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INSTITUTO POLITÉCNICO
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ONMOVE

Gamified mobility as a service

Luís Alonso Pinheiro

Escola Superior de Tecnologia e Gestão

2025

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Engenharia Informática

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Professor Doutor Luís Barreto
Professor Doutor António Amaral

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RESUMO

À medida que os meios de transporte urbano enfrentam desafios para continuar a fornecer serviços eficazes, surgem novas abordagens para o transporte. Uma das abordagens para enfrentar este desafio é a utilização de serviços de mobilidade partilhada (como a partilha de bicicletas, viagens carro partilhadas, entre outros), especialmente em combinação com o transporte público tradicional, para que a utilização desta combinação de sistemas de transporte sirva como um substituto para o transporte privado. Esta adaptação, é especialmente relevante entre os utilizadores de campus académicos (tal como alunos, professores e outros trabalhadores), logo, temos como principal objetivo a criação de mecanismos e serviços que permitam e incentivem estes utilizadores a atingirem uma mobilidade mais ativa e sustentável. A gamificação tem sido uma área de desenvolvimento em expansão durante os últimos anos com a intenção de explorar novas formas de melhorar a adoção e a atividade dos utilizadores em diversas plataformas diferentes. Uma das definições mais consensuais é que a gamificação representa "a utilização de elementos de design de jogos em contextos não relacionados com jogos" [1], e é com base nesta definição que este trabalho foi desenvolvido. Este tópico ganhou atenção significativa nos últimos anos devido ao seu potencial para motivar os utilizadores numa variedade de domínios. Estes domínios abrangem desde a educação e saúde até ao marketing e os negócios. Ao integrar princípios de design de jogos como pontos, medalhas e tabelas de classificação, entre outros, a gamificação visa tornar as tarefas mais agradáveis, aumentar a motivação e encorajar comportamentos positivos. Examinamos vários frameworks diferentes, como o Octalysis, o Gameful Design Heuristics e o RECIPE, tendo em conta a taxonomia dos utilizadores e a teoria motivacional utilizada. Ao apercebermo-nos do potencial e importância destas áreas de estudo, e com o objetivo de promover meios de transporte mais sustentáveis e ativos, pretende-se desenvolver uma aplicação móvel de Mobility as a Service denominada OnMove e melhorar a eficácia e a adoção da aplicação através da utilização de diferentes técnicas de gamificação. A metodologia de investigação segue uma abordagem de Design Science Research (DSR), envolvendo ciclos iterativos de conceção, desenvolvimento e avaliação. A aplicação OnMove foi submetida a testes de usabilidade utilizando a ferramenta Attrakdiff, que confirmou a sua qualidade pragmática e atratividade, indicando uma experiência de utilizador positiva. A dissertação conclui que a gamificação, quando aplicada de forma cuidadosa, pode impulsionar mudanças

comportamentais no sentido de um transporte mais sustentável. Trabalho futuro irá centrar-se na implementação de novos elementos de gamificação identificados e na realização de estudos empíricos adicionais para medir o seu impacto no envolvimento dos utilizadores e nos padrões de mobilidade. Esta investigação contribui para o crescente corpo de conhecimento sobre MaaS e gamificação, oferecendo insights práticos para o desenvolvimento de soluções de mobilidade mais eficazes, eficientes e sustentáveis.

Fevereiro de 2025

ABSTRACT

As urban transport systems face challenges in providing adequate services, new approaches to transportation are emerging. One such approach to address this challenge is using shared mobility services (such as bike sharing, ride-sharing, among others), especially in combination with traditional public transport, so this combination of transport systems is a substitute for private vehicles. This is particularly relevant amongst academic campus users (students, teachers and other workers). It is, thus, important to create mechanisms and services that promote a more sustainable and active mobility among such users. Gamification has been an expanding area of development during the last couple of years, intending to explore new and practical ways to improve user adoption and activity on several platforms. One of the most agreed-upon definitions is that gamification represents "the use of game design elements in non-game contexts" [1], and it is based on this definition that the developments in this work were made. The topic has gained significant attention recently for its potential to motivate and engage individuals in various domains. These domains can vary from education and healthcare to marketing and business. By integrating game design principles such as points, badges, and leaderboards, gamification aims to make tasks more enjoyable, increase motivation, and encourage positive behaviours. We examined several frameworks, such as the Octalysis, the Gameful Design Heuristics and the RECIPE framework, analyzing the player taxonomy or motivational theory they utilize. The research methodology follows a Design Science Research (DSR) approach, involving iterative design, development, and evaluation cycles. Key findings suggest that gamification can significantly enhance user motivation and long-term commitment to sustainable mobility practices. The OnMove app was subjected to usability tests using the Attrakdiff tool, which confirmed its pragmatic quality and attractiveness, indicating a positive user experience.

The dissertation concludes that gamification, when applied thoughtfully, can drive behavioral change towards more sustainable transportation. Future work will focus on implementing the identified gamification elements and conducting further empirical studies to measure their impact on user engagement and mobility patterns. This research contributes to the growing body of knowledge on MaaS and gamification, offering practical insights for developing more effective and engaging mobility solutions.

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Luis Alonso Pinheiro
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Acronyms

CO_2 - Carbon Dioxide
CP - Comboios de Portugal
DP - Design Principles
GadML - Game Adaption Language
GaML - Game Model Language
GDF - Gamification Design Frameworks
GGDFs – General Gamification Design Frameworks
GHG - Green House Gases
GiML - Game Instance Model Language
GsML - Game Simulation Language
GT - Gigaton
ICT – Information and communication technology
IEA – International Energy Agency
IPP-ESS - Instituto Politécnico do Porto's Escola Superior de Saúde
KEG – Kaleidoscope of Effective Gamification
LoISa – Lens of Intrinsic Atoms
MaaS - Mobility as a Service
MDE - Mechanics, Dynamics and Emotions
METs - Metabolic Equivalent of Task
MT - Metric Ton
MVP - Minimum Valuable Product
OIT - Organismic Integration Theory
SDT - Self Determination Theory
VKT - Vehicle Kilometers Travelled
WHO – World Health Organization

1. Introduction

The International Energy Agency (IEA) has identified three main contributors to carbon emissions: electricity with 42% of total carbon emissions, transportation with 23% and industry with 19% of emissions [2]. The harmful consequences of transportation, such as pollution, traffic jams, and climate change, have emphasized the necessity for increased utilization of cleaner and more efficient transportation methods, particularly in urban areas. Propelling a behavior change has been recognized as a crucial aspect in transitioning from driving personal cars to using alternative and healthier means of transport. One approach to address this challenge is using shared mobility services (such as bike sharing and ride-sharing, among others), especially in combination with traditional public transport, so this combination of transport systems is a substitute for private vehicles. As a result of this approach and the development of new technology and ICT, a new concept arose called Mobility as a Service (MaaS). The authors at [3] state, "*This bundling of mobility modes presents a shift away from the existing ownership-based transport system toward an access-based one. It offers users a tailored hyper-convenient mobility solution, with a promising perspective to substitute private cars*." Encouraging sustainable commuting behaviors, such as walking, cycling, and using public transportation, can significantly reduce the negative environmental impact of transportation and improve users' health and well-being [4]. The development of an efficient transportation system is critical for the improvement of living standards. Therefore, it can contribute mitigating current environmental concerns, notably climate change [5], and adopting new mobility habits could contribute to increasing health conditions and ensure that citizens adopt a sustainable mobility standard.

1.1 Motivation

The use of motorized transport is one of the primary sources of Greenhouse Gas (GHG) emissions among energy-dependent sectors and is predicted to rise by 80% between 2007 and 2030 [6]. According to the IEA, "*The Global carbon dioxide (CO_2) emissions from energy combustion and industrial processes grew 0.9% or 321 Mt in 2022 to a new all-time high of 36.8 Gt*" [7], rebounding from the decrease in emissions caused

by the COVID pandemic, meaning that the need for Mobility Management (MM) is of a vital necessity.

Therefore, policies that encourage active modes of transportation, such as cycling, may, for example, increase the population's physical activity and decrease air pollution, thus reducing the burden of conditions such as cancers, diabetes, heart disease, and dementia [8]. According to the World Health Organization (WHO), a shift to active means of transportation, such as walking, cycling, and public transport, can provide greater and immediate health benefits than improving the efficiency of fuel and vehicles. Shifting from private motorized transport to walking, cycling, and rapid transit/public transport can reduce cardiovascular and respiratory diseases from air pollution, traffic injuries, and noise-related stress. Additionally, increased physical activity can provide considerable benefits, such as preventing some cancers, type 2 diabetes, heart disease, and other obesity-related risks [9].

To further motivate the users to adopt this healthier means of transportation, the concept of gamification was considered and studied. Gamification can support the transition of users' mobility habits to be more active and sustainable, supporting the adoption of a better quality of life and well-being. However, it is necessary to know the existing evidence regarding gamification in different contexts and, thus, identify the potential for applying it in sustainable mobility.

Gamification, using game design elements in non-game contexts [1], has been an expanding area of development during the last couple of years to explore new and practical ways to improve user adoption and activity on several different platforms [10]. This approach has shown promise in its potential to increase user commitment when adopting sustainable travel behavior [11]. Gamification can leverage the motivational power of games to engage users, provide feedback, and create a sense of progress towards a goal. These techniques have positively impacted several fields, including Education and Learning, where gamification among learners brings predominantly positive results [12]. Nevertheless, researchers have been studying and confirming gamification's potential in collaborative learning environments [13]. These collaborative learning environments are a simple and effective way to test, in real environments, gamification effectiveness and efficiency. Despite that, some evidence shows that dynamically adapting gamification elements produces better results than static adaptation [14]. Furthermore, narrative/storytelling is the most used motivational affordance, followed by complete and

board games. Most studies present positive outcomes regarding gamification among learners [14].

Gamification now covers a broader range of well-being domains than before. However, developers underutilize aspects like randomness, artificial challenge, and social cooperation to improve mental health and well-being [16] [17]. While 59% of studies report positive effects, 41% show mixed or neutral effects. The most substantial evidence supports gamification for behavioral outcomes, especially physical activity, with weaker evidence for cognitive impacts. Despite a novelty effect that declines over time, gamified interventions support participants' well-being [18]. Developers commonly use game elements such as points, levels, leaderboards, badges, avatars, quests, social graphs, and virtual goods [19]. Gamification can promote healthcare and healthy habits, mainly in eating and physical exercise. For success, developers must incorporate user feedback on thoughts, behaviors, and actions [20]. Physical activity is the most targeted health behavior; more theory-driven studies are needed [21].

Gamification has also been adopted in the field of sustainability, and the adoption of sustainable practices, namely in energy and water consumption approaches, can be explored to develop and improve existing interventions towards more sustainable food, transportation, and leisure activities. There is an avenue for research exploring how gamification through interactive technologies, including wearables, can be applied to advance individual sustainable consumption while aiming at making these technologies sustainable [22]. Gamification is effective in influencing users to adopt more sustainable energy consumption habits. Notwithstanding, there is a need for more quantitative and empirical research [23]. The study showed that gamification is an effective tool for engaging with diverse stakeholders and enabling learning, changes in public policy, and behavioral change [24].

Further studies are needed to design and implement gamification to maximize skill development while addressing a multi-generational workforce's diverse psychological and motivational needs [25]. The Gamification frameworks show promising results, and they positively impact knowledge management systems by fostering dynamic interaction and cooperation, motivating employees to transfer knowledge, promoting organizational learning, and increasing employee involvement and commitment. The success of

knowledge management systems depends significantly on the game's design and the dynamics and mechanics used [26]. The most utilized affordances in production and logistics operations are goals and objectives, multimedia feedback, and metaphorical/fictional representations. The affordance of shadowing previous work and visualizing a worker's past performance to help benchmark current performance has shown promising results [27].

Even though gamification is being studied in several areas, the authors in [15] found that out of the 40 reviewed mobile applications for health and climate change co-benefits, only 10 explicitly encouraged behavior change by rewarding the user for his sustainable behavior or provided clear incentives. They also found that the highest-rated mobile applications had features related to user interaction and elements of Gamification.

1.2 Objectives

Based on the previous section (1.1) regarding the motivation for this dissertation, we see that incentivizing the user is a crucial part of the solution to make the population change their travelling behaviors and motivate the adoption of greener and healthier means of transportation. The use of shared mobility services shows promising results in motivating this much-needed behavior change. Namely, by using recent Information and communication technology (ICT) developments and utilizing MaaS systems allied with Gamification techniques, we aim to propel the adoption of more sustainable and healthier means of transportation.

Recognizing the importance and potential of this field of study and promoting more sustainable and active transportation among university campus users (students, teachers, and staff), the main objective of this dissertation is to improve a MaaS mobile application called OnMove and apply gamification technics to further motivate the users. This app will enable users to combine various transport options (car-sharing, bicycles, trains, buses, walking) into a single route, allowing them to choose and integrate different mobility options for a single trip.

According to the developments planned for the OnMove application, an architecture will be defined that promotes its effectiveness and information security and allows the inclusion of different gamification elements or even different frameworks [29] [30]. At the same time, another objective is to subject the OnMove App to usability tests

to improve the user experience and, in this way, ensure that it can be used regularly. Simultaneously, a survey (created by the Escola Superior de Saude do Instituto Politécnico do Porto, which was also analyzed and validated by its ethics Commission) will be implemented to gather information on the user's health status and determine their cardiovascular risk.

1.3 Methodology

The research methodology recommended in the project involves an abductive approach, adopting multiple strategies, such as the implementation of the questionnaire, case study and design science research, in a transversal time horizon and ensuring the necessary care using data and its subsequent analysis.

The Design Science Research (DSR) methodology was the most suitable for the research project context and challenges. This methodology employs a building/evaluation loop to methodically approach the development of a solution to a problem that has already been recognized (use of private cars / motivating the users to adopt healthier means of transportation). This process involves incrementally utilizing the design, testing it, and developing artefacts. As a result, it is feasible to determine which aspects of the artefact are appropriate for implementation and which are not, allowing for artefact improvement until a desirable solution to the problem is reached [16][17].

The author [18], Ken Peffers, defined six different activities for adopting DSR:

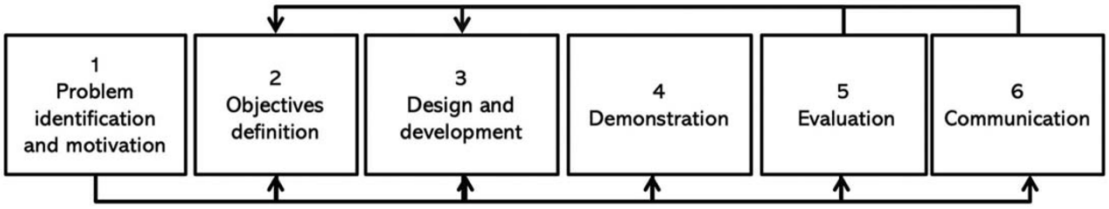

Figure 1 - Activities of DSR. Source [24].

1. Problem identification and motivation: This activity defines the research problem and justifies the search for a solution. Doing so motivates the researcher and the audience to pursue the solution and better understand the problem.
2. Objectives definition: can be quantitative or qualitative objectives but must be inferred logically from the defined problem. The resources required to define the objective properly can be knowledge of the state of the art/problem (current solutions, their efficacy, among others).
3. Design and development: The actual creation of the artefact. The researcher should determine the artefacts' desired functionalities and architecture in this stage. The produced artefacts can be constructs, models, methods, or instantiations [16].

4. Demonstration: This activity aims to demonstrate the efficacy of the previously produced artefacts regarding the solution to the problem. This demonstration can be attained via experimentation, simulation, case study, proof, or other appropriate activity.
5. Evaluation: Observe how well the artefact supports a solution. In this activity, the researcher should compare how well the developed artefact works against the defined objectives. It requires the presentation of relevant metrics and analysis techniques.
6. Communication: Share the attained results (the problem, the importance, the artefact, the utility, the efficacy) with the appropriate audiences.

The first two activities, "Problem Identification and Motivation" and "Objectives Definition", were developed with the help of a focus group consisting of 10 people (students and teachers) of different academic backgrounds, such as Health, Software Engineering, and Mechanical Engineering, among others, with the goal of defining the problem, the motivation and the objectives that would lead to incentivizing the use of more sustainable, responsible and healthier means of transportation among university users. To achieve this goal and modal change, a MaaS application was developed, which led to a prototype of the OnMove App. Activity 3 of DSR, Design and Development, involves idealising the gamified approach for the MaaS application. Activity 4 is the creation of storyboards and high-fidelity mockups of the newer version of the application. The fifth activity assesses how well the proposed artefacts solve our problem, employing a usability test utilizing the tool Attrakdiff [19]. The final DSR activity aims to share our findings with the scientific community to contribute to our research topic and utilize the feedback to improve subsequent iterations.

