvement. Additionally, the background information of the participant was gathered, as shown in Table 5.5.

The remaining two parts of the questionnaire outlined only one question each. Thus, we continued with the second part of the interview, addressing our first question: *"To what extent the game induced a reconsideration of your mobility behaviour?"*. Our expectation from this question was to gain insight into what level of impact our game might have after taking part in the simulation. The last part concerned the second question: *"What game elements were effective in persuading you to keep playing and consider changing your mobility habits?"*. With this question, our intention was to analyze which elements can be helpful to keep players invested and to achieve positive effects afterwards.

A summary of the results according to each question is presented in what follows.

5.4.2. Results

To what extent the game induced a reconsideration of your mobility behaviour?

We asked the ten interview participants if taking part in the simulation supported them to consider a change in their mobility choices. Six out of ten declared a positive attitude about the impact of the game, while the other four inclined towards a negative answer.

Participants who expressed a positive feeling about the game, appeared to share an interest towards sustainability. They showed enthusiasm for such tools that can improve daily habits and decisions. Regarding our business simulation game, the reasons mentioned for using it include: getting to know one's mobility decisions and understand environmental impact better, exploring different views on mobility alternatives, the gamification aspect and additional features, especially the dashboard. To quote one of the interview participants: *"The game can raise awareness on the impact of daily mobility choices. Not just that, but it can also persuade users to analyze and review their mobility behaviour. Everything has been designed and organised tightly. There is no need for additional sources to understand the topic. Also, I discovered information that I didn't know beforehand."*.

All those who answered that the game had no impact on their mobility behaviour, had the same reasoning. These users did not think the use of such an app would make any difference for them, since they were already adopting a sustainable mobility lifestyle. For example, most of them were already choosing to walk or use public transport almost all the time, and therefore did not have an interest in pursuing such an app. Another observation was that mobility decisions are impacted by different motivations or contexts and thus cannot be influenced enough by technology tools.

What game elements were effective in persuading you to keep playing and consider changing your mobility habits?

Generally, the participants in the interview shared a positive attitude towards the game and enjoyed its overall design. However, some of them noted that a more detailed on-boarding experience is necessary, to help grasp the purpose of the game and the numerous features. Other observations concerned the storyline. The stories could also be improved to be interactive, in order to keep the player engaged in the game, as well as providing more diverse information about the activity patterns and mobility options. Still, most of the interview participants liked the idea behind the profiles, with the possibility to select a predefined one or create your own. In addition, they found the dashboard to be quite important for the purpose of the game. Participants appreciated the different visualization forms and charts of their progress in the dashboard section. This element was considered the most helpful one in the direction of persuading them to continue the simulation.

Suggestions were made about possible new features. One idea was to be able to add different people for a specific travel (for example, even if a user has an individual profile, they could be travelling with other people in specific situations). Someone even proposed to integrate a family household, such that each individual player can link its own profile to those of its family (or the people they travel more often with). During the simulation, they should be able to choose for each selected activity pattern if they are travelling alone or with specific people from their household. Other recommendations involve the stories, which can be revamped to be diverse, regarding the content of the storyline, and less repetitive, meaning to have a larger number of stories and show different ones in each simulation. Also, related to the overall gamification strategy, proposals to keep the user invested cover a points accumulation technique in the stories, or other features like challenges and rewards.

5.5. Summary

RQ4 - How is such a game perceived by people?

The last step towards successfully developing such a tool is to conduct an evaluation of the application presented in Chapter 5. In this sense, a case study was carried out in the Romanian city of Cluj-Napoca, and its suburban regions, including commuters.

In order to determine if our design was successful in supporting the sustained engagement in our mobility game, a mixed-method approach was employed, to evaluate the outcome of the case study. The two-fold anaysis consisted of a quantitative questionnaire, followed by qualitative feedback interviews. Regarding the quantitative analysis, the survey focused on the technology acceptance constructs and motivational effects of game-based elements. In general, the ratings received from users were positive, with the highest scores being registered for the *"perceived ease of use"* (of the game) construct and the dashboard feature.

The qualitative analysis concentrated on two general questions. Conducted interviews revealed that participants who expressed a positive attitude about the game already shared an interest towards sustainability. These participants considered the followings to be strengths of the game: getting to know one's mobility decisions and understand environmental impact better, exploring different views on mobility alternatives, the gamification aspect and incorporated features (e.g. the dashboard). Interviewees who inclined towards a negative answer did not think the use of such an app would make any difference for them, since they were already adopting a sustainable mobility lifestyle. Both categories of interviewees made suggestions on possible improvements, such as: a more detailed on-boarding experience, an interactive and diverse storyline, more inclusive profiles, a better gamification strategy which covers a points accumulation technique or other features like challenges and rewards.

Overall, the outcome of the evaluation discloses that the developed CTMobility tool was perceived with a positive attitude and has potential in supporting people make sustainable mobility decisions. Most participants admitted that seeing the information on sustainable mobility led them to rethink their mobility habits and consider different and better choices.

5.6. Discussion

As a continuation to the performed evaluation, this section addresses some changes in the profile comparison feature, the discovered threats to validity and the possibilities for future work.

Profile comparison

The profile comparison interface looked slightly different when the evaluation was performed. These differences affect the day-type charts. Instead of having the current drop-down to select a specific day type, all four were displayed at the same time on the chart, with lines being drawn instead of data points. Also, the actual values for the points were not shown. Figures 5.4 and 5.5 represent the initial illustration of the profile comparison day-type charts. It is visible that these charts were difficult to read.

Figure 5.4.: Old profile comparison charts (1)

Figure 5.5.: Old profile comparison charts (2)

The profile comparison interface currently looks as depicted in the Implementation chapter, for both the admin (Figures 4.15 and 4.16) and the participant (Figures 4.23, 4.24, 4.25 and 4.26). The received feedback was considered and the interface was improved. The results can now be visualised in a more clear manner, that facilitates their reading and understanding.

Threats to validity

It is not uncommon for a study to come across a number of threats to validity, which may impact the outcome of the research. Our business simulation game method is not excluded from this rule. Therefore, the limitations of this work need to be discussed.