1.4 Dissertation Outline

The outline for this dissertation is as follows:

- Chapter 1 – Introduction. It outlines the motivation for developing this dissertation, the objectives, and the methodology used in the elaboration.
- Chapter 2 – Theoretical Background. This chapter analyses the literature about Mobility as a Service, Gamification, Motivational Theories, Player Taxonomy and Gamification Frameworks.

- Chapter 3 – OnMove app. It features the mockups relative to the gamification elements and their respective usability evaluation, as well as all the application features and the backend tests.
- Chapter 4 – Results and Discussion. Summary of the elaborated work, consisting of a summary of the dissertation and the possible future work.
- Chapter 5 – Conclusions and Further Developments

2. Theoretical Background

The current chapter provides a base of knowledge about the areas of interest of this dissertation. The concept of MaaS (section 2.1) will be explored, and its state of the art will be analyzed (subsection 2.1.1) along with some examples of its integration challenges and desired outcomes (subsection 2.1.2). The concept of gamification (section 2.2) will also be explored, including introducing motivational theories, player taxonomy, gamification frameworks, and gamification use cases.

2.1 Mobility as a Service (MaaS)

Mobility-as-a-Service (MaaS) combines different transportation modes, essential information, and purchasing into a unified user experience. Integrating mobility with the "as-a-Service" model revolutionizes the transport sector through sophisticated data processing. Introduced by Heikkilä in 2014 [20], MaaS is described by the MaaS Lab as a user-focused, intelligent mobility management system. This system unites various mobility service providers, offering users a digital platform to plan and pay for their trips. MaaS addresses current customer demands and anticipates future mobility challenges, promoting a more inclusive, efficient, and sustainable society [21].

2.1.1 MaaS: Bibliometric Analysis

A search with the keyword "*Mobility as a Service*" was executed on Scopus, providing a dataset that contained 1004 documents. The first filters applied to the dataset were English language, document type, article, book, book chapter, and conference paper. This step removed 84 documents, leaving the dataset with 920 papers. The resulting dataset was inserted in the Bibliometrix [22] R library, allowing to visualize the MaaS publications information more intuitively. The following section (2.1.1) provides an overview of the state of the art of MaaS, starting with a bibliometric analysis.

In Figure 2, a general overview of the theme can be obtained.

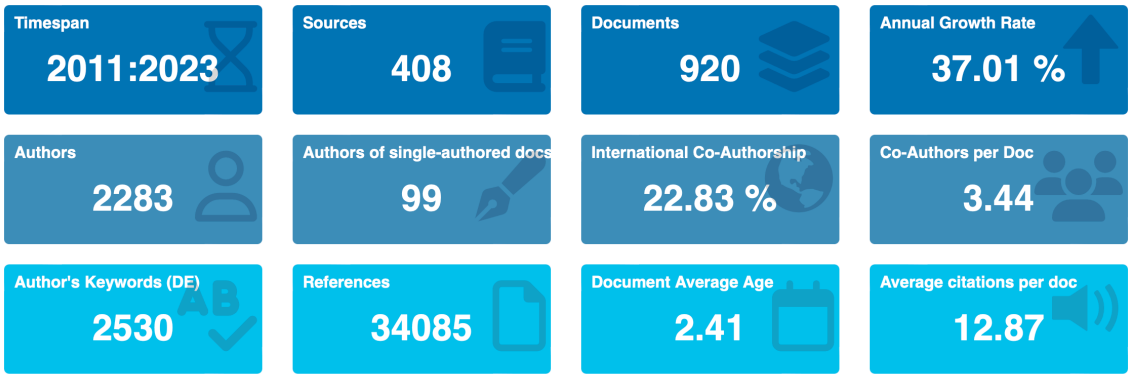

Figure 2 - MaaS – Overview. Source[22]

Analyzing this data (Figure 2), it is clear that the concept of MaaS is growing rapidly (37.01% annual growth) and in a very short period (average document age is 2.41 years), even though the very first appearance of the keyword "Mobility as a Service" is in 2011. As seen in Figure 3, mobility as a service has been a growing development area since it emerged.

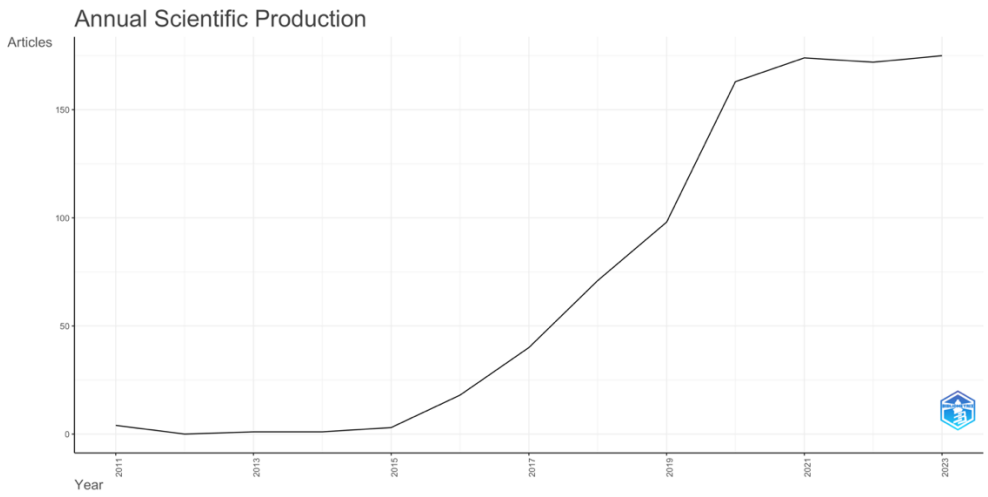

Figure 3 - MaaS - Annual Scientific Production

The top 5 sources with more MaaS publications are available in Table 1. Four of these journals are classified as Q1/Q2, and Transportation Research Procedia is where conference papers in the field are published.

Table 1 - MaaS - Most Relevant Sources

Source	Number of Documents
Transportation Research Part A: Policy and Practice	48
Sustainability (Switzerland)	40
Research in Transportation Business and Management	22
Research in Transportation Economics	20
Transportation Research Procedia	19

At the time of this research, Table 2 lists the most relevant authors.

Table 2 - MaaS - Most Relevant Authors

Author	Number of Publications
Hensher D.A.	24
Mulley C.	16
Smith G.	13
Kamargianni M.	12
Sochor J.	12

The most common affiliations related to the publication of MaaS documents are available in Table 3. In which it is possible to identify important contributions from institutions in northern Europe and Australia, as well as other sources of entities related to the transport context and the role of its different stakeholders.

Table 3 - MaaS - Most Relevant Affiliations

Affiliation	Number of Documents
University of Sydney Business School	51
Chalmers University of Technology	39
National Renewable Energy Laboratory	37
Eindhoven University of Technology	35
Not reported*	34

The most relevant keywords (over 50 occurrences) when publishing about MaaS are (Table 4):

Table 4 - MaaS - Most Relevant Keywords

Keyword	Occurrences
Public Transport	144
Mobility	110
Transportation System	65
Sustainable Development	61
Mobility as a Service	58
Mobility Service	55
Urban Transportation	55

Mobility as a Service (MaaS) is a service that is provided to the user on a mobile app platform, which integrates all the aspects of the travel experience (booking, payment and live information about the trip), many times combining different means of transportation,

such as trains, buses and car-sharing [23]. This emerging concept is considered one of the solutions to address the global trend of urbanization and its environmental impact.

This is due to two emerging trends [24]**:**

- People's attitudes and values continue to shift towards greater environmental consciousness. As joint/shared ownership or ownership-free models (car or bike sharing, for example) become more prevalent, new opportunities arise for developing innovative travel offers or services.

- Progress and widespread adoption of mobile Information and Communication Technology (ICT) have enabled the development and experimentation of novel offers. This is due to the technological advancements in the field of ICT and the proliferation of mobile ICT.

Several different studies have already made efforts to define MaaS, providing a comprehensive list of definitions [3], [25], [26], [27], along with [28], [29], [30], [31], [32], [33] that allows us to differentiate the following MaaS features:

- Multi-Modal Transport Offering, Intermodal Journeys, Payment Options, Digital Platform Access, Service Bundle, Decision-Making Support, and Multiple StakeHolders.

It is also possible to differentiate the stakeholders included in MaaS: **The Provider:** Cooperates with all sides (stakeholders), providing the service for the costumers. The **Transport Services Providers:** sell seats, rent vehicles, and provide transport information. The **Technology and Services Providers:** offer technical solutions. The **Authorities:** Regulate the activity and create policies. The **Customers:** Use the MaaS product [28].

In [28], the authors [28] identified **11 implications/thematic areas** of shifting to a MaaS transport paradigm (See Table 5):

- Market Visibility, Centralized Data Gathering, Vehicle Utilization, Accessibility, Transport Affordability, Digital Access, Modal Shift, Market Shares, Environment, Health and Wellbeing, and Financial Support.

Table 5 - MaaS - Opportunities/Challenges. Source [28]

Category	**MaaS Opportunities/Strengths**	**MaaS Challenges/Weaknesses**
Market Visibility	- Exposure to a broader customer range for transport service providers - Shift of the general public's view of public transport being an isolated service to it being part of an innovative transport ecosystem - Possible partnerships with more prominent players for shared-use mobility providers	- Less recognition for transport service providers' brands - A partial or even complete loss of authority for public transport providers
Centralized Data Gathering	- Better understanding of service, more effective management of transport user needs and evidence-based allocation of existing transportation resources for transport service providers - For public authorities, visibility over their localities to make more demand-centric policy decisions	- Private transport operators rarely open their data to third-party organizations - Requires many trust-building exercises and guaranteed fair marketplaces for all the MaaS stakeholders to be willing to share data and cooperate rather than compete
Vehicle Utilization	- Substitution of underutilized public transport vehicles by shared-use mobility services in rural areas for better utilization of resources	- Public resistance to substitution as new services may not live up to the convenience and cost-effectiveness of a fixed public transport service - View of public transport as a symbol of guaranteed accessibility for rural areas
Accessibility	- In cities, shared-use mobility options could top-up conventional public transport during peak hours - Shared use mobility to be used as feeders to public transport, improving accessibility in areas with infrequent public transport schedules or limited infrastructure	- Generally, it is only in urban, densely populated areas with low car ownership rates that sharing schemes have a chance to succeed
Transport Affordability	- Negotiation power of MaaS Operator to obtain lower prices for services due to having access to customers of all transportation services	- A shift to a MaaS paradigm creates a monopoly that may lead to a shortage of transportation alternatives and rising transport prices, consequently

Digital Access	- Ease of access to a multitude of transport options via a single digital interface	- Transport users of lower digital literacy or no previous exposure to mobile technology could be left out when shifting to a MaaS-centric paradigm
Modal Shift	- Potential to reduce dependency on private cars due to the convenience of fully integrated mobility offering	- Transport users are still likely to remain attached to their cars for reasons other than convenience - Public transport users may shift to car-based shared-use mobility options
Market Shares	- The attractiveness of MaaS to private car users leads to increased market shares, higher revenues, and profits for transport service providers - Pressure off government subsidies and increased cost-effectiveness of public spending	- If no desired modal shift occurs and/or car-based shared use mobility is emphasized via MaaS platforms, the public transport market share is likely to be cannibalized
Environment	- Reduction of congestion levels due to shift away from private cars and onto public transport and multimodal travel - Lower emissions and pollution	- If public transport users shift to car-based shared use mobility, then the likely outcomes of MaaS are adverse for the environment
Health and Wellbeing	- Awareness and encouragement of walking and cycling	- Replacing active modes that promote health and wellbeing with car-based shared mobility could happen
Financial Support	- Low to no investment needed to initiate MaaS	- For MaaS that genuinely meet societal goals, continuous financial support in the form of subsidies for prioritizing more sustainable transport modes is necessary

Each of the mentioned categories is, at the same time, an opportunity and a challenge; each of them can impact the outcome of the adoption of a Mobility as a Service Infrastructure.

2.1.2 MaaS Overview: Implementation Challenges and Desired Outcomes

A high-relevance document in this area, from Hensher, D.A [34], in which the author presents several possible offers that Bus services may provide in the future, identifying several obstacles to overcome, for example, the fullscale adoption of MaaS for conventional public transport, the sharing of vehicles outside of company plans but it also foresees some possible positive outcomes when applying MaaS to the bus services, such as reducing traffic congestion.

Another document that stands out is [35], where the authors presented three development scenarios about how MaaS can be provided and analyzed and possible implications for public transport for each. The main takeaway of this research is that for MaaS to be successfully implemented in a viable and sustainable way in a community, there is a need to find the regulatory "*sweet spot*" with appropriate regulations and incentives.

The authors of [36] present a question regarding the challenges raised by MaaS for urban governance. The authors analyze several MaaS societal implications and potential unanticipated implications of current MaaS conceptualizations (Health, Environment and Social Inclusion). In [36], the concept of utilizing MaaS as a more sustainable and healthier alternative to regular public transport is also questioned, and the authors conclude that "whilst MaaS could be designed to influence behaviors to be more sustainable, this must be designed in from the start, particularly as the bundling process will obscure the true costs of individual journeys".

The article [37] provides a systematic literature review on the MaaS area of application. The authors find several barriers to implementing MaaS (see Figure 4) and some actions that must be executed to implement it successfully. According to the authors: "The conceptual framework shows that the risks associated with MaaS in cities depend on the barriers encountered during the implementation process. Overcoming these risks and achieving the desired outcomes (reduced Vehicle Kilometers Travelled (VKT), parking, ownership, and social equity) is dependent on addressing both the supply and demand side barriers identified".

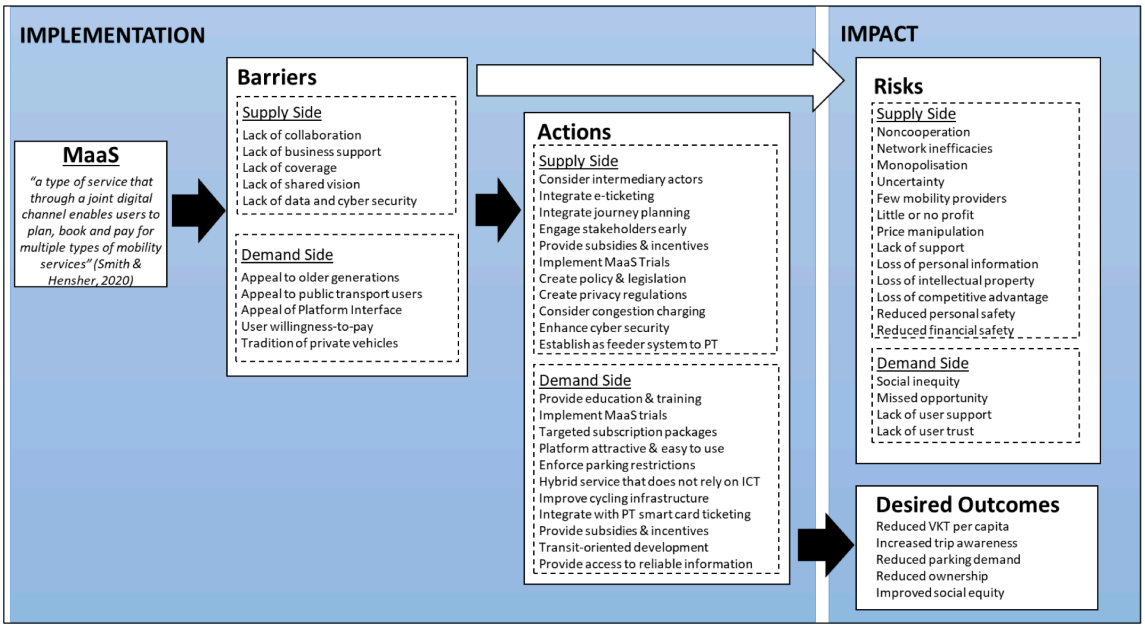

Figure 4 - MaaS implementation - Source[37]

2.2 Gamification

As discussed in Chapter 1, the users must be motivated to propel modal habit change. Gamification is an effective way to give users the extra motivation they need to adopt more sustainable and healthier means of transportation. One of the most agreed-upon definitions is that gamification represents "*the use of game design elements in non-game contexts*" [38]. By utilizing this expanding area of development, and as in the last couple of years it has been used to explore new and practical ways to improve user adoption and activity on several different platforms [10], this work aims to apply this concept to the developed OnMove mobile application to influence users adoption and longevity on the platform.

To properly develop gamified applications and overcome some of the limitations referenced in subsection 2.1.2 of this chapter, it is necessary to understand how different users are motivated towards a goal and how many types of users there are. In subsections 2.2.1 and 2.2.2, it will discussed different Motivational Theories and Player Taxonomies that are well present in the Gamification Literature.

It is also important to understand how an adequately developed gamified application comes to be. In subsection 2.2.3, it is presented the available literature about the type of Frameworks utilized for its proper development.

In the last subsection (subsection 2.2.4), we analyze the findings of the previous subsection by comparing the different frameworks and cross-referencing them with the motivational theories and player taxonomy used. The gamification frameworks utilized during the development of this dissertation are the result of this analysis.

2.2.1 Motivational Theories

A well-known psychological theoretical framework called Self-Determination Theory (SDT) has been applied in various fields, including the social sciences, medicine, and education. According to SDT, for people to function at their highest level and feel the happiest, they must meet their basic psychological needs of autonomy, competence, and relatedness. That is why, per [52], internal and external factors influence human behaviour. Understanding SDT in game design can assist creators in producing more interesting and inspiring games that support these fundamental psychological demands, ultimately resulting in a more rewarding player experience.

The application of SDT in game design has gained significant attention in recent years, with several studies highlighting the importance of autonomy, competence, and relatedness in player motivation and engagement [39]. Game designers can utilize SDT to create games that provide players with choices and control (autonomy), challenges that grow with their skills (competence), and opportunities for social interaction and collaboration (relatedness).

SDT is composed of 5 key mini-theories[40]: (1) Cognitive Evaluation Theory, (2) Organismic Integration Theory, (3) Causality Orientations Theory, (4) Basic Psychological Needs Theory, (5) Goal Contents Theory.

Cognitive Evaluation Theory: People can be intrinsically motivated to complete tasks and sometimes feel that the task is inherently enjoyable or challenging.

Organismic Integration Theory: Extrinsic Motivation (motivation to complete a task to achieve some tangible reward) does not always compromise persistence or well-being. Through repetition of a task, people can begin to internalize it and the task can be integrated into the people's values and tendencies.

Causality Orientations Theory: Focuses on the individual differences between incentives. Different subjects can feel motivated by different tasks/goals. Some people can feel motivated by autonomous tasks and completely demotivate others.

Psychological Needs Theory: Identifies three key basic psychological needs that a person must strive to fulfil: Autonomy, Relatedness and Competence. Fulfilling these three needs promotes the motivation and well-being of the individual.

Goal Contents Theory: Differentiates goals that typically foster extrinsic motivation from the ones that foster extrinsic motivation. Goals relating to financial gain, appearance, or popularity diminish persistence and undermine fundamental needs. On the other hand, goals that relate to community, personal growth and relationships tend to promote the user's well-being.

The application of SDT in game design has gained significant attention in recent years, with several studies highlighting the importance of autonomy, competence, and relatedness in player motivation and engagement [39]. Game designers can utilize SDT to create games that provide players with choices and control (autonomy), challenges that

grow with their skills (competence), and opportunities for social interaction and collaboration (relatedness).

Game element	Definition	Autonomy	Competence	Relatedness
Achievements	Completing goals.		x	
Avatars	Visual of a player's character.	x	x	x
Badges	Visual of achievements.		x	
Boss Fights	Special challenges at the end of a level.		x	
Collections	Sets of accumulated items or badges.		x	x
Combat	Defined challenge.		x	
Content Unblocking	Privilege for players.		x	x
Gifting	Sharing resources with others.	x		x
Leaderboards	Visual displays of social comparison.		x	x
Levels	The player's progressive.	x	x	x
Points	The virtual rewards against the player effort.		x	
Quests	Predefined challenges.	x	x	x
Social Graph	Representation of players' social network.		x	x
Teams	Group of players for a common goal.			x
Virtual Goods	Game assets.	x	x	x

Figure 5 - Game Elements in relation with SDT. Source [41]

Figure 5. illustrates how Autonomy, Competence and Relatedness are achieved by utilizing game elements.

Flow Theory [56] defines flow as a state that occurs when a person engages in challenging but not too tricky activities. This is achieved by finding the balance between challenge and skill. When applying the theory to gamification, the developers must ensure that the player's skill level is in balance with the game mechanics they will apply. If the game mechanic presents too big of a challenge to the user, they may become frustrated over time and eventually reduce the use of the gamified application. On the other hand, if the challenge is too easy, the player will not feel stimulated enough, causing him to feel bored and disengaged. Another key principle of Flow Theory is the feedback aspect of the game mechanics. Feedback should be evident and direct to help the users stay focused on their goals and in a state of flow. Immersion is another key aspect of this theory and is relevant to gamification design. When developing the gamified application, the designers must design the game mechanics to let users feel immersed and compelled in their actions. This can be achieved by applying game elements such as storylines, social interaction, and visual and auditory cues.

2.2.2 Player Taxonomy

When developing and using a General Gamification Design Framework for a myriad of different users and players, the taxonomy of said users is an important consideration. By considering the users' attributes, the developer can design the

gamification elements to better relate to each user, increasing the chances of user motivation, involvement, and adoption of the gamified systems. When researching the Gamification Design Frameworks, two different types of player taxonomy were observed to be used: (1) Bartles Taxonomy [42] and (2) HEXAD Taxonomy[43].

Bartle's Taxonomy [42], differentiates four different player types, each with its preferences. These four different player types are: (1) Achievers, (2) Socializers, (3) Explorers and (4) Killers.

- **Achievers:** The achiever player type prefers to gain points, levels, achievements, and other concrete development measures.
- **Socializers:** The socializer player type is someone who prefers the social aspect of the application. Typically, this player type is very motivated by the interaction with other players. Typical gamification mechanics relevant to socializers include chats, cooperation tasks, and social media integration.
- **Explorers:** The explorer player type enjoys exploring an application's different possibilities. They are motivated when discovering new things or uncovering easter eggs (small hidden bonuses inside a game/application), as discovery is the "prize" for this player type.
- **Killers:** According to Bartle, it is the most uncommon player type, as only 1% of players fall in this category. Similarly to achievers, they enjoy earning points and levels. However, the killer player type wants the other players to lose. This player type is highly competitive, and victory is the prime motivator.

Based on the Bartle Taxonomy, the authors [43] proposed a new taxonomy consisting of six different types of players that differ according to the type of motivation that relates to them (Intrinsic or Extrinsic Motivation) as defined by SDT. The HEXAD model [29] is also based on the three types of intrinsic motivation described in SDT: Relatedness, Competence and Autonomy, but with the added type of Purpose. The player types are the following: (1) Socializers, (2) Free Spirits, (3) Philanthropists, (4) Achievers, (5) Players and (6) Disruptors. For example, the gamification user types hexad scale by [43] maps the different player types with the game elements that apply to each.

- **Socializers:** Motivated by relatedness. This player type focuses on the interaction between users. The game design elements related to them are teams, social comparison/competition, and social connection.
- **Free Spirits:** Motivated by autonomy. They relate to game elements such as discovery missions, easter eggs and freedom of exploration.

- **Philanthropists:** Motivated by Purpose, typically altruistic. The game design elements that apply to Philanthropistss are collection and trading, gifting, knowledge sharing, and administrative roles.
- **Achievers:** Motivated by competence. This player type wants to be rewarded for their progress. The game elements that apply are, for example, challenges, levels, and certificates.
- **Players:** Motivated by extrinsic rewards. This player type feels highly motivated to earn prizes/rewards. The recommended game elements are, among others, points, rewards, badges or achievements.
- **Disruptors:** Motivated by change. This player type enjoys disrupting the system/application. The suggested design elements to apply to this player type are, for example, innovation forums, development tools and anonymity.

2.2.3 Gamification Frameworks

With the expansion of the field of gamification, several different gamification frameworks have been developed to aid developers in applying gamification features to their applications, each with its own set of unique design principles and components. We analyzed and compared several different GDF intending to aid gamification developers and researchers in choosing correctly, within the different available frameworks, which one better suits their purpose. A summary of each GDF is provided, and lastly, we differentiate key attributes of each: Advantages, Disadvantages, Focus, Applicability, Motivational Theory, Player Taxonomy and Empirical Validation.

The following frameworks were compared:

- Octalysis [44]; KEG - Kaleidoscope of Effective Gamification [45]; LoISA - Lens of Intrinsic Skill Atoms [46]; RECIPE [47]; Gameful Design Heuristics [48]; A Design Framework for Adaptive Gamification Applications [49]; The MDE Framework [50]; GDF - A Gamification Design Framework Powered by Model-Driven Engineering [51]; A framework for the agile design of personalized gamification services [52]; How to design gamification? A method for engineering gamified software [53].

The Octalysis framework [58] was created in 2015 by Yu-kay Chou, who had previously published books and created its website [54]. This framework is designed as an Octagon, with each one of its sides representing 1 of the 8 Core Drives. These Drives are Epic Meaning, Empowerment, Social Influence, Unpredictability, Avoidance, Scarcity, Ownership and Accomplishment. Each Driver has different types of game techniques associated with it.

For example, Status Points, Badges, and leaderboards are associated with the Core Driver of Accomplishment. The 8 Drivers are divided into two parts: the left-brain drivers (related to Extrinsic Motivations) and the right-brain ones (related to Intrinsic Motivations).

The Framework is also divided between White Hat Gamification (Drivers at the top of the Octagon) and Black Hat Gamification (Drivers at the bottom). According to Chou, "*If something is engaging because it lets you express your creativity, makes you feel successful through skill mastery, and gives you a higher sense of meaning, it makes users feel very good and powerful. On the other hand, if you are always doing something because you don't know what will happen next, you are constantly in fear of losing something, or because there are things you can't have, even though you would still be extremely motivated to take the actions, it can often leave a bad taste in your mouth*.".

To access the Octalysis application, the framework user must calculate the Octalysis Score (**Phase 1**). To do so, we need to classify each of the Drivers on a scale of 1 to 10 based on personal judgment, data, and experience flows and proceed to calculate the square of the number to get the Core Drive Score. Once all 8 Drivers are calculated, the Driver Scores are added to get the final Octalysis Score. Chow also developed extra phases to the Octalysis Framework. **Phase 2** consists of adding four new phases representing the four stages of the player's journey: Discovery - What makes the users utilize the platform?; Onboarding - How the user learns the rules and tools. Scaffolding - Normal utilization of the platform, and Endgame - How to keep the users active.

Phase 3 adds a third dimension to the Octalysis Framework, Bartle's Player Types (Achievers, Explorers, Socializers and Killers) [29]. This third phase provides the application developer with a view of how each driver influences each player type in the four stages.

The authors of KEG – Kaleidoscope of Effective Gamification [45], based on the works of [39], [55], [56], [57] and with the addition of a new concept called the Perceived Layer of Fun, developed the Kaleidoscope of Effective Gamification. This Framework is divided into 5 Layers.

Beginning in the model's center, the Effective Gamification Core establishes "*the nucleus of player experience, which is the cohesion from all model layers. It represents core objectives of a design enabling effective gamification*".

The second layer is the Motivated Behavior Layer, where the developers must identify users' needs based on intrinsic and extrinsic motivations. The influencers of intrinsic motivations on this layer are autonomy, competence, and relatedness, and extrinsic motivations include badges, points, leaderboards, incentives, and rewards.

The next layer of the model is the Game Experience Layer, which represents the development and creation of the gameplay experience. The developer designs and integrates the application's actions, challenges, and achievements in this layer.

The Game Design Process Layer is next. The developer applies the Game Design Elements such as Interface, Mechanics, Models and Principles. Here, we identify goals within each subsystem to create a fun experience for the user while stimulating motivation.

The last layer is the Perceived Layer of Fun, which is "*what a player can see and aesthetically experience in terms of audio, visuals, interface design, tangible interactions and intangible experiences*". The authors also explain that this layer represents "excitable attributes, elements of surprise characteristics, fun in accomplishing milestones and the use of exciting hypermedia effects". Utilizing this layer makes the users more motivated to utilize the system, making the application of gamification effective.

The LoISA - Lens of Intrinsic Skill Atoms framework [46] proposed in this article is a comprehensive approach to gameful design that consists of 4 different and important steps:

- Identifying relevant intrinsic skill atoms: The first step in applying the framework is identifying the specific intrinsic skill atoms most relevant to the design goal. Intrinsic skill atoms are the components of games that inherently motivate players, such as challenges, rewards, feedback, and social interaction.
- Mapping atoms to design goals: Once the relevant intrinsic skill atoms have been identified, the next step is to map them onto the specific design goals for the game experience. This involves considering how each intrinsic skill atom can be used to support the overall purpose and goals of the design.
- Create game mechanics: After mapping the intrinsic skill atoms to the design goals, the next step is to use these atoms to create specific game mechanics such as points, levels, badges, and quests. These mechanics are designed to leverage players' intrinsic motivation and create engaging and rewarding experiences.
- Test and iterate: once the game mechanics are developed, the next step is to test them with users and revise the design based on feedback and data. This involves continuously refining and improving the game experience to optimize engagement and motivation.

Overall, the Lens of Intrinsic Skill Atoms framework provides a structured approach to gameful design that draws on established theories of motivation and engagement. By breaking games down into their parts and leveraging players' intrinsic motivation, the method aims to create more engaging and satisfying gameful experiences.

This framework presented by Nicholson, RECIPE [47] is based on six key concepts:

- Reflection - helping participants explore other interests and past experiences that can deepen engagement and learning.
- Engagement - encouraging participants to discover and learn from others interested in the real world.
- Choice - developing systems that put power in the hands of participants.
- Information - using game design and game presentation concepts to allow participants to learn more about the real-world context.
- Play - allowing freedom to explore and fail within boundaries.
- Exposure - creating stories for participants that are integrated into the real-world environment, allowing them to create their own.

After considering these key points, the developers can focus on which part of the RECIPE to focus on to develop a valuable system:

- What are the key game elements in the gamification system?
- How can Exposition help players connect game activities to the real world?
- How are players offered a choice of activities?
- In what ways can players be provided with information about their actions?
- How can players engage with each other?
- How can players reflect on their actions?

The Gameful Design Heuristics [48] are a set of 28 Game Design Heuristics designed to evaluate and identify design gaps in any gameful software. The heuristics are divided into three categories (1- intrinsic motivation, 2- extrinsic motivation, 3- context-dependent motivation):

- **Intrinsic motivation** is related to the three intrinsic needs introduced by SDT [57], [58] (competence, autonomy, and relatedness), as well as 'purpose" and 'meaning' as facilitators of internalization [58], [59] and 'immersion' as proposed by [60], [61] and Malone [62]
- **Extrinsic motivation** is related to affordances that provide an outcome or value separate from the activity, as SDT [70] and Chou [67] proposed: ownership and rewards, scarcity, and loss avoidance.
- **Context-dependent motivation** includes feedback, unpredictability, and disruption affordances, which can provide intrinsic or extrinsic motivation depending on contextual factors. For example, the application can provide feedback to the user on intrinsically or extrinsically motivated tasks.

Therefore, feedback can provide intrinsic or extrinsic motivation depending on the nature of the task with which it is associated.

A Design Framework for Adaptive Gamification Applications [49] propose a framework for designing adaptive gamification applications that can be adapted to the individual user needs and preferences. The framework involves four design principles: (1) Purpose of Adaptivity, (2) Adaptivity Criteria, (3) Adaptive Interventions, and (4) Adaptive Game Mechanics and Dynamics.

- The **purpose of adaptivity** focuses on four principles: Changing the state of the user, supporting participation, supporting learning, and creating meaning between an end user and activity.
- **Adaptivity Criteria** involve collecting information about the user's preferences, skills, and behavior. It focuses on seven principles: Player Type/Personality Type, Context, Level of Knowledge, usage data, Defined Goals by end-user, User, and Reputation/Status.
- **Adaptive Game Mechanics and Dynamics** lists the adaptive gamification elements, focusing on Feedback, Level Difficulty, Points and Competition/Customized Challenges.
- **Adaptive Interventions** refer to gamification elements that show the results of the adaptation process as an intervention in the front-end layer focusing on Showing Recommendations/Suggestions, Personalized Content, Adaptive Navigation/Path and Adaptive user interface.

The Mechanics Dynamics and Emotions (MDE) Framework developed by [50] is a gamification framework adapted from the game design literature [63]. The framework divides the users into four categories: **players, designers, spectators, and observers.**

- **Players:** are those who participate in the gamified experience. They are the real players, actively participating and profoundly engaging with the experience. Players can include potential, new or existing employees and/or customers of a company.
- **Designers are the decision-makers in organizations developing, designing, and often managing and maintaining** the gamification experience. For example, these designers might be human resource managers in improving employee engagement. Designers are very active in the design of the experience, but once the experience begins, they are predominantly passively involved, monitoring the experience and ensuring that it meets organizational goals.

- **Spectators:** are the people who do not directly participate in the gamified experience but whose presence affects the functioning of the gamified experience. Spectators are part of the gamified environment (e.g., audience members) and are, therefore, highly involved in the experience.
- **Observers:** These are outsiders who passively participate in and absorb the experience. They have no direct influence on the gamified experience and can only observe it from the outside. However, the presence and the number of observers impacted the experience's popularity.

The Mechanics are the decisions that designers who wish to gamify a non-game context make to determine the goals, rules, setting, context, types of interactions (i.e., opponents), and boundaries of the situation to be gamified.