First and foremost, so far the focus of the research was given only by a Romanian location, represented by one city, Cluj-Napoca, and its surrounding area. This city comes with its very traits concerning infrastructure, topographic landscape and history of encouraging sustainable mobility habits. In addition to this, most of the case study participants were targeted via two principal channels: the faculty of computer science and an IT company. Therefore, only a certain community is addressed and might result in bias.

Secondly, we managed to find a relatively small number of voluntary participants at the interviews conducted as part of the qualitative analysis. The convenience sample can also be seen as a limiting factor. This leads, unfortunately, to restricted results for the qualitative analysis of the study.

Both of these conditions were due to time and resource limitation. In the future, it would be highly interesting to assess multiple cities and the countryside, approaching larger groups of participants at the same time.

Future work

A number of opportunities for future work can arise from our research. The current work aimed at creating a business simulation game approach for promoting and strengthening sustainable mobility. Further research is necessary to improve our tool, by considering the evaluation outcome.

Improvements extracted from the results can be incorporated within future work. These include: integrating a family household, such that each individual player can link its own profile to the people they travel more often with, revamping the stories and inserting new gamification strategies: a points accumulation technique in the stories, challenges and rewards.

Moreover, it is essential for future work to continue the case study inside wider and more varied communities. Thus, a plan for future work is to gather more people to test our web application. Also, an expanded questionnaire for the quantitative analysis could investigate better the user preferences. We also plan to introduce a persuading mechanism that encourages users to leave feedback for our mobility tool from within the application. This could be done with the help of the gamification strategies mentioned in the previous paragraph.

6. Conclusions

The proposal of this thesis is a business simulation game approach for encouraging sustainable mobility. We selected simulation gaming to be our research technique in order to build a controlled and dynamic environment that allows participants to determine, encounter and verify a number of mobility scenarios.

Overall, the thesis reports the following aspects. First of all, it includes a presentation of the research matter, accompanied by the motivation behind it and expected goals. Subsequently, a theoretical substantiation of the current work on the chosen subject is supposed to place our research inside the already existing literature. In addition to this, the design and development of the suggested technique are described, together with an inquiry of the implementation and evaluation mechanisms. An analysis of the conducted tests is presented in detail, addressing the proposed study design, procedures and the result clarification.

The aim of this work was targeted with the help of the following research questions:

- **RQ1** - What are typical business simulation games for sustainable mobility and their adopted solutions?
- **RQ2** - How can the simulation game for sustainable mobility be designed?
- **RQ3** - How can a simulation game for sustainable mobility be implemented?
- **RQ4** - How is such a game perceived by people?

The corresponding results are summarised as follows.

RQ1. This work presents the applicability and impact of business simulation games in the context of mobility and sustainable transport. The performed literature review managed to outline the state-of-the-art, to discuss and evaluate existing approaches of applying simulation games as a tool for promoting and encouraging sustainable mobility. The solutions range from gamification platforms which integrate the principles of service-oriented architecture or machine learning algorithms, to recommender systems and data collection tools. Two studies which do not comprise an implementation solution were also reviewed, for completeness. The extracted information from the existing contribution represented the foundation layer of our own development in the field.

RQ2. Following the research process, the proposal focused on creating a gamification concept to encourage sustainable travel and mobility. The intention was to assist sustainable travel behaviours, while admitting that in real life, people have a wide set of interests. From the game design process, we focused on the development of the simulation game prototype and identified four stages. We have separately described each one of them: roles (user profiles), scenarios (user stories), accounting schema (the user response) and operating procedure (the simulation). As part of the design development, we also considered the use case view, prototype design, the data model, profile comparison and dashboard design for the visual display of data.

RQ3. The first step was identifying and prioritizing the functional requirements, in relation with the theoretical concepts. Afterwards, we created the business simulation game as a web application, using a divided implementation approach, in order to see how people respond, by developing user-tailored stories. The players' mobility choices for each such story were monitored and analysed towards the sustainability cause. The user responses in the simulation game were gathered to compose a dataset of mobility choices. The resulted CTMobility tool facilitates the purpose of the business simulation game for sustainable mobility, to encourage sustainable travel and mobility through a new proof-of-concept.

RQ4. Evaluation was performed with a group of people residing in the urban area. One case study was conducted, to investigate the user responses in the simulation, and then evaluated via a mixed-method technique. The performed analysis was realised from a two-fold perspective: quantitative, based on a survey given to participants in the case study, and qualitative, using interviews. The reached outcome implies that the simulation game has the potential to draw the attention of people concerned with the topics of sustainability. The positive responses towards the gamification aspects and features suggest that it holds a promising capability in supporting people make sustainable mobility decisions.

Future work will consider implementing and introducing additional new features and persuading mechanisms. We also plan to extend the experimental evaluation considering a range of different communities, as an attempt to better evaluate the effectiveness of the developed business simulation game towards the sustainable mobility goal.

To conclude, the aim of this thesis was to propose a business simulation game for sustainable mobility, titled CTMobility. We have analysed and developed multiple concepts and design configurations, ranging from profiles, activity patterns, mobility choices, to dashboard and profile comparison. We have conducted experiments from different perspectives and reached the conclusion that our approach meets the desired goal, that of encouraging users to ponder on their mobility behaviour, to develop more sustainable mobility habits.

Bibliography

[1] Susanne Böhler, Sylvie Grischkat, Sonja Haustein, and Marcel Hunecke. Encouraging environmentally sustainable holiday travel. *Transportation Research Part A: Policy and Practice*, 40(8):652–670, 2006.

[2] Efthimios Bothos, Dimitris Apostolou, and Gregoris Mentzas. Choice architecture for environmentally sustainable urban mobility. CHI EA '13, page 1503–1508, New York, NY, USA, 2013. Association for Computing Machinery.

[3] Tilman Bracher, Jürgen Gies, Jörg Thiemann-Linden, Klaus J Beckmann, Thomas Warnecke, Irene Schlünder, Aichinger Wolfgang, Wiechmann Susanne, and René Bormann. *Handbuch der kommunalen Verkehrsplanung*. VDE Verlag: Berlin, Germany, 2011.

[4] Christian Brand, Anna Goodman, Harry Rutter, Yena Song, and David Ogilvie. Associations of individual, household and environmental characteristics with carbon dioxide emissions from motorised passenger travel. *Applied Energy*, 104:158–169, 2013.