There are **three** types of mechanics: setup, rule, and progression**.** Gamification mechanics are the fundamental aspects of the gamified experience: they determine who the leading players are, how they interact, how one wins or loses, and where and when the experience takes place. The mechanics form the structure in which the gamified experience exists. However, mechanics alone are not enough to create an experience that leads to behavior change in target employees or customers. From this structure, both **Dynamics and Emotions** animate the experience and are the key to the desired behavior change.

- The dynamics of gamification is the type of player behavior that results from participation in the experience, unlike mechanisms that the designer sets, gamification dynamics are created by how players follow the mechanisms chosen by the designers.
- Gamification emotions are the mental, affective states and reactions evoked in individual players when they participate in a gamified experience. Emotions result from how players follow the mechanisms of the dynamics.

A Gamification Design Framework using Model-Driven Engineering [64][64] that comprises three different layers, namely:

- **The Gamification Model Language GML** (Game Elements) - Here, the developer specifies the essential core elements to describe the gameful system. Here, the game concepts (ID, domain, and owner) and the children's concepts (such as actions, badge collections, points, etc.) are defined.
- **The Game Model Language GaML** - (Game Mechanics) - The GaML instantiates the concepts defined in the GML.

- **The Game Instance Model Language (GiML)** - (Game Dynamics) - Here, the developer specifies the players/teams involved in the game. The GiML binds the previously defined game definitions (from GaML) with the appropriate instantiation details.

It also provides two different Game Utilities:

- **The Game Simulation Language (GsML)** - Utility Language. Allows to simulate scenarios. A GameDefinition and a set of SingleGameExecution elements are the two main elements of the GameSimulation.
- **The Game Adaption Language (GadML)** - Utility Language. Allows developers to adapt certain game features to particular users (for example, generate tailored challenges).

A framework for the agile design of Personalized Gamification Services [52] presents a framework for the agile design of gamification services. The GDF is composed of four different phases, each one with its unique concepts:

- **Declaration** - First phase of the framework. The objective is to acquire the necessary information to develop the application.
    1) **Problems -** Identify difficulties to be solved by Gamification.
    2) **Causes -** Identify the reasons for the previously reported problems.
    3) **User Stories -** Descriptions of the objectives.
    4) **Acceptance Tests** - List of concrete behaviors that quantify the achievement level of each user story.
- **Creation** - Second phase of the framework. The appropriate design element is added to each acceptance test's narrative (metaphor). The result of this phase is an MVP. All the components described below must be aligned with the metaphor and follow the **SPARC** Dimensions (**Sense, Purpose, Autonomy, Relatedness, Competence**) to align with the SDT principles.
    1) **Players -** Create user prototypes to represent each player type. HEXAD User Types Framework [43] is used.
    2) **Game Mechanics** - Select the game mechanics (Leaderboards, Teams, Challenges, Voting, Gifting, Exploration).
    3) **Stages** - Define the application stages (Discovery, On-Boarding, Mid-Game, End-Game) and what Game Mechanics to use in each. Based on [19].
    4) **Actions** - Dynamics of the gamified application. Development of Use Cases for all different proposals, with a Player, a Game Mechanic and a Stage.

5) **Triggers** - Personalized feedback according to specific actions

- **Execution** - Testing the developed MVP. Tracking and logging the users' actions is necessary (Phase 3).
- **Learning** - Analysis and measurement of the activities to further improve the motivational effects of the application (Phase 4).

In reference [53], a method for engineering gamified software is presented based on a literature review and expert interviews. The authors created a list of thirteen design principles (DP) that should be met to develop a gamified application. Each principle is linked to at least one of the seven method phases of the framework in the following manner:

- **Project Preparation** - "All activities that must be executed before the project starts" - **DPs**: 2,6,7,9.
- **Analysis of context and users** - "Activities that are used to identify the necessary knowledge of users, processes and the project itself" - **DP**: 1.
- **Ideation** - "Activities to develop ideas for gamification designs" - **DPs**: 8,13.
- **Design** - "Designing gamification and creation of prototypes" - **DPs**: 3,4,5,12,13.
- **Implementation of Design** - "deployment of a gamified software" - **DPs**: 4,11,13.
- **Evaluation** - "Evaluation and testing of the software" - **DP**: 9.
- **Monitoring** - "Monitoring the performance of the software after the release" - **DPs**: 9,10,11.

2.2.4 Frameworks Discussion

Comparing (Table 6) the frameworks analyzed in the previous section (section 2.2.3), we can cross reference them with the utilised Motivational Theory and Player Taxonomy.

By adding empirical validation and the Advantages/Disadvantages, we concluded that:

Table 6 - Frameworks Comparison Table

Framework	Author(s)	Advantages	Disadvantages	Motivational Theory	Player Taxonomy	Empirical Validation?
Octalysis	[44]	Comprehensive, well-known, practical, and flexible	Complex and overwhelming	SDT	Bartle Taxonomy	Yes Case Studies
KEG	[45]	Comprehensive, user-centred, and adaptable	Limited empirical validation	SDT	No	No
LoISA	[46]	Comprehensive, user-centred, and adaptable	Complex and requires game design expertise	Flow Theory and SDT	No	No
RECIPE	[47]	Simple, straightforward, and adaptable	Limited coverage of motivational aspects	SDT	Bartle Taxonomy	No
Gameful Design Heuristics	[48]	Comprehensive, practical, and adaptable	Small Sample Size	SDT	HEXAD	Yes Expert Reviews, Case Study
A Design Framework for Adaptive Gamification Applications	[49]	Comprehensive, adaptable, and well-structured	Specific test scenario. Limited general use validation.	SDT, user-centered theoretical framework and Organismic Integration Theory (OIT)	HEXAD	Yes. Case Study (6 Months)
The MDE Framework	[50]	Comprehensive and adaptable	Limited coverage of motivational aspects	-	-	No

GDF - A Gamification Design Framework Powered by Model-Driven Engineering	[51]	Model-Driven Engineering. Adaptable.	Complex and requires game design expertise. Limited coverage of motivational aspects.	-	-	Yes. Case Study
A framework for the agile design of personalized gamification services	[52]	User-Centered Design, Practical, Flexible	Limited Validation outside of the Education Field	SDT	HEXAD	Yes. Case Studies
How to design gamification? A method for engineering gamified software	[53]	Comprehensive, Flexible	Previous Knowledge of Software Engineering Needed. Limited Coverage of Game Design Elements	-	-	Yes. Literature Review, Expert Interviews, Case Study

- **Motivational Theory:** Out of the ten analyzed General Gamification Design Frameworks, six of them: Gameful Design Heuristics [48], Octalysis [44], KEG [45], RECIPE [47], a Design Framework for Adaptive Gamification[49], a framework for agile design of personalized gamification services [52] **utilized** the Self Determination Theory as a Motivational Theory, three of them: The MDE Framework [50], GDF [51], How to design gamification? A method for engineering gamified software [53] **did not** use a Motivational Theory to ground their developments. Only one LoISa [46] utilized **a mix** of SDT and Flow Theory.
- **Player taxonomy:** Regarding player taxonomy, **two** frameworks, Octalysis [44], RECIPE [47] utilized the Bartle Taxonomy, three: Gameful Design Heuristics [48], A Design Framework for Adaptive Gamification [49] and A framework for agile design of personalized gamification services [52] utilized the HEXAD taxonomy and the remaining five **did not** utilize any kind of player taxonomy.
- **Empirical Validation:** In terms of validation six different GGDFs have **presented** expert validation or case studies: Gameful Design Heuristics [48], Octalysis [44], A Design Framework for Adaptive Gamification [49], GDF [51], A Framework for Agile design of personalized gamification services [52] and How to design gamification? A method for engineering gamified software [53].

By combining these three key characteristics, we can conclude that the most comprehensive General Gamification Design Frameworks (GGDFs) are: **Gameful Design Heuristics** [48], **Octalysis** [44], **A Design Framework for Adaptive Gamification** [49], **A framework for agile design of personalized gamification services** [52].

The use of one of the presented GGDFs does not exclude the use of another. For example, developers/designers that choose to use the Octalysis Framework [44] as a tool to help them develop the gamified system can then evaluate the created application utilizing the Gameful Design Heuristics [48] to evaluate the applied gamification elements and see if the developments appropriately made cover all the fields validated by the heuristics. By combining both frameworks, we can assume that the resulting application will have a higher degree of efficacy, providing higher motivation for the users, thus resulting in a well-applied use of gamification techniques. As gamification uses in mobility is crucial to shift the behavior of the user, it is recommended that a mobility app that promotes sustainable and active mobility through the use of gamification should be designed using the framework "A framework for the agile design of personalized gamification services" by [52], as it utilizes an agile development methodology, which has been proven to allow the development of a Minimum Valuable

Product (MVP) gamified system in a short amount of time, it utilizes the HEXAD player taxonomy (which has been proven, via case studies and research papers[65], [66], to be a very effective manner of classifying users to apply gamification techniques), and is validated via several case studies. To further improve the efficacy of this framework, the developers should, throughout the development of the system, utilize the Gameful Design Heuristics by [48] to guarantee that the chosen gamification elements cover all the presented heuristics, thus improving the chances of successful gamification.

2.3 Gamification Applied to Mobility

Upon searching for the web tool Scopus, with the search query "(gamification AND mobili* AND sustainab*) OR (gamification AND mobili*) OR (gamification AND sustainab*)", we can observe (Figure 6). However, a slight drop is visible in 2022, and there has been an apparent growth in publications about these three topics combined.

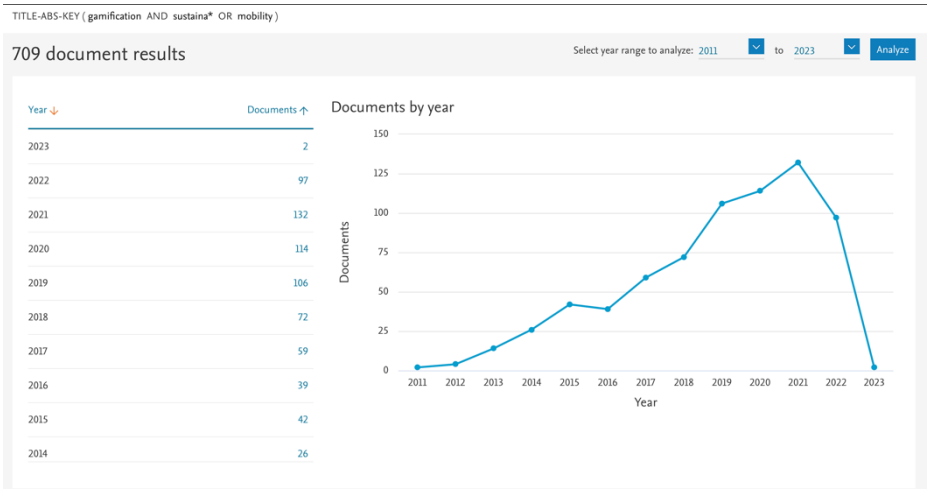

Figure 6 - Gamification, Mobility and Sustainability

Using the VOSViewer tool, we were able to analyze the most common author keywords on this data set, and we see (Figure 7) that the words that occurred the most/had a "link strength" higher than 100 were serious games, motivation, augmented reality and smart city.

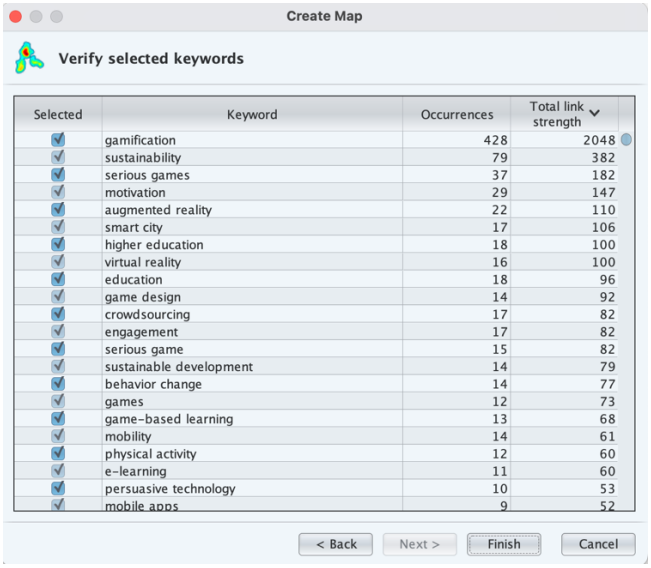

Figure 7 - Keywords GMS

The previously selected keywords were added to the query on Scopus, and a data set containing 5529 documents was retrieved (Figure 8).

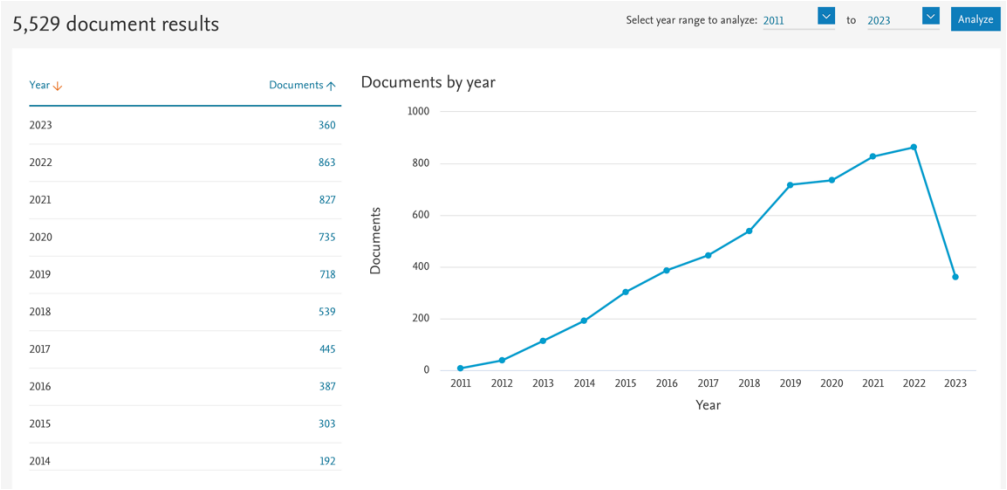

Figure 8 - Papers by Year - Full Dataset

The first filter applied to the dataset was (1) – Publication Stage = Final. By applying this filter, 94 articles were removed. Filter (2) – Language of Original Document = English resulted in a filtering of 227 lines. Filter (3) – Document Type = Article or Conference Paper allowed us to refine the dataset by eliminating 716 entries. The fourth applied filter was (4) – Citation Number >= 10. Upon the application of (4), 3291 entries reduced the dataset. The fifth (5) and last filter applied was the removal of papers related to the field of Education/Learning as it applies to the current research focus. By applying (5), 459 articles were removed, leaving the final dataset with 742 articles for analysis.

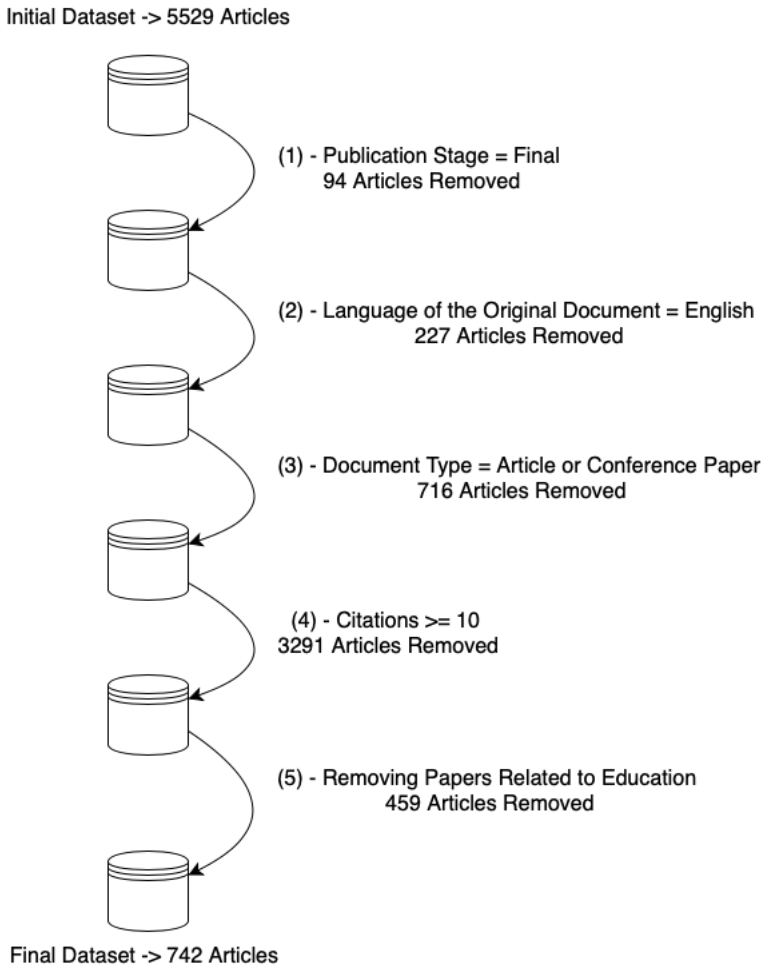

Figure 9 - Dataset Filtering

Upon analyzing the final dataset, we can observe two distinct clusters of keywords (Figure 10).