[5] Gabriel Campeanu. *GPU Support for Component-based Development of Embedded Systems*. PhD thesis, Mälardalen University, 2018.

[6] European Commission. Green paper: Towards a new culture for urban mobility. Last accessed: 25.07.2024. URL: http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52007DC0551.

[7] European Commission. Together towards competitive and resource-efficient urban mobility. Last accessed: 25.07.2024. URL: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52013DC0913.

[8] European Commission. White paper 'roadmap to a single european transport area—towards a competitive and resource efficient transport system'. Last accessed: 25.07.2024. URL: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0144:FIN:EN:PDF.

[9] Fred D. Davis. Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, 13(3):319–340, 1989.

[10] Sebastian Deterding, Alessandro Canossa, Casper Harteveld, Seth Cooper, Lennart E Nacke, and Jennifer R Whitson. Gamifying research: Strategies, opportunities, challenges, ethics. In *Proceedings of the 33rd annual ACM conference extended abstracts on human factors in computing systems*, pages 2421–2424, 2015.

[11] Salvatore Di Dio, Enza Lissandrello, Domenico Schillaci, Brunella Caroleo, Andrea Vesco, and Ingwio D'Hespeel. Muv: A game to encourage sustainable mobility habits. In Gentile M., Allegra M., and Söbke H., editors, *Games and Learning Alliance - 7th International Conference, GALA 2018, Proceedings*, Lecture Notes in Computer Science, pages 60–70, United States, January 2019. Springer Publishing Company. Games and Learning Alliance. GALA 2018 ; Conference date: 05-12-2018 Through 10-02-2019.

[12] Salvatore Di Dio, Francesco Massa, Antonino Nucara, Giorgia Peri, Gianfranco Rizzo, and Domenico Schillaci. Pursuing softer urban mobility behaviors through game-based apps. *Heliyon*, 6(5):e03930, 2020.

[13] Janet E Dickinson and Derek Robbins. Representations of tourism transport problems in a rural destination. *Tourism Management*, 29(6):1110–1121, 2008.

[14] Ghislain Dubois, Paul Peeters, Jean-Paul Ceron, and Stefan Gössling. The future tourism mobility of the world population: Emission growth versus climate policy. *Transportation Research Part A: Policy and Practice*, 45(10):1031–1042, 2011.

[15] Richard D. Duke. A paradigm for game design. *Simulation & Games*, 11(3):364–377, 1980.

[16] Richard D Duke and Jac Geurts. *Policy games for strategic management*. Rozenberg Publishers, 2004.

[17] Domokos Esztergár-Kiss, Yuliia Shulha, Attila Aba, and Tamás Tettamanti. Promoting sustainable mode choice for commuting supported by persuasive strategies. *Sustainable Cities and Society*, 74:103264, 2021.

[18] Anthony J Faria, David Hutchinson, William J Wellington, and Steven Gold. Developments in business gaming: A review of the past 40 years. *Simulation & gaming*, 40(4):464–487, 2009.

[19] Figma. The collaborative interface design tool. Last accessed: 26.07.2024. URL: `https://www.figma.com/prototyping/`.

[20] Flask. Micro web framework. Last accessed: 26.07.2024. URL: `https://flask.palletsprojects.com/en/3.0.x/`.

[21] Bundesministerium für Klimaschutz; Umwelt; Energie; Mobilität; Innovation und Technologie. Österreich unterwegs 2013/14. Last accessed: 01.06.2024. URL: `https://www.bmk.gv.at/dam/jcr:fbe20298-a4cf-46d9-bbee-01ad771a7fda/oeu_2013-2014_Ergebnisbericht.pdf`.

[22] Regine Gerike, Audrey de Nazelle, Mark Nieuwenhuijsen, Luc Int Panis, Esther Anaya, Ione Avila-Palencia, Florinda Boschetti, Christian Brand, Tom Cole-Hunter, Evi Dons, et al. Physical activity through sustainable transport approaches (pasta): a study protocol for a multicentre project. *BMJ open*, 6(1):e009924, 2016.

[23] Greentripper. Calculate CO2 emissions. Last accessed: 26.07.2024. URL: https://www.greentripper.org/en.

[24] Casper Harteveld. *Triadic game design: Balancing reality, meaning and play*. Springer Science & Business Media, 2011.

[25] Raman Kazhamiakin, Enrica Loria, Annapaola Marconi, and Mauro Scanagatta. A gamification platform to analyze and influence citizens' daily transportation choices. *IEEE Transactions on Intelligent Transportation Systems*, 22(4):2153–2167, 2021.

[26] Raman Kazhamiakin, Annapaola Marconi, Alberto Martinelli, Marco Pistore, and Giuseppe Valetto. A gamification framework for the long-term engagement of smart citizens. In *2016 IEEE International Smart Cities Conference (ISC2)*, pages 1–7, 2016.

[27] Raman Kazhamiakin, Annapaola Marconi, Mirko Perillo, Marco Pistore, Giuseppe Valetto, Luca Piras, Francesco Avesani, and Nicola Perri. Using gamification to incentivize sustainable urban mobility. In *2015 IEEE First International Smart Cities Conference (ISC2)*, pages 1–6, 2015.

[28] Reza Khoshkangini, Annapaola Marconi, and Giuseppe Valetto. Machine learning for personalized challenges in a gamified sustainable mobility scenario. In *Extended Abstracts Publication of the Annual Symposium on Computer-Human Interaction in Play*, CHI PLAY '17 Extended Abstracts, page 361–368, New York, NY, USA, 2017. Association for Computing Machinery.

[29] Barbara Kitchenham and Stuart Charters. Guidelines for performing systematic literature reviews in software engineering. *Technical report, ver. 2.3 ebse technical report. ebse*, 2007.

[30] Jan Klabbers. *The magic circle: Principles of gaming simulation*. Rotterdam, The Netherlands: Sense Publishers, 2006.

[31] Ioanna Kourounioti and Lránt Tavaszzy. Data collection on shipper's preferences using simulation games: : A synchromodality case study. In *2020 Forum on Integrated and Sustainable Transportation Systems (FISTS)*, pages 309–314, 2020.