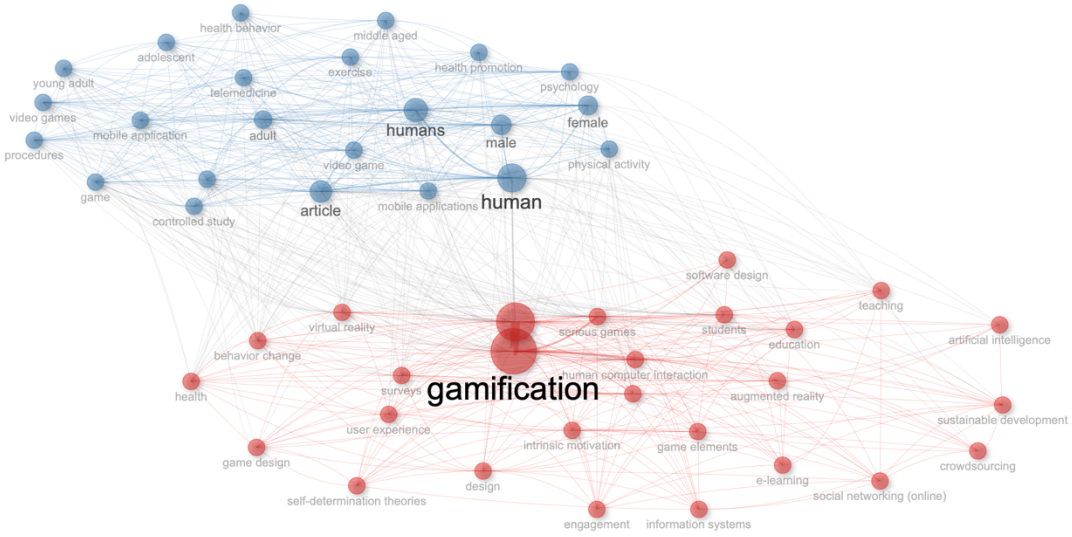

Figure 10 - Main Clusters

Thus, we can see how gamification interacts with the users in this type of system and the parameters that are most studied and analyzed when designing/developing gamified applications.

2.3.1 Use Cases

The study investigates how game mechanics affect the users' cycling riding frequency. After analyzing a large amount of data regarding three large-scale and recurring annual encouragement cycling campaigns, the authors conclude that by designing competitive programs, these strategies prove to be effective across all spans of riders, and also conclude that the use of smartphone applications has the potential to increase the participation of the users. However, Weber *et al.* also conclude that the most significant finding of the study is that even the slightest variation in incentive can prove to be effective and lead to substantial changes in user engagement, either for new or veteran riders and that due to the high impact that this modal shift in transportation method represents to the environment, researchers should pay more attention to these techniques [67].

Mobi - modal shift through gamification:

Mobi is a use-case scenario that introduces gamification features to the mobility subject. In the first iteration, the data of 10 participants was analyzed in the test phase, and the researchers concluded that the participants were enthusiastic about the game-like approach, increasing the frequency of the participants using more eco-friendly means of transportation. The participants were more conscious about their travel mode, resulting in a drop in CO_2 emissions of almost one tone. Another key finding was that playing in teams instead of individually increased engagement, leading to more engagement and better results [5]. After the initial trials, Mobi was applied to six countries, one of them Portugal, and it achieved positive results in all six. Some of the main takeaways found after the termination of the project in 2016 were that by applying game-like incentives, the use of sustainable means of transportation went from 57 per cent to 80 per cent, exceeding the project goal and that the CO_2 emissions were reduced by 27 per cent during the game [68]

Streetlife Field Trials - Applied gamification approaches as a key to more sustainable mobility behavior.

The case describes integrating a competitive gamification approach into a mobility planning App and evaluates the impact of such measures on the users' carbon emissions. It used a simulation setup derived from data collected during the field test. The

investigators found that the share of bicycle transportation increased from 12 to 14 per cent for the entire Berlin population, and the percentage of daily motorized trips decreased significantly. The researchers also conclude that these competitive gamification techniques should be applied to other means of transportation, such as public transport so that the impact on the transportation systems can be better balanced and the outcomes can be more inclusive [69]

Incentivizing Commuter Cycling by Financial and Non- Financial Rewards:

Researchers collaborated with the developers of the "Cyclers" app to evaluate financial and non-financial motivational features. Test subjects were divided into five groups, each receiving different motivational treatments: smart gamification, two types of financial rewards, a combination of both, or no specific motivation (control group). The study used a rigorous randomized experimental design and unobtrusive data collection. The findings indicated that smartphone apps could effectively change commuting habits, with combined financial and non-financial rewards leading to increased cycling frequency. Small monetary rewards significantly motivated increased cycling, while smart gamification alone did not. The study suggests further evaluating individual gamification elements to determine their impact on sustainable transportation adoption [70].

Evaluation of an incentive program to stimulate the shift from car commuting to e-cycling in the Netherlands

This paper analysed the impact of monetary rewards on adopting an e-cycling commute. The users' activity was tracked using a smartphone app, and the rewards were attributed based on the distance each user travelled and given the average e-cycling commute distance. Users should take up to a year to achieve the maximum reward value (1000C). The main conclusions of this study were that ”E-bike use by former car commuters in an e-cycling incentive program amounted to 68 per cent after one month and 73 per cent after half a year of participation”. The use of e-bikes decreases if the total distance of the trip is over the 20-kilometre checkpoint, and the adoption of e-bike use for commutes is influenced by age, gender, physical condition, car ownership and household composition [71].

Deconstructing gamification: evaluating the effectiveness of continuous measurement, virtual rewards, and social comparison for promoting physical activity.

Oren Zuckerman and Ayelet Gal-Oz evaluated the impact of two gamification techniques, Virtual Rewards and Social Comparison, using a prototype app called

"StepByStep" to promote routine walking. The app tracked users' walking habits via their mobile phone accelerometer. Two studies were conducted: one without incentives and one with gamification techniques. In the first study, the app established a baseline walking time before setting personalized daily goals. In the second study, virtual rewards (points) and social comparison (scoreboard) were applied. The findings showed that the gamified version was as effective as the quantified version in promoting active mobility habits. Users responded well to quantified features, but the scoreboard's acceptance varied, and the point system was often seen as meaningless. The authors concluded that designers should develop novel measures for reflecting on users' activity and advised systematic evaluations of gamified elements to understand their motivational impact[72].

Gamification and sustainable mobility: Challenges and opportunities in a changing transportation landscape.

The authors present a heavy link between urbanization and the need for enhanced mobility and sustainability. However, delivering mobility-related information is insufficient for the end users to adopt more sustainable means of transportation. In a society where users seek the fastest, safest, and most economically viable way to move around, the efficacy of the cooperative incentives method is questioned, giving the techniques based on user competition more relevance. Literature review shows that integrating gamification techniques on current and emerging ICT solutions can motivate users and lead to higher engagement in sustainable travel behaviors. One of the main conclusions of this study is that further research should focus on what incentives to apply to trigger behavioral changes in the end users to make the applications efficient and sustainable. The authors also note that it is important to determine under what conditions cooperative behaviors can be more efficient in providing personalized information and motivating sustainable mobility change adoption [73].

Using gamification to incentivize sustainable urban mobility.

This study, conducted in Rovereto, Italy, evaluated the effectiveness of gamification in promoting sustainable mobility through a mobile app. Over 5 weeks, users first familiarized themselves with the app, then received sustainable mobility recommendations, and finally experienced gamification techniques (points/leaderboards, badges, and monetary incentives like a free bike-sharing pass). The findings showed that gamification increased app usage for urban mobility planning, encouraged alternative routes, and positively influenced users to adopt more sustainable mobility patterns, reducing private car use and increasing walking and cycling [74].

Does gamification work? - A literature review of empirical studies on gamification

Hamari *et al.* [10] analyzed various studies on gamification across contexts like education, work, health, and commerce. The research included both quantitative and qualitative methods. The main finding is that gamification generally improves user adoption, though some caveats exist. Quantitative studies showed positive outcomes, while qualitative studies highlighted the complexity of gamification. Future research should consider the service context and user profiles to apply gamification techniques better, noting that external rewards can undermine intrinsic motivation.

Promoting sustainable travel behavior through the use of smartphone applications: A review and development of a conceptual model

The authors developed a conceptual model for promoting sustainable behavior through mobile apps using a literature review guided by PRISMA [6]. Key findings include the importance of customization, user feedback, and simple, appealing design. Higher motivation and involvement lead to better results and long-term commitment. The main takeaway is that segmenting the target population enhances user-centred campaigns, tailored objectives, and contextualized content. Future research should analyse travel behavior changes and base empirical studies on behavior theory [11].

2.3.2 Takeaways

Following an extensive review of the current state of gamification and sustainable mobility and analyzing various studies and their conclusions, we have identified techniques that could potentially enhance user adoption of more sustainable and active transportation methods. These techniques include:

- **Badge System**: This system provides users with specific objectives to complete to earn badges.
- **Reward System**: This system aims to incentivize users with non-financial rewards, such as vouchers for healthy meals on campus or scooter rentals, upon completing predetermined tasks or objectives.
- **Scoreboard Feature**: This feature allows users to view their ranking regarding their sustainable efforts.

Additionally, we have incorporated three supplementary game design elements to ensure comprehensive engagement and optimized stimulation for all types of players:

1. **Quests**
2. **Contribution Mechanism**
3. **Anti-Cheat Measures**

2.3.3 Matching Heuristics with the Game Design Elements

In order to arrive at the final set of game design elements, the following step is to match the defined gamification techniques with the Gameful Design Heuristics. Table 7 was developed in order to facilitate the comprehension of the mapping. Considering the previously referred findings, the following game design elements can potentially positively influence users' motivation and long-term commitment to modal shift and healthier travel behavior utilizing the OnMove App.

Table 7 - Matching Heuristics with Game Design Elements

Matching Heuristics with the Game Design Elements		
Heuristic	**Description**	**Game Design Element**
IMH1. Meaning	Identification of meaningful contribution	Incentivize more sustainable /healthier means of transportation
IMH2. Information and Reflection	Providing information and opportunities for reflection	Incentivize more sustainable /healthier means of transportation
IMH3. Increased Challenge	Providing challenges that grow with users' skills	Quest increase in difficulty
IMH4. Onboarding	Providing challenges for newcomers	Easier Quests Beginners
IMH5. Self-challenge	Discovering or creating new challenges	Create personalized Quests
IMH6. Progressive Goals	Presenting the next achievable goal	Quest Log
IMH7. Achievement	Monitoring and displaying achievements or advancements	Progress bars, badges, quest log

IMH8. Choice	Providing the possibility to make choices	Possibility to change routes, different means to complete quests
IMH9. Self-expression	Allowing users to create new content	Ride Sharing, Provide input about road events
IMH10. Freedom	Allowing experimentation without serious consequences	Testing Different Routes, Quests
IMH11. Social Interaction	Providing the possibility to connect with others	Social Media Connection, Group Quests, Leaderboards
IMH12. Social Cooperation	Providing the possibility to work with others to achieve a common goal	Cooperative gameplay (cooperative quests/goals)
IMH13. Social Competition	Providing the possibility to challenge or compare with others	Competitive gameplay (competitive quests/goals)
IMH14. Fairness	Providing opportunities for success and progression for newcomers	Easy Quests Beginners
IMH15. Narrative	Providing a meaningful story	Future Work
IMH16. Perceived Fun	Providing the possibility to interact and be part of the story	Future Work
EMH1. Ownership	Providing users with the possibility to possess virtual goods or build a profile over time	Badges and player profiles
EMH2. Rewards	Incorporating a reward system to incentivize interactions and continued use	Points and badges systems

EMH3. Virtual Economy	Results can be exchanged for in-system and outside rewards	Point system / Rewards Allow the user to trade points for rewards
EMH4. Scarcity	Incorporating rare rewards or items to increase their perceived value	Limited edition or rare badges
EMH5. Loss Avoidance	Creating urgency to act immediately to avoid possible losses	Timed Badges / Quests
CDH1. Clean and Immediate Feedback	Providing immediate feedback of changes or accomplishments	Activity Graphs , Notifications
CDH2. Actionable Feedback	Providing information on the next available action	Activity Graphs, Quest Log
CDH3. Graspable Progress	Providing information on the users' path ahead for progression	Activity Graphs , Quest Log, Badges
CDH4. Varied Challenges	Presenting a heterogeneity of tasks	Different types of challenges and gameplay
CDH5. Varied Rewards	Offering a heterogeneity of rewards	Different types of rewards and incentives
CDH6. Innovation	Providing users with the possibility to contribute with ideas and content	Create personalized Quests, provide input about road events, create carpooling.
CDH7. Disruption Control	Implementing cheating control measures	Anti-cheat systems and fair play policies (Future Work)

The next step is to combine everything, including heuristics, game design elements, and HEXAD player types. This way, we ensure the stimuli are applied to all possible users. In Table 8, we mapped each Game Design Element with the Player Type it relates to and the Game Design Heuristics it matches.

Table 8 – Matching Game Design Elements with HEXAD

Matching each of the used GDE with the HEXAD player type and with what Heuristics it complies with		
Game Design Element	Hexad Player Type	Heuristics Met
Quests	Achiever, Player	IM: H1, H2, H3, H5, H6, H7, H8, H10, H11, H12, H13, H14. EM: H1, H2, H3, H4, H5 CD: H1, H2, H3, H4
Personalized goal tracking	Achiever, Player, Free Spirit	IM: H2, H3, H4, H5, H6, H7, H10. EM: H1, H2,H3, H5. CD: H1, H2, H3.
Rewards and collectibles	Achiever, Socialiser, Player	EM: H1, H2, H3, H4, H5. CD: H1, H2, H3.
Social features (friends, leaderboards)	Socialiser, Player	IM: H11, H12, H13, H14. EM: H3 CD: H1, H6
Contribution Mechanism	Free Spirit, Philanthropist	IM: H9, H11, H12 CD: H6
Cheating prevention measures	Disruptor	CD: H7

3. OnMove App

Applying the takeaways from the previous chapter and applying them to a Campus Mobility as a Service platform led to the creation of the OnMove app. The results obtained will also be anaylized with the aim to discover differences in user engagement and longevity regarding the adoption and utilization of more sustainable means of transportation.

3.1 OnMove Version 1

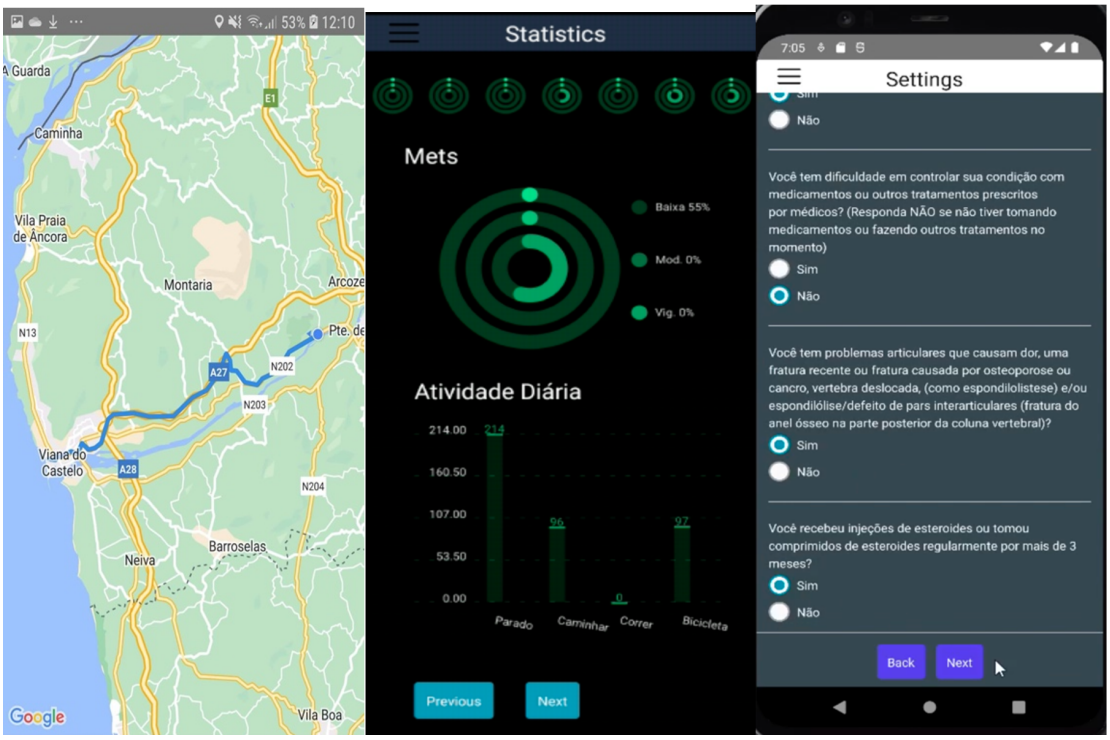

Figure 11 - Maps, Activity, and Health Survey

The OnMoveV1 mobile application is an app that currently allows the Users to (Figure 11):

- Use different mobility routes by combining different means of transportation such as trains, academic buses, ridesharing, walking, and driving. The routes are displayed using map components.
- Estimate the mobility efforts of each day by tracking the user activity via mobile phone sensors or wearable devices and displaying it using activity charts.
- Recommend the ideal activity level for each user by answering a questionnaire and recommending the routes accordingly.
- Ridesharing.