[32] Shalini Kurapati. *Situation Awareness for Socio Technical Systems: A simulation gaming study in intermodal transport operations*. PhD thesis, Delft University of Technology, 2017.

[33] Shalini Kurapati, Daan Groen, Heide Lukosch, and Alexander Verbraeck. Microgames in practice: A case study in container terminal operations. *The shift from teaching to learning: Individual, collective and organizational learning through gaming simulation*, pages 333–346, 2014.

[34] Shalini Kurapati, Ioanna Kourounioti, Heide Lukosch, Lóránt Tavasszy, and Alexander Verbraeck. Fostering sustainable transportation operations through corridor management: A simulation gaming approach. *Sustainability*, 10(2), 2018.

[35] Jeffrey LaMondia, Tara Snell, and Chandra R Bhat. Traveler behavior and values analysis in the context of vacation destination and travel mode choices: European union case study. *Transportation research record*, 2156(1):140–149, 2010.

[36] Diem-Trinh Le-Klaehn and C Michael Hall. Tourist use of public transport at destinations–a review. *Current Issues in Tourism*, 18(8):785–803, 2015.

[37] Diem-Trinh Le-Klähn, Jutta Roosen, Regine Gerike, and C Michael Hall. Factors affecting tourists' public transport use and areas visited at destinations. *Tourism Geographies*, 17(5):738–757, 2015.

[38] Heide Lukosch, Shalini Kurapati, Daan Groen, and Alexander Verbraeck. Microgames for situated learning: A case study in interdependent planning. *Simulation & Gaming*, 47(3):346–367, 2016.

[39] Annapaola Marconi, Michela Ferron, Enrica Loria, and Paolo Massa. Play&go, an urban game promoting behaviour change for sustainable mobility. *Interaction Design and Architecture(s)*, 40, 2019.

[40] Igor S Mayer. The gaming of policy and the politics of gaming: A review. *Simulation & gaming*, 40(6):825–862, 2009.

[41] Bob Mckercher and Gigi Lau. Movement patterns of tourists within a destination. *Tourism geographies*, 10(3):355–374, 2008.

[42] Johanna Meurer, Dennis Lawo, Christina Pakusch, Peter Tolmie, and Volker Wulf. Opportunities for sustainable mobility: Re-thinking eco-feedback from a citizen's perspective. In *Proceedings of the 9th International Conference on Communities amp; Technologies - Transforming Communities*, Camp;T '19, page 102–113, New York, NY, USA, 2019. Association for Computing Machinery.

[43] Alexandra Millonig and Konstantin Mitgutsch. Playful mobility choices: Motivating informed mobility decision making by applying game mechanics. *EAI Endorsed Trans. Ambient Syst.*, 1:e3, 2014.

[44] United Nations. The 17 sustainale development goals. Last accessed: 26.07.2024. URL: `https://sdgs.un.org/goals`.

[45] Juan L Nicolau and Francisco J Mas. The influence of distance and prices on the choice of tourist destinations: The moderating role of motivations. *Tourism Management*, 27(5):982–996, 2006.

[46] Francesco Orsi and Davide Geneletti. Assessing the effects of access policies on travel mode choices in an alpine tourist destination. *Journal of Transport Geography*, 39:21–35, 2014.

[47] Lawrence A Palinkas, Sapna J Mendon, and Alison B Hamilton. Innovations in mixed methods evaluations. *Annual review of public health*, 40:423–442, 2019.

[48] Rocco Palumbo, Mohammad Fakhar Manesh, Massimiliano Matteo Pellegrini, Andrea Caputo, and Giulia Flamini. Organizing a sustainable smart urban ecosystem: Perspectives and insights from a bibliometric analysis and literature review. *Journal of Cleaner Production*, 297:126622, 2021.

[49] Irina Paraschivoiu and Thomas Layer-Wagner. *Placemaking for Urban Sustainability: Designing a Gamified App for Long-Term, Pro-Environmental Participation*, page 186–191. Association for Computing Machinery, New York, NY, USA, 2021.

[50] Vincent Peters, Marleen van de Westelaken, and Jorn Bruining. Simulation games as a safe environment: What can game designers and facilitators do to guard the psychological security of participants? *Studies in Simulation and Gaming*, 22(SPECIAL):59–64, 2012.

[51] pgAdmin. Platform for PostgreSQL. Last accessed: 26.07.2024. URL: https://www.pgadmin.org/.

[52] Ferdinand Pospischil and Markus Mailer. The potential of cycling for sustainable mobility in metropolitan regions–the facts behind the success story of innsbruck. *Transportation Research Procedia*, 4:80–89, 2014.

[53] PostgreSQL. Relational database. Last accessed: 26.07.2024. URL: https://www.postgresql.org/.

[54] Psycopg2. Database adapter for PostgreSQL. Last accessed: 26.07.2024. URL: https://pypi.org/project/psycopg2/.

[55] PyCharm. Python IDE for data science and web development. Last accessed: 26.07.2024. URL: https://www.jetbrains.com/pycharm/.

[56] Shannon Sahlqvist, Yena Song, and David Ogilvie. Is active travel associated with greater physical activity? the contribution of commuting and non-commuting active travel to total physical activity in adults. *Preventive medicine*, 55(3):206–211, 2012.

[57] Philipp Schlemmer, Cornelia Blank, Bartosz Bursa, Markus Mailer, and Martin Schnitzer. Does health-oriented tourism contribute to sustainable mobility? *Sustainability*, 11(9), 2019.

[58] Anna Scuttari, Francesco Orsi, and Ruben Bassani. Assessing the tourism-traffic paradox in mountain destinations. a stated preference survey on the dolomites' passes (italy). *Journal of Sustainable Tourism*, 27(2):241–257, 2019.

[59] Hamid R Seddighi and Antonis L Theocharous. A model of tourism destination choice: a theoretical and empirical analysis. *Tourism management*, 23(5):475–487, 2002.

[60] Ercan Sirakaya and Arch G Woodside. Building and testing theories of decision making by travellers. *Tourism management*, 26(6):815–832, 2005.

[61] Zacharoula Smyrnaiou, Evangelia Petropoyloy, Stefano Menon, and Vincenzo Zini. From game to guidance: The innovative evaluation approach of the p4g simulation business game. In *2017 Fourth International Conference on Mathematics and Computers in Sciences and in Industry (MCSI)*, pages 148–153, 2017.

[62] Wouter M van den Hoogen, Wijnand A IJsselsteijn, and Yvonne AW de Kort. Exploring behavioral expressions of player experience in digital games. In *Proceedings of the workshop on Facial and Bodily Expression for Control and Adaptation of Games ECAG*, volume 2008, pages 11–19. Citeseer, 2008.

[63] Desirée Verbeek and Hans Mommaas. Transitions to sustainable tourism mobility: The social practices approach. *Journal of sustainable tourism*, 16(6):629–644, 2008.

[64] WebStorm. The JavaScript and TypeScript IDE. Last accessed: 26.07.2024. URL: `https://www.jetbrains.com/webstorm/`.

[65] Simon Wells, Henri Kotkanen, Michael Schlafli, Silvia Gabrielli, Judith Masthoff, Antti Jylhä, and Paula Forbes. Towards an applied gamification model for tracking, managing, encouraging sustainable travel behaviours. *ICST Transactions on Ambient Systems*, 1:e2, 10 2014.

[66] Judit Zoltan and Bob McKercher. Analysing intra-destination movements and activity participation of tourists through destination card consumption. *Tourism Geographies*, 17(1):19–35, 2015.

Acronyms

AUC Area Under the Curve. 17

CSV comma-separated values. 59, 65

FS Filtering & Sorting. 17

HCI Human-Computer Interaction. 13, 19

ML Machine Learning. 17

RQ Research Question. 4

SD Standard Deviation. 97

SDG Sustainabe Development Goal. iii, 1

SLR Systematic Literature Review. 5, 7, 8

Glossary

activity pattern An activity pattern is a fixed scenario consisting of the following properties: description (the activity), distance (measured in km) and mobility options. 29, 35, 36

admin An admin is a type of user who does not engage in the simulation, but manages the data and flows. This user has access control. 28

day type The day type of a simulation can be: regular day with overtones slow and busy, or vacation day with overtones labour or vacation. 30, 35, 36

member A member belongs to a profile. An individual profile has one member, while a family profile has at least two members. 27, 28

mobility option A mobility option incorporates details such as name and transport-related attributes: travel time, costs and CO2 emission. Each mobility option is linked to an activity pattern. 31, 35, 36

profile The game incorporates the concept of user profiles which can be of two types: individual (the user makes mobility choices from the perspective of one person) or family profile (the user makes mobility choices from the perspective of a family with a given number of members). 27, 28, 35, 36

regular user A regular user is of non-admin type; it takes part in the simulation, but its access to admin functionalities is restricted. 28

response The user's response in the simulation is recorded and links all concepts, because it represents the mobility choice, together with an explanation, made by a user with a given profile, for a story built on an activity pattern, happening for a given simulation. 35, 36

simulation A simulation means a complete flow: the user chooses a day type together with activity patterns. Then, for each generated story, a mobility option is selected. 35, 36

story A story includes an activity pattern and additional variable properties: selected day type, weather and accessibility conditions. 30, 35, 36

A. Appendix

A.1. Quantitative Analysis Questionnaire

Business Simulation Game For Sustainable Mobility
We denote our business simulation game for sustainable mobility as CTMobility, in the survey.

I. In the first part, indicate the level of agreement with the statements.

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
1. Using CTMobility helps me become aware of my decisions and their impact.	◯	◯	◯	◯	◯
2. I find CTMobility useful in my mobility choices.	◯	◯	◯	◯	◯
3. Learning to use CTMobility has been easy for me.	◯	◯	◯	◯	◯
4. My interaction with CTMobility is clear and understandable.	◯	◯	◯	◯	◯
5. I find using CTMobility to be enjoyable.	◯	◯	◯	◯	◯
6. The actual process of using CTMobility is pleasant.	◯	◯	◯	◯	◯

7. I have a positive feeling towards the use of CTMobility.	◯	◯	◯	◯	◯
8. I would recommend others to use CTMobility for their mobility habits.	◯	◯	◯	◯	◯
9. CTMobility helps me understand my CO2 emissions.	◯	◯	◯	◯	◯
10. CTMobility determines me to reconsider my mobility behaviour.	◯	◯	◯	◯	◯

II. In the second part, please rate how useful you found the features of the game software.

	Very useless	Useless	Neutral	Useful	Very useful
1. Stories (the storyline for the activity patterns, the CO2 information in the stories)	◯	◯	◯	◯	◯
2. Mobility tracking (keeping record of mobility history)	◯	◯	◯	◯	◯
3. Dashboard (visualisation of user progress, CO2 information and travels)	◯	◯	◯	◯	◯
4. Profile comparison (visualisation of the user's progress, CO2 information and travels in comparison with other profiles)	◯	◯	◯	◯	◯

A.2. Qualitative Analysis Questionnaire

Business Simulation Game For Sustainable Mobility
We denote our business simulation game for sustainable mobility as CTMobility, in the questionnaire.

I. The goal of the interview is to supply more awareness on the impact of the CTMobility game, as well as the understanding of gamification as a persuasive mechanism. The aim is to see if taking part in the simulation helped consider a change in the mobility choices.

Please write and choose the corresponding information:

- Age:
- Gender:
- Household: SH = single household; FH = family household no children; FH+n = family household with n children; SA = shared apartment
- Living area: rural / urban
- Preferred means of transport: Walk / Bike / Public transport / Car

II. Please answer the next question:
To what extent the game induced a reconsideration of your mobility behaviour?

III. Please answer the next question:
What game elements were effective in persuading you to keep playing and consider changing your mobility habits?