3.1.1 Application Architecture

The architecture for building the mobile application OnMove was Micro-services utilizing Kubernetes (see Figure 12), allowing for greater flexibility on each service and improving each service's independence. All data the app utilises is distributed by the back end, leaving only the health-related data regarding the Health Module on the app. However, the questionnaire answers are also registered on the back end for posterior consultation and analysis. The app only attains the health risk factor based on the questionnaire answers. For building the application, we chose the JavaScript library React Native[75], and the back-end utilizes Node.js [76].

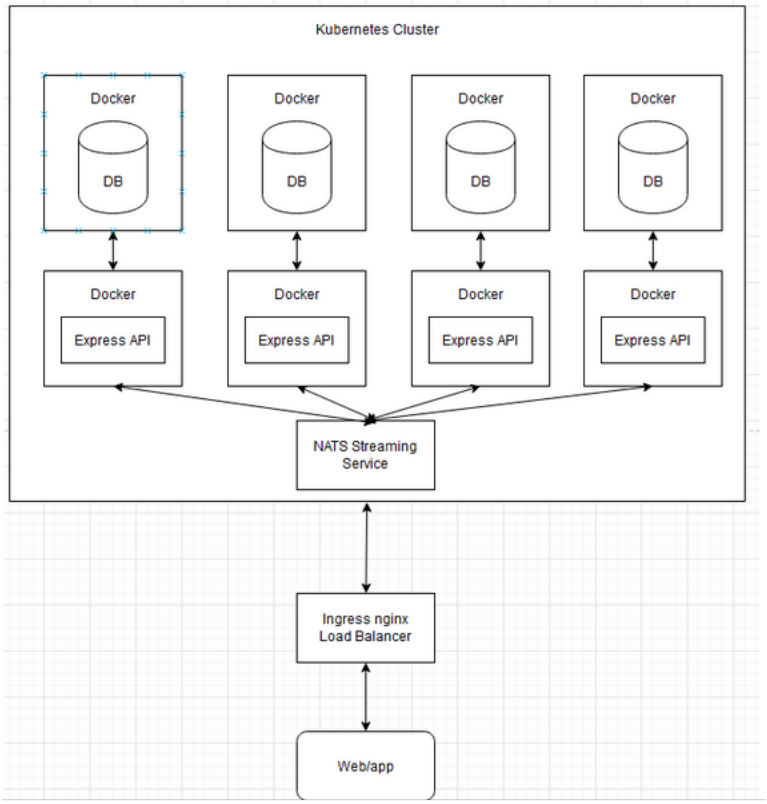

Figure 12 - Application Architecture

3.1.2 Main Features

In order to develop the UX Design/Mockups of the new version of the OnMove app, we established a partnership with Catarina Fernandes, a master's degree design student at the Escola Superior de Tecnologia e Gestão of the Instituto Politécnico de Viana do Castelo. Her work also resulted in her master's degree thesis [77].

Register

Figure 13 – Register. Source[77]

In order to register (Figure 13) on the OnMove app, the user must insert the following data: Name, Email, Password, Biography (Optional), Phone Number, Birthdate, Gender, Weight, and Height.

The attributes of birthdate, gender, weight, and height are essential for the health questionnaire/survey to assess the profile's health risk and recommend an appropriate activity level. The Student/Non-Student attribute is still under consideration. It would be

valuable for users to know if the person who created the ridesharing ticket is a student. However, this attribute may lose relevance if the application expands beyond the IPVC institution.

Login

To log in (Figure 14) to the application, the user must insert his email and password, which were registered in the previous step.

Figure 14 - Login. Source[77]

Homepage:

After going through the Login, the user will land on the Homepage screen (Figure 15).

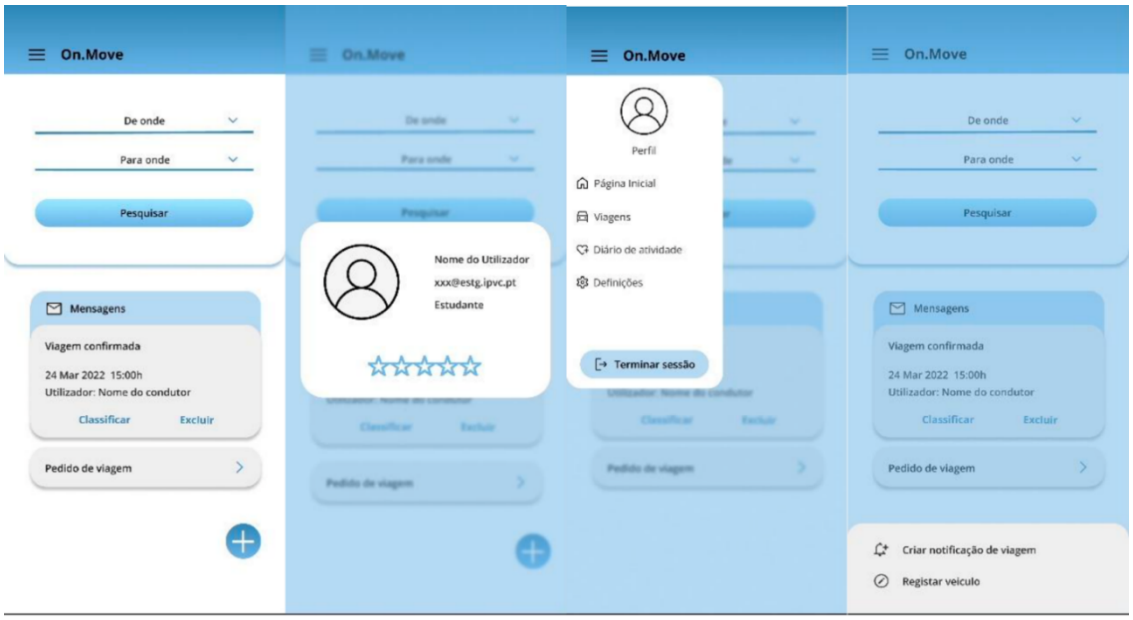

Figure 15 - Homepage . Source[77]

In this screen, the user can see:

- Where from / Where to – trip data to see all available routes from and to their desired location.
- Messages – Any type of notification regarding the ridesharing functionality, such as confirmed ridesharing trips or requests.
- Create new rideshares – By accessing the plus sign, users can create a new rideshare ticket or register a new vehicle to create their rideshares.
- Sidebar Menu – From the top left corner of the screen, the user can access three services: Trips, Activity Record, and Settings.

Ridesharing Ticket:

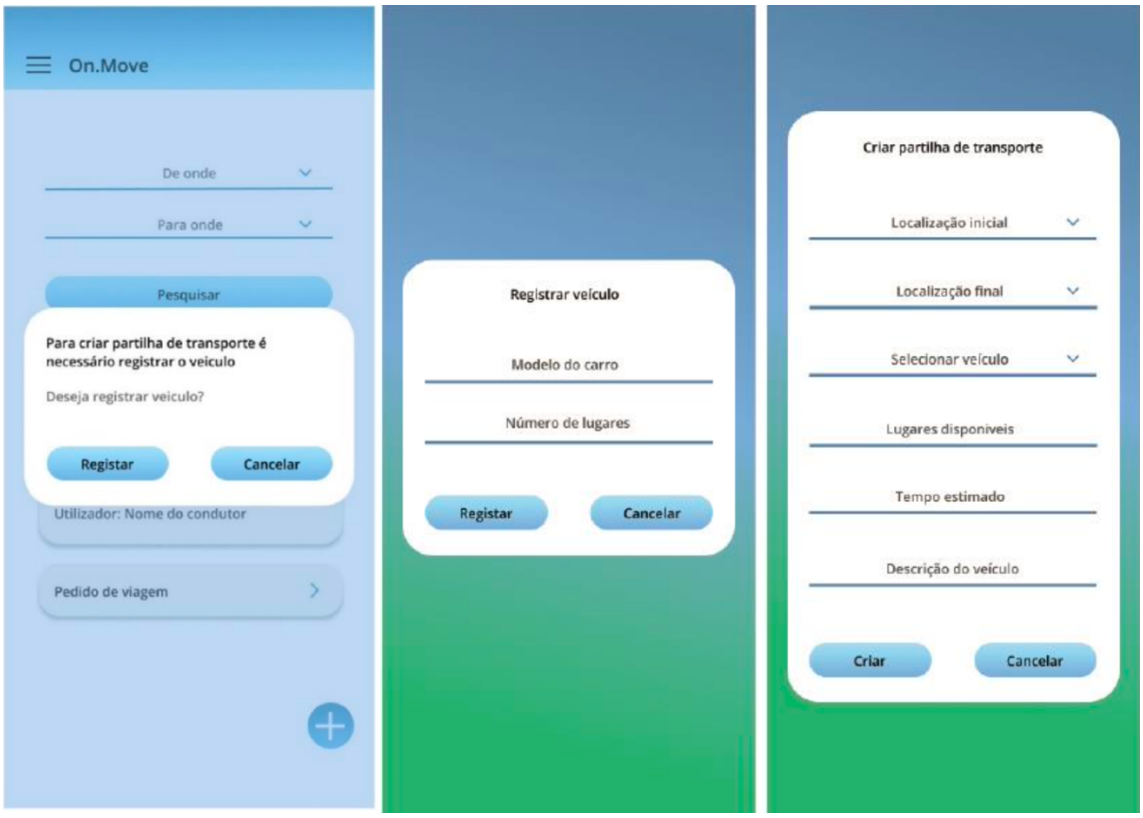

Figure 16 - Ridesharing Ticket. Source[77]

As previously stated, to create a new rideshare (Figure 16), the user must have at least one registered vehicle. Information on the "car model" and "number of available seats" must be provided to do so. The last step is to provide the information relative to the new rideshare trip:

- An Initial Location and End Location must be defined. Also, the information regarding the vehicle, namely the number of available seats at the time, the estimated trip time, and the vehicle description, is included.

The smartphone application features carpooling capabilities, which allows for sharing a transportation mode. This service aids in easing user mobility, promotes sustainable mobility, and lessens the need for transportation in a given area. It will be a free service for users to provide rides and take advantage of the trip.

The user who wants to provide the service may submit a notification containing information about the trip so that users of the application can access it and, if they so choose, confirm their participation.

Route System:

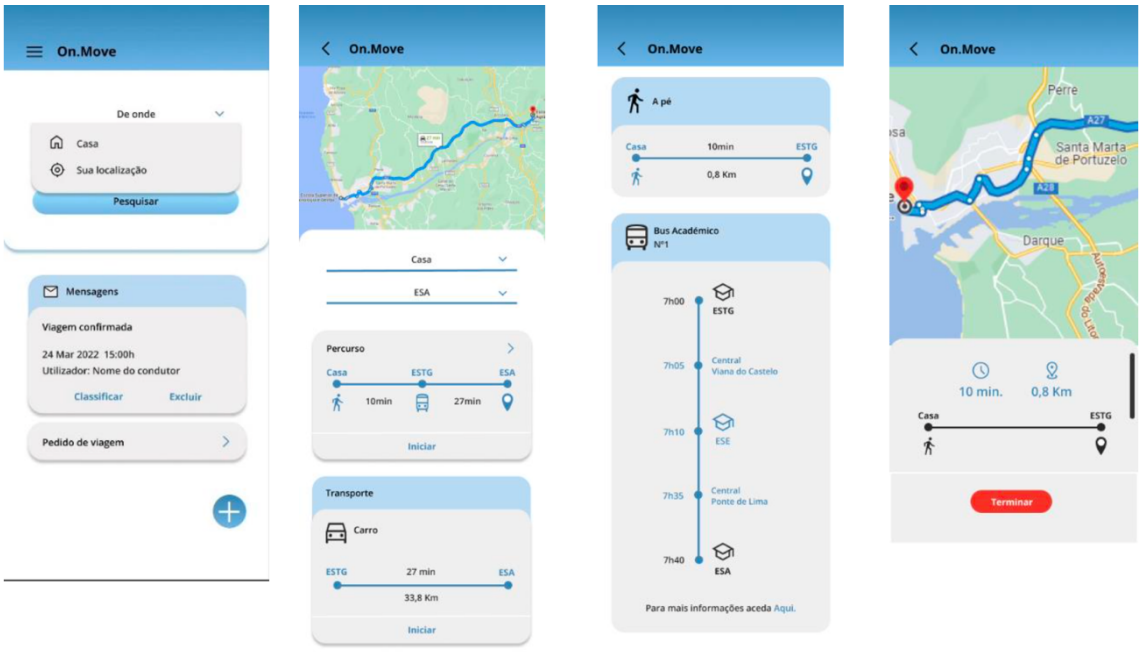

Figure 17 - Route System. Source[77]

On the first screen of Figure 17, we can see the dropdown menu form, from which the user can choose the initial and final locations of the desired trip. After selecting these variables, the user is moved to the second screen, where we can see the map outline of the route and, on the lower part of the screen, the different mobility approaches for the same trip. After selecting one, the user can see more details about each part of the trip, such as the distance, time duration, and map navigation.

User Profile:

On the first screen from the left (Figure 18), the user can see his profile information and an option to edit his profile (right screen of Figure 18). If the user taps the avatar/picture icon, he can modify or delete the profile picture.

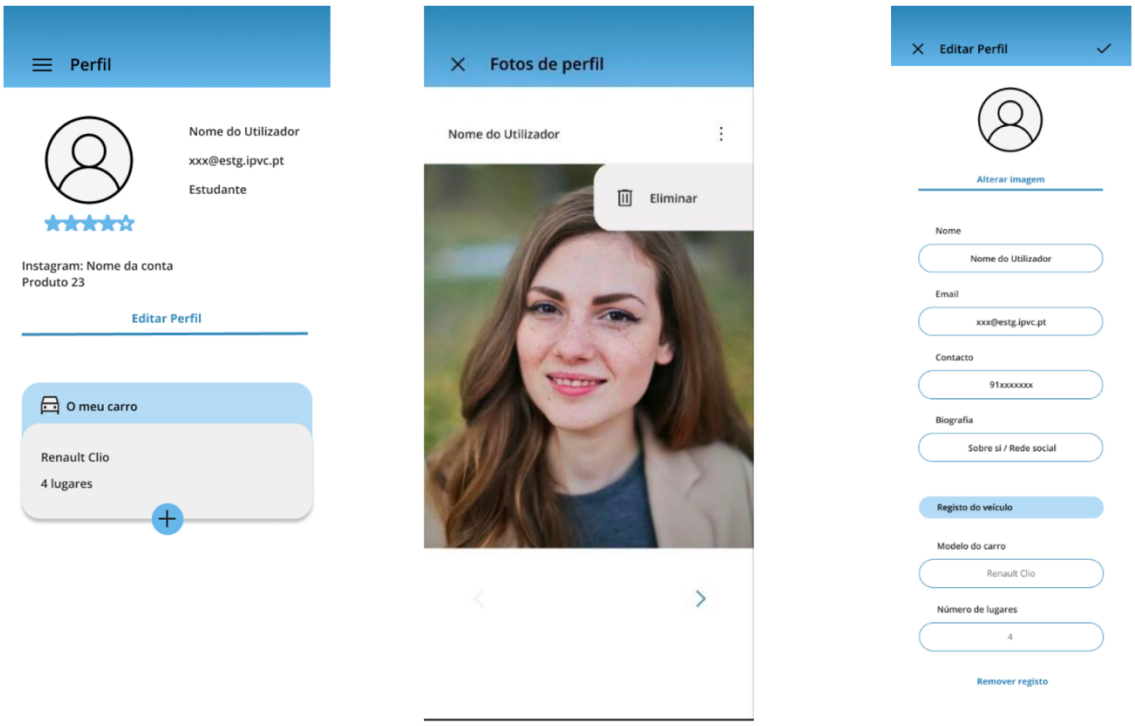

Figure 18 - User Profile. Source[77]

Ridesharing Trips:

The trips screen (Figure 19) comprises the Notifications and Request tab.

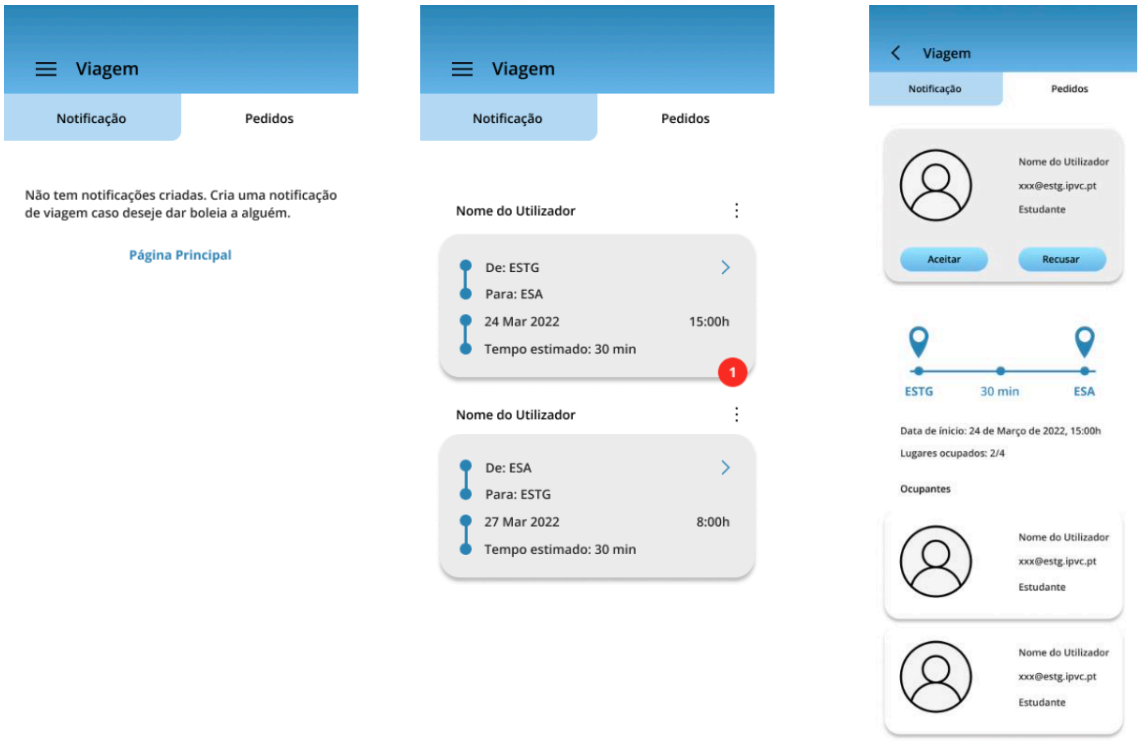

Figure 19 - Ridesharing Trip. Source[77]

Requests Tab:

If the user has not created any carsharing trip, he is redirected to the Homepage to create one (Figure 19, left screen).

If the user has already created a rideshare ticket, he can visualize any user that has requested to join on his trip (Figure 19, center screen). By clicking on the request, the page changes (Figure 19, right screen), and he can see the user's profile and accept or decline his participation in the trip. If the driver accepts the new user on his ride, the number of available seats automatically decreases, and the other party receives a confirmation notification.

Notifications Tab:

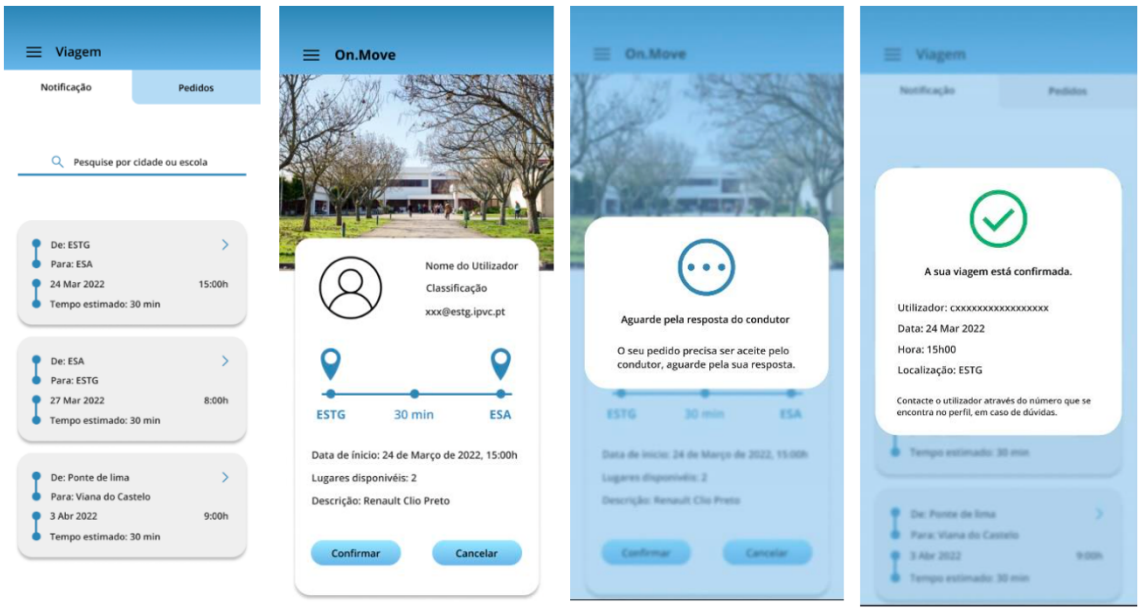

Figure 20 - Rideshare Notification. Source[77]

On the Notifications tab, users can search for the available ridesharing trips created by other users (Figure 20, left screen) by using the search bar at the top of the page.

After tapping on one of the results, the trip information is provided, as well as the profile information of the user that created the trip (Figure 34, second screen from the left). If the user chooses to accept the ride, he will create a request, and it will be directed to the waiting screen (Figure 20, third screen from the left), where he will stay until the driver confirms his request. Upon the passenger's confirmation, the user will receive the trip confirmation (Figure 20, last screen), and the trip will be confirmed.

Activity Record:

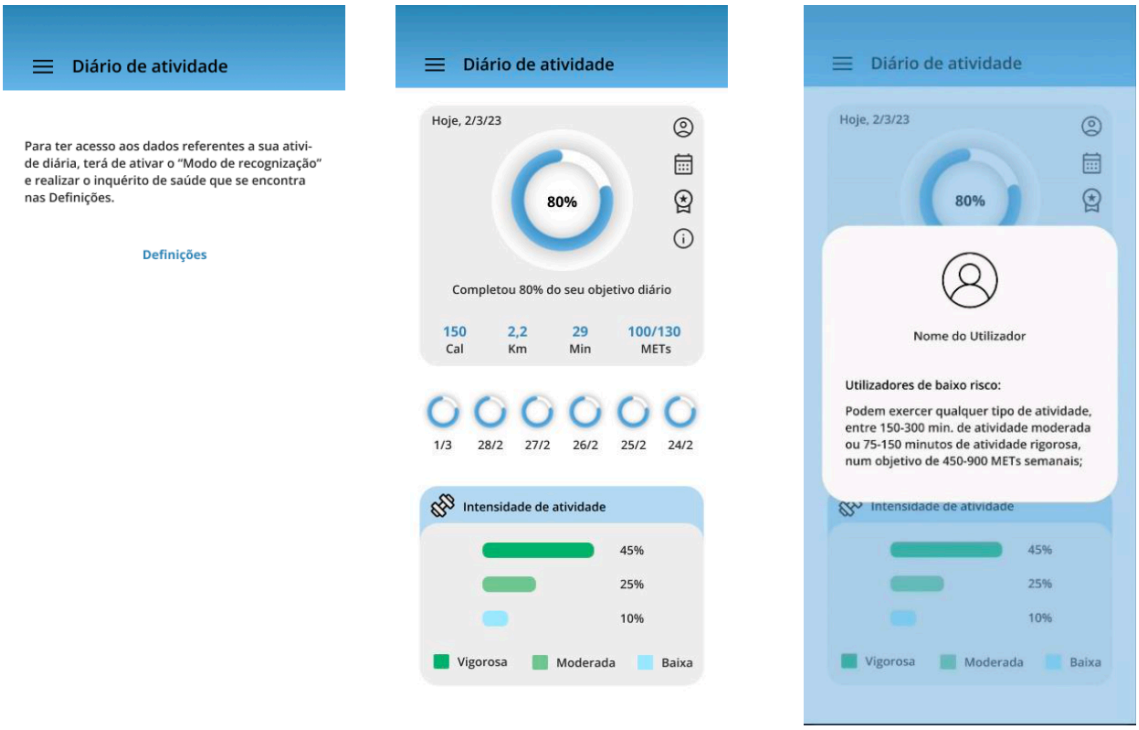

Figure 21 - Activity Record. Source[77]

The Activity Record screen allows the user to visualize all the recorded information about his daily activity, but only if he has previously completed the health survey (Figure 21, left screen). He can access the activity record only after answering the survey (Figure 22) and enabling the activity recognition (Figure 23, left screen) on the settings tab.

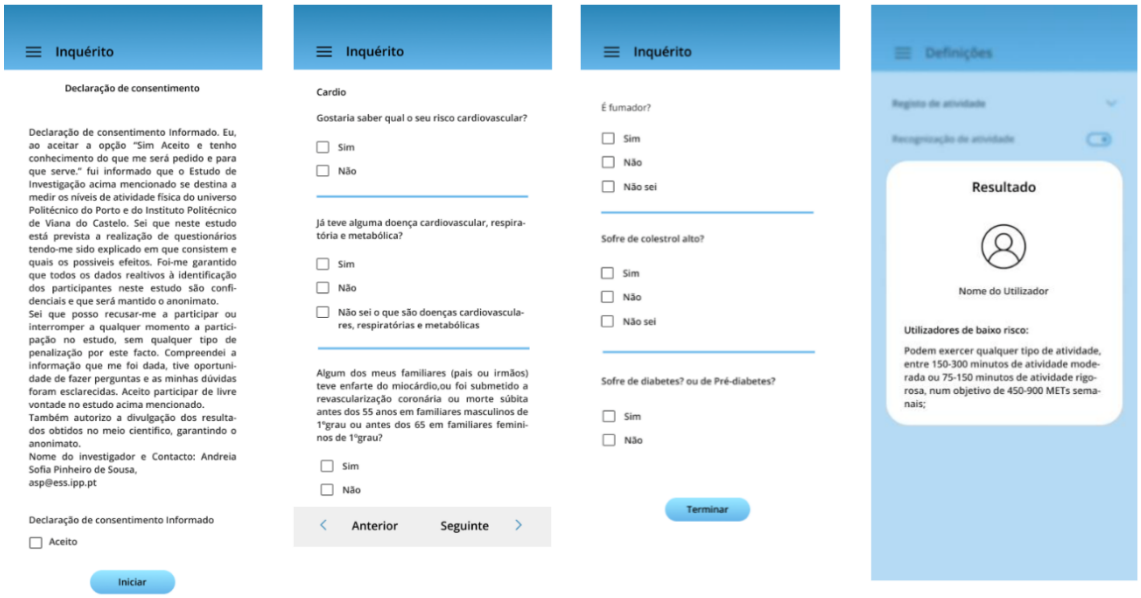

Figure 22 - Health Survey. Source[77]

The main objective of the health module of the mobile application is to promote a more sustainable and healthier lifestyle. To do so, the application gathers data to allow to:

- Classify cardiovascular risk by answering a questionnaire.
- Calculate the METs (Metabolic Equivalent of Task [78]) of each type of activity (light, medium, hard).
- Identify the type of activity practiced by the user (walking, bicycle, running), the distance and the duration of the activity.

The Instituto Politécnico do Porto's Escola Superior de Saúde (IPP-ESS) developed the survey to gather information on the user's health status and determine their cardiovascular risk. Through the declaration of consent, we will notify the user during the survey's execution of its goal and the person(s) responsible for its creation. During the first week of using the program, we will observe the user to assess and categorize their physical capabilities to set daily exercise goals. After a week of tracking, the application will propose the activity level and daily goals based on the collected data adjusted to the user's profile.

There are two different types of user profiles:

Low-risk users: can engage in any activity for up to 450-900 METs per week, aiming for 75-150 minutes of vigorous activity or 150-300 minutes of moderate activity.

Users at intermediate risk: capable of 150–300 minutes of moderate-intensity activity with a weekly target of 450–900 METs.

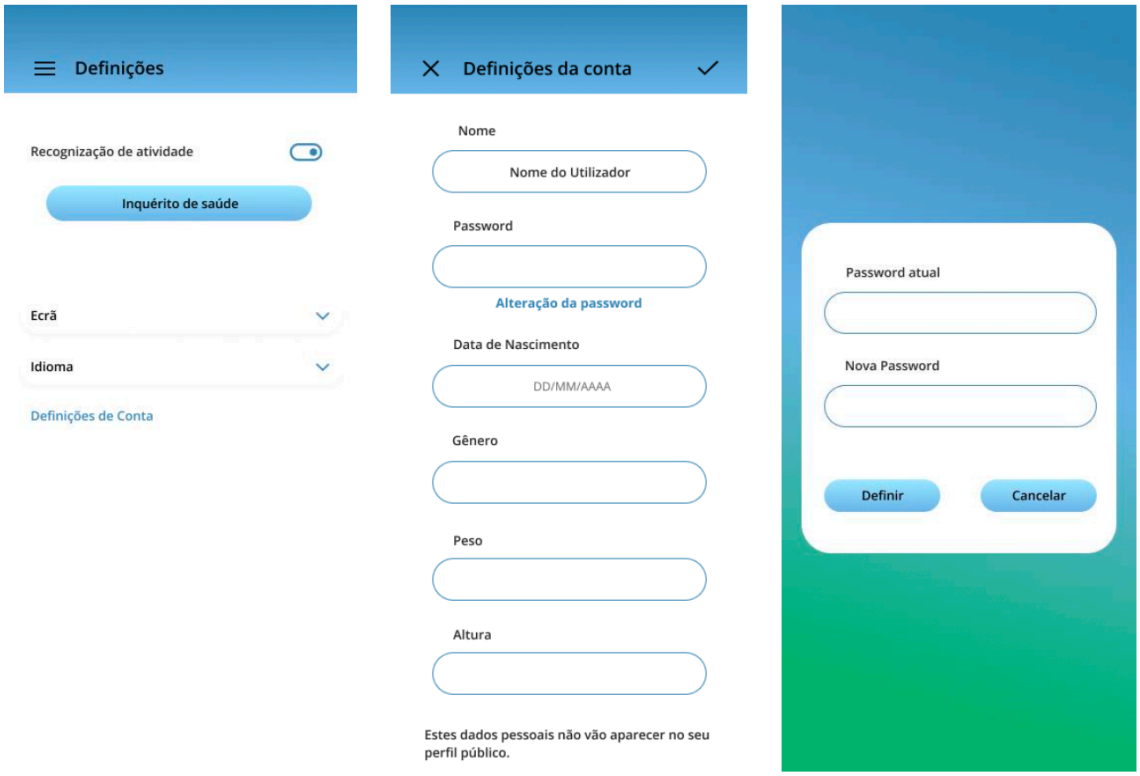

Figure 23 - Settings. Source[77]

After answering the survey and enabling activity recognition, the user gains access to his activity information (Figure 21, centre screen), where he can see and visualise all recorded activity via activity graphs.

The circular graph presents the daily activity in percentages and other daily metrics. The columns graph provides detailed information about the user intensity of the daily activities (low, medium or high intensity). The user can also access more information by tapping on the small icons next to the circular graph:

- Profile – health risk information (Figure 21, right screen).
- Calendar – Visualize the activity information for the selected day. (Figure 24, left screen).
- Badges – Daily Badge Status (Figure 24, centre screen).
- Icon – Information about the METS attribute (Figure 24, right screen).