A.3. Case Study - Absolute Results

A.3.1. Mobility Choices

	Regular days	**Vacation days**	**All trips**
Walk	136	125	261
Ride own bike	43	39	82
Rent bike	1	4	5
Public transport	170	126	296
Own car	107	97	204
Cab	9	21	30
Plane	0	20	20
Total	466	432	898

Table A.3.: Number of travels made for each mode of transport by the participants in the case study

	Regular-Slow days	**Regular-Busy days**	**All regular trips**
Walk	80	56	136
Ride own bike	19	24	43
Rent bike	1	0	1
Public transport	72	98	170
Own car	48	59	107
Cab	5	4	9
Plane	0	0	0
Total	225	241	466

Table A.4.: Number of regular-day travels made for each mode of transport by the participants in the case study

	Vacation-Labour	Vacation-Vacation	All vacation trips
Walk	55	70	125
Ride own bike	15	24	39
Rent bike	1	3	4
Public transport	56	70	126
Own car	35	62	97
Cab	9	12	21
Plane	2	18	20
Total	212	220	432

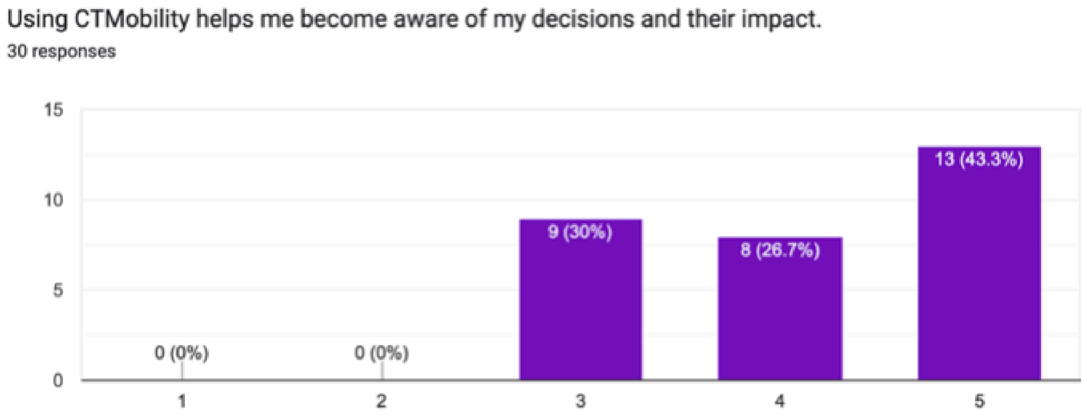
Table A.5.: Number of vacation-day travels made for each mode of transport by the participants in the case study

A.3.2. User Feedback

	Cost	Time	Dist	Env	Health	Well-being	Comfort	Total
Walk	6	14	56	3	41	128	5	253
Ride own bike	9	3	1	0	35	30	7	85
Rent bike	1	1	0	0	1	4	0	7
Public transport	96	54	13	2	0	12	121	298
Own car	5	39	25	0	0	4	123	196
Cab	1	10	5	0	0	0	18	34
Plane	0	8	1	0	0	0	12	21

Table A.6.: Number of user responses given for each mode of transport per category by the participants in the case study

A.4. Quantitative Analysis - Survey Results



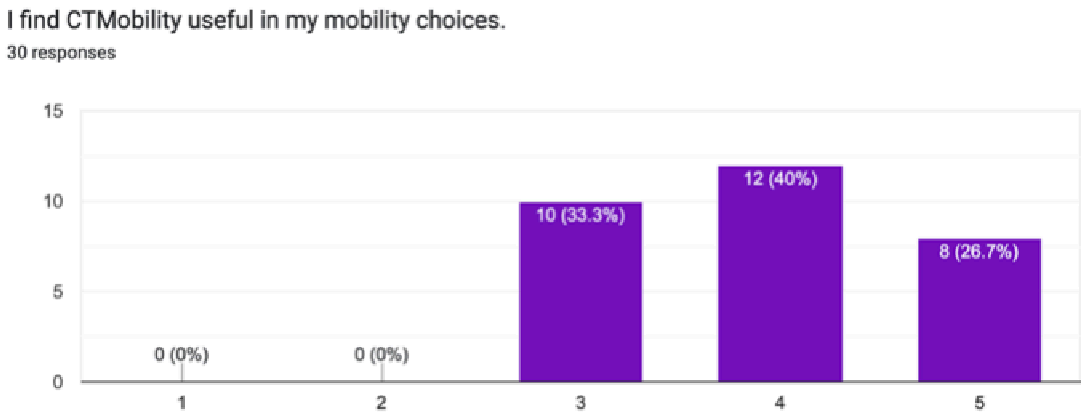
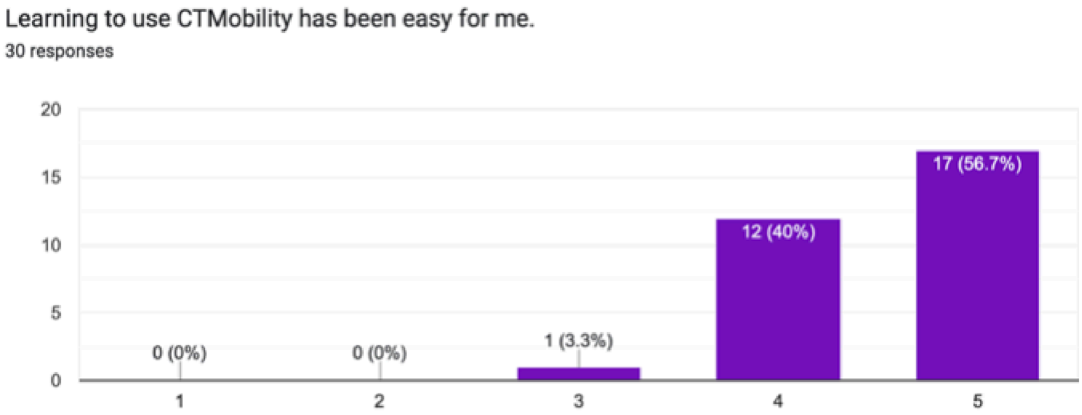


Figure A.1.: Responses received for I.1., I.2. statements



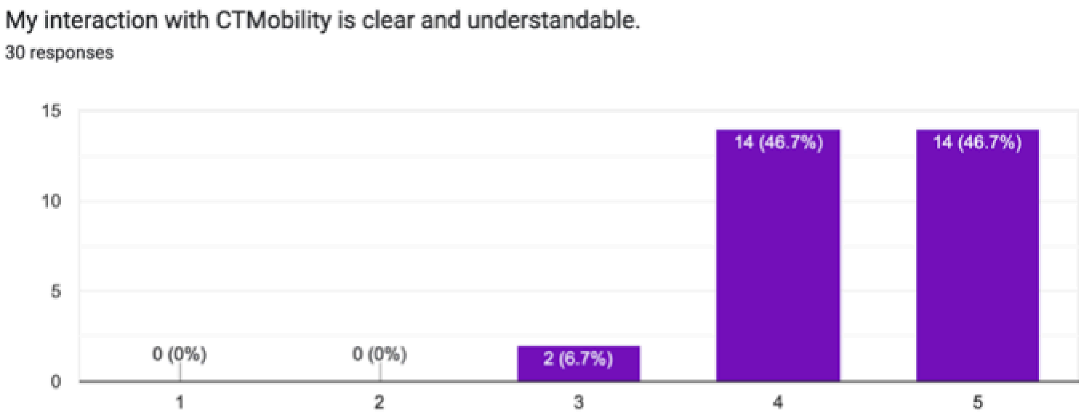


Figure A.2.: Responses received for I.3., I.4. statements

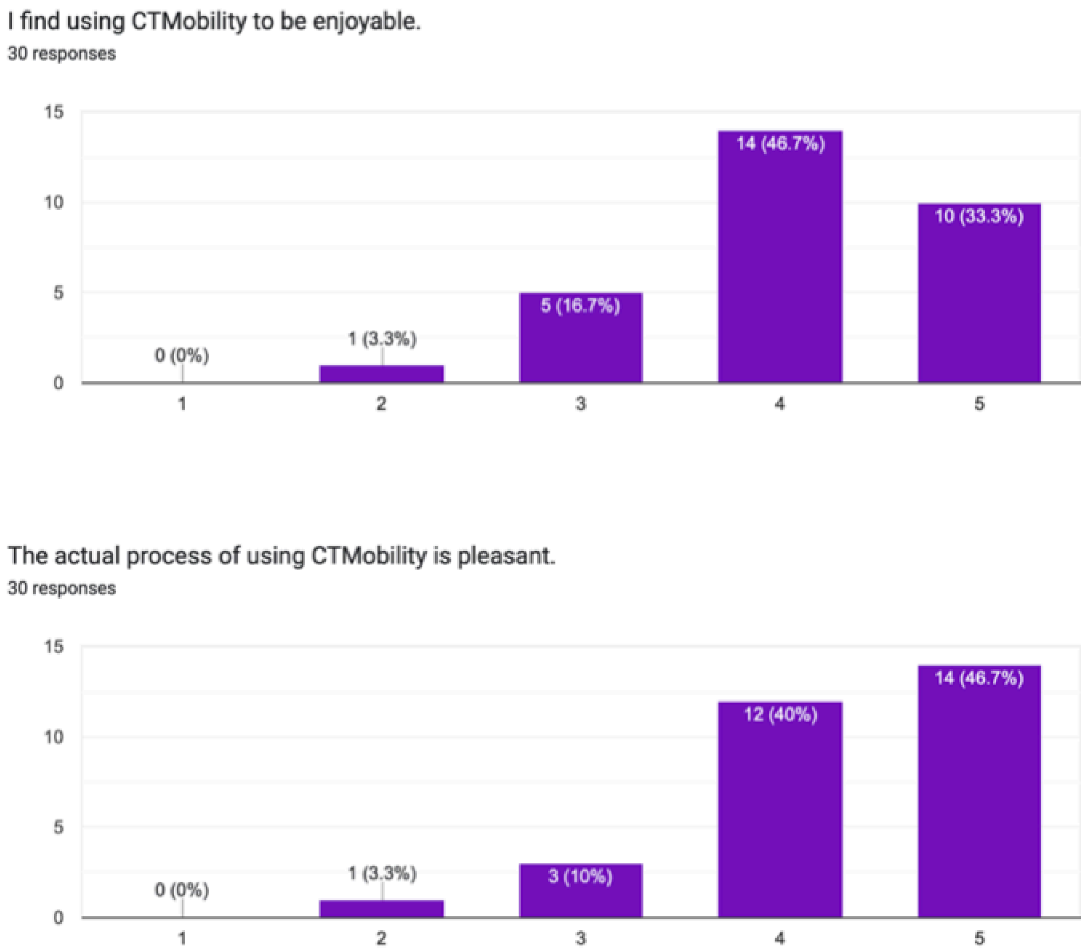


Figure A.3.: Responses received for I.5., I.6. statements

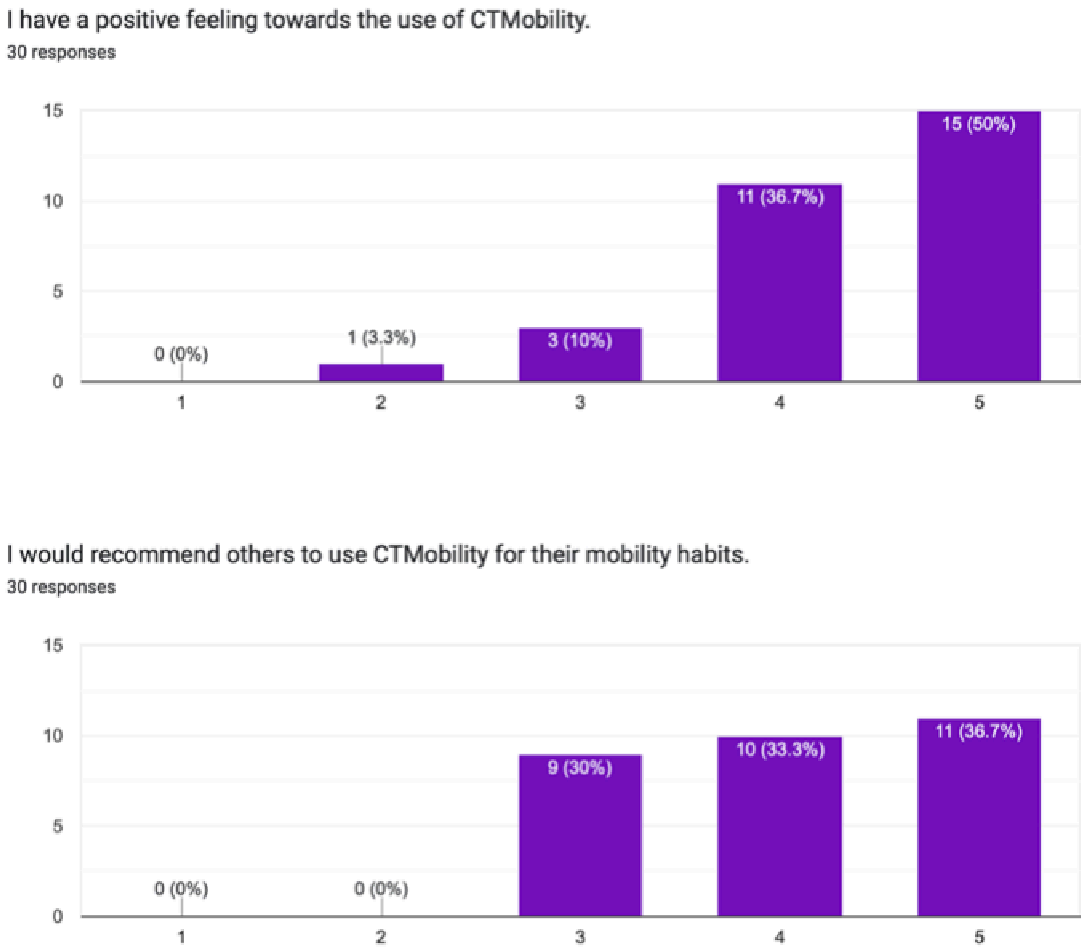
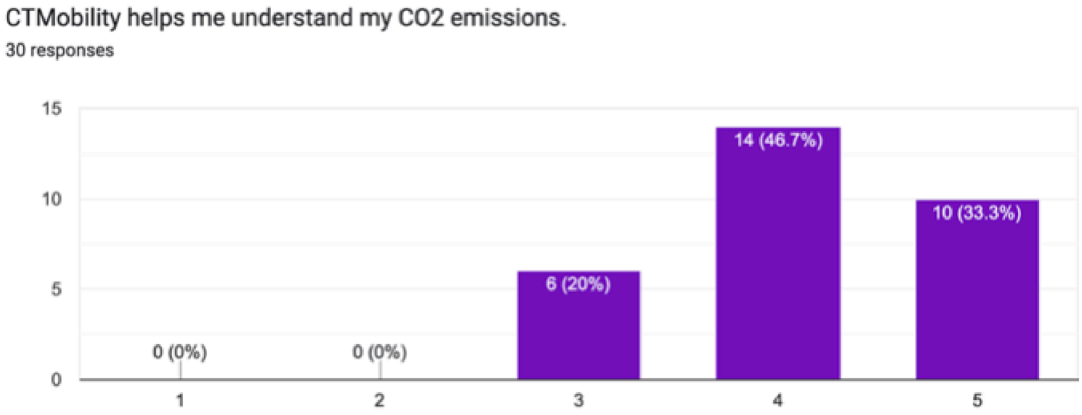


Figure A.4.: Received responses to I.7., I.8. statements



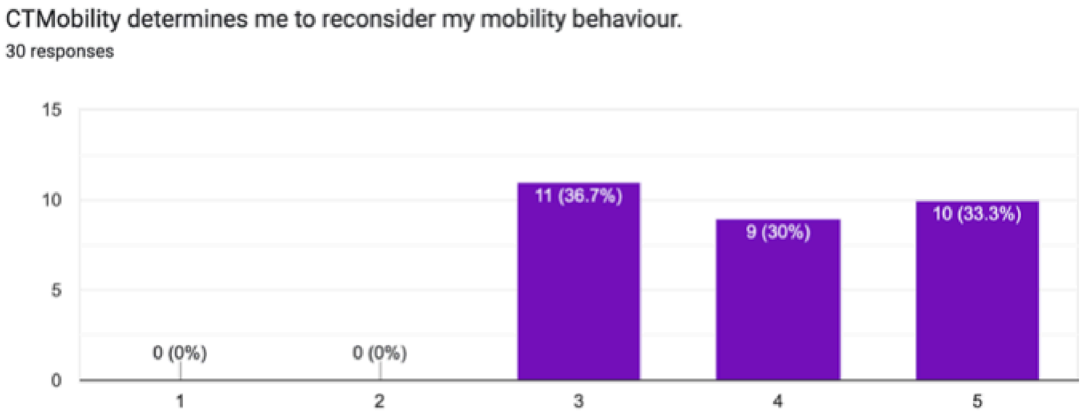


Figure A.5.: Responses received for I.9., I.10. statements

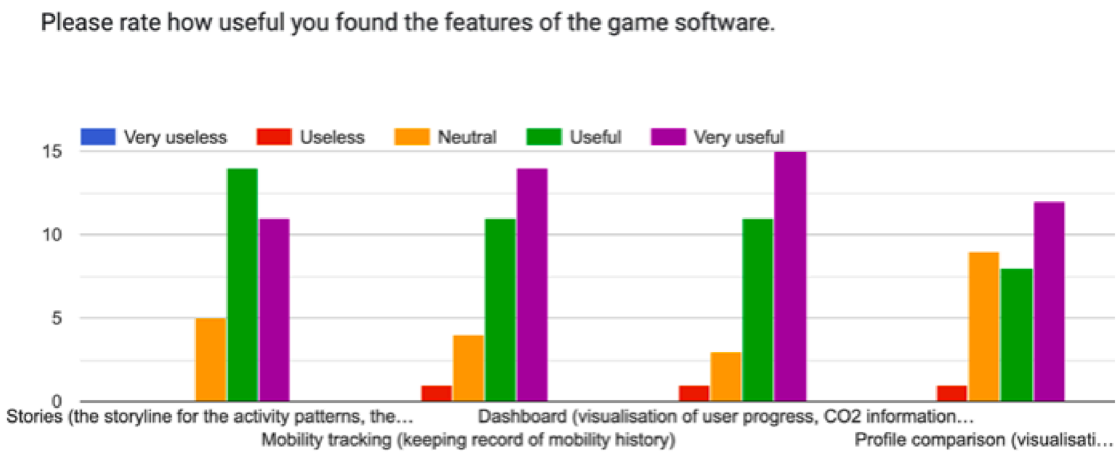


Figure A.6.: Ratings received for II.1. - II.4. statements