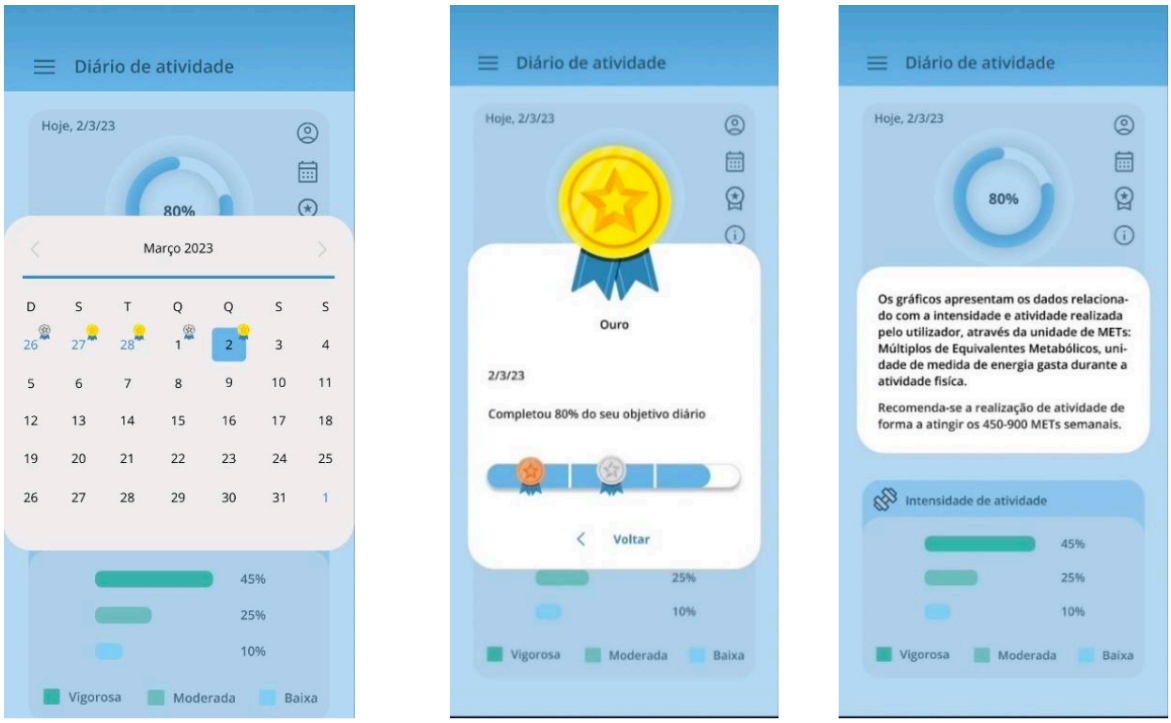

Figure 24 - Calendar, Badges and Info. Source[77]

Settings:

On the Settings screen, the user can:

- Activate the activity recognition size (Figure 23, left screen).
- Access the health survey size (Figure 23, left screen).
- Change colour modes, language and font size (Figure 23, left screen).
- Edit account information (Figure 23, center and right screens).

Mobility Routes:

The application contains the route system service to encourage environmentally friendly mobility and help reduce harmful gas emissions. The application's route system provides information on stations and timetables and is its primary service. It suggests routes and the appropriate modes of transportation to get users to their destinations. The application details the Academic Bus routes and the CP (Comboios de Portugal) timings for the project's current phase. The Alto-Minho area is the main centre of the route system.

3.2 OnMove Version 2 – UI/UX and Gamification

The updated OnMove app will feature an enhanced, user-friendly UI and a newly integrated Gamification Module. Based on the takeaways from Chapter 2 (Table 7), we established that the gamification elements that should be applied are:

- **Quests**

Introducing Quests/Missions gives users a clear objective, such as hitting 10 kilometers on foot daily or a bicycle ride of 20 kilometers. By doing this, we motivate the users daily and reward them upon completion. The quests' difficulty will increase, providing the user easy onboarding and growing challenges.

- **Contribution Mechanism**

The contribution mechanism aims to help the application users to feel more part of the platform. It allows users to create reports such as informing other users of a blocked road, reporting accidents, or providing other relevant information.

- **Anti-Cheat Measures**

By having effective anti-cheat measures, we ensure that the players do not feel discouraged from hitting their objectives when an exploit is, for example, being used by a malicious user to alter their movement goals or to help them get more rewards more quickly.

- **In-Platform Badge System**

The user can track how many badges he has collected and what ones he is pursuing. There are several types of badges available in the application, such as Distance Objectives (different ones are earned according to the checkpoint reached, for example, 5km/10km/25km etc.), Time Objectives (once again with different sub-types according to the checkpoint), Special Day Objectives (special events on determined days where some challenge is given to the user, for example doing a 10 km ride in under 30min) and leader-board achievements (each time a user achieves first place on the leader-board for a week/month/year he earns a badge, like is shown in Figure 24.

- **Leaderboard**

The leaderboard tracks all metrics collected from registered users, classifying them. Divided into two categories (time and distance), the leaderboard ranks users in an orderly manner, allowing users to see who is leading each week or month and how far they are from improving their position.

By applying these Gamification Design Elements (GDEs), we aim to motivate users to adopt more sustainable and healthier modes of transportation.

3.2.1 Usability Test

In order to perform a usability test, an evaluation method must be applied that records both the perceived pragmatic quality, the hedonic quality, and the attractiveness of an interactive product. Attrakdiff [19] is a free tool used to evaluate the three aspects, with the advantage of being one of the most frequently used standardized questionnaires in the Human-Computer Interaction (HCI) field for usability purposes. The theoretic model on which it is based is that a product is separated into two different aspects: pragmatic and hedonic qualities [79]:

- Pragmatic: Pragmatic Quality (PQ) takes up the aspects usually associated with classical usability, such as efficiency, effectiveness and other task-related aspects relevant to user interaction.
- Hedonic: Aspects of Hedonic Quality (HQ) such as beauty, originality and innovativeness influence the overall perception and enjoyment a user has when interacting with a product and has no direct connection with the execution of a task by the user but rather the importance in itself.

The following illustration (Figure 25) demonstrates the theoretical work model and how the pragmatic and hedonic qualities influence the subjective perception of attractiveness, giving rise to consequent behavior and emotions [19].

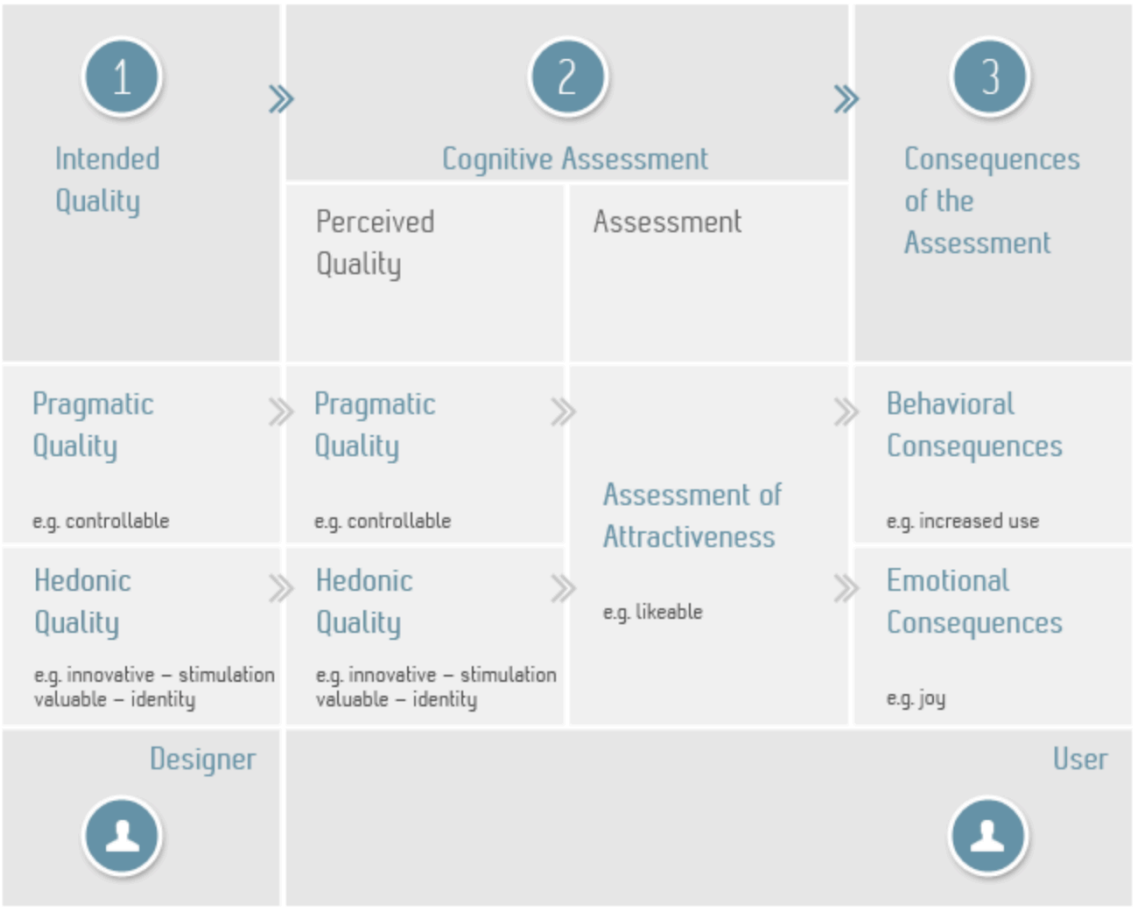

Figure 25 - Attrakdiff - Theoretical Work Model. Source[78]

To measure the attractiveness, Attrakdiff applies measurement in the format of semantic differentials. It consists of 28 seven-step items whose poles are opposite adjectives (e.g. "confusing - clear", "unusual - ordinary", "good - bad"). Each set of adjective items is ordered on a scale of intensity (Figure 26).

	1	2	3	4	5	6	7	
human	☐	☐	☐	☐	☐	☐	☐	technical
isolating	☐	☐	☐	☐	☐	☐	☐	connective
pleasant	☐	☐	☐	☐	☐	☐	☐	unpleasant
inventive	☐	☐	☐	☐	☐	☐	☐	conventional
simple	☐	☐	☐	☐	☐	☐	☐	complicated
professional	☐	☐	☐	☐	☐	☐	☐	unprofessional
ugly	☐	☐	☐	☐	☐	☐	☐	attractive
practical	☐	☐	☐	☐	☐	☐	☐	impractical
likeable	☐	☐	☐	☐	☐	☐	☐	disagreeable
cumbersome	☐	☐	☐	☐	☐	☐	☐	straightforward
stylish	☐	☐	☐	☐	☐	☐	☐	tacky
predictable	☐	☐	☐	☐	☐	☐	☐	unpredictable
cheap	☐	☐	☐	☐	☐	☐	☐	premium
alienating	☐	☐	☐	☐	☐	☐	☐	integrating
brings me closer to people	☐	☐	☐	☐	☐	☐	☐	separates me from people
unpresentable	☐	☐	☐	☐	☐	☐	☐	presentable
rejecting	☐	☐	☐	☐	☐	☐	☐	inviting
unimaginative	☐	☐	☐	☐	☐	☐	☐	creative
good	☐	☐	☐	☐	☐	☐	☐	bad
confusing	☐	☐	☐	☐	☐	☐	☐	clearly structured
repelling	☐	☐	☐	☐	☐	☐	☐	appealing
bold	☐	☐	☐	☐	☐	☐	☐	cautious
innovative	☐	☐	☐	☐	☐	☐	☐	conservative
dull	☐	☐	☐	☐	☐	☐	☐	captivating
undemanding	☐	☐	☐	☐	☐	☐	☐	challenging
motivating	☐	☐	☐	☐	☐	☐	☐	discouraging
novel	☐	☐	☐	☐	☐	☐	☐	ordinary
unruly	☐	☐	☐	☐	☐	☐	☐	manageable

Figure 26 - Attrakdiff Questionnaire

Each of the middle values of an item group creates a scale value for Pragmatic Quality (PQ), Hedonic Quality and ATTractiveness (ATT). HQ includes Hedonic Quality – Identity (HQ-I) and Hedonic Quality – Stimulation (HQ-S), being HQ-I a measure in user experience research and HQ-S related to user motivation and excitement.
The scientific community widely adopts the tool, and the authors have published several studies confirming the validity and usefulness of their work [80][81][82][83].

3.2.2 Results

In order to evaluate our mobile application prototype, we surveyed 20 people with different backgrounds, professions, and ages. The survey results are disclosed in Figure 27.

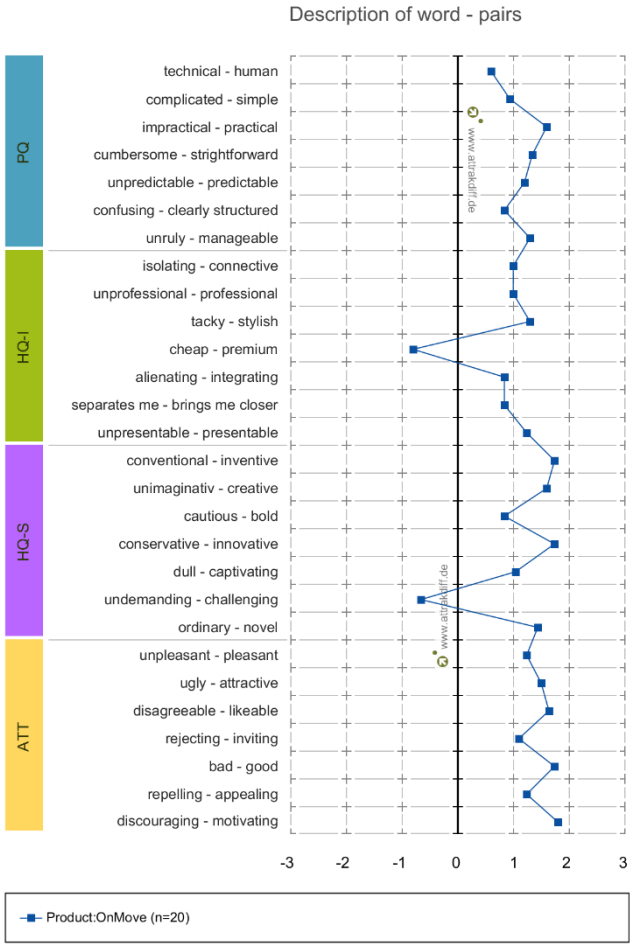

Figure 27 - Word-Pairs Attrakdiff Results

In Figure 28, we can observe a more abstract representation of the questionnaire results. According to the Pragmatic Quality, Hedonic Quality Stimulation (HQ-S) and Attractiveness (ATT) score above 1 (1,12/1,11/1,47 respectively), with the lowest score being Hedonic Quality Identification (HQ-I) slightly below 1 with a score of 0,78.

- Pragmatic Quality (PQ) = 1.12
  The system demonstrates a high level of functionality, efficiency, and usability, suggesting that users perceive it as effective in supporting task completion. A score above 1.0 indicates that the system successfully facilitates users in achieving their objectives.
- Hedonic Quality – Stimulation (HQ-S) = 1.11
  This metric assesses the extent to which the system provides stimulation, novelty, and engagement. A score above 1.0 suggests that users find the system to be not only functional but also somewhat engaging and enjoyable.
- Hedonic Quality – Identification (HQ-I) = 0.78
  HQ-I measures the degree to which users perceive the system as an extension of

their identity and self-expression. While the score remains positive, it is lower than the other dimensions, indicating that users may not strongly identify with the system on a personal level. This could imply that while the system is effective and engaging, it does not foster a deep emotional connection or a strong sense of brand affiliation.

- Attractiveness (ATT) = 1.47
  The overall perceived appeal of the system is notably high, with an ATT score of 1.47. This suggests that users find the system aesthetically pleasing and emotionally satisfying, contributing positively to their overall user experience.

The results indicate that the system exhibits strong usability, as evidenced by the high PQ score. Additionally, the system is engaging and stimulating, as reflected in the HQ-S score. However, the relatively lower HQ-I score suggests that users may not develop a strong personal connection with the system, which could be relevant in contexts where brand identity and user affiliation play a significant role. Finally, the high Attractiveness score suggests that users perceive the system positively in terms of visual and emotional appeal, reinforcing a favorable overall user experience.

These findings suggest that while the system effectively supports pragmatic and hedonic aspects of usability, further enhancements in personalization and identity-driven features could strengthen user engagement and attachment.

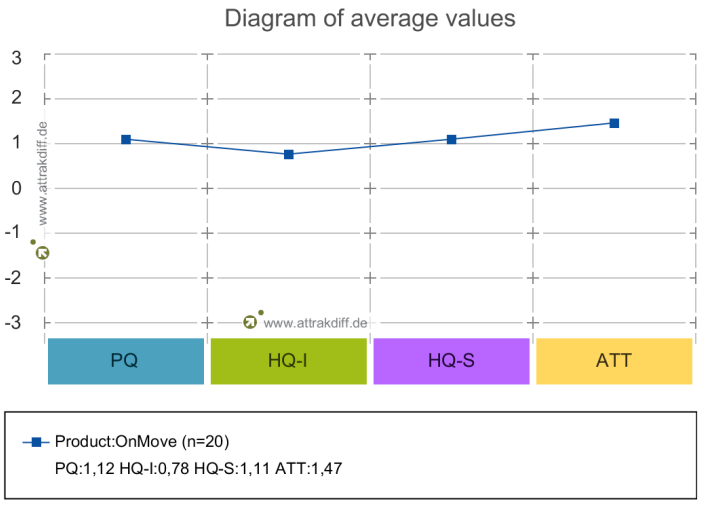

Figure 28 - Attrakdiff Results Diagram Average Values

Analyzing the Portfolio-presentation (Figure 29), we can see that the application scores higher on the Pragmatic Qualities with a score of 1,12 (confidence 0,34) than on Hedonic Qualities with a score of 0,95 (confidence 0,26). Due to the deviation, we can also see that the test results are between the desired and task-oriented. Both results are satisfactory for our goal as a task-oriented application could lead users to use the app for their interest and a cause with a higher meaning, such as Sustainability and Health.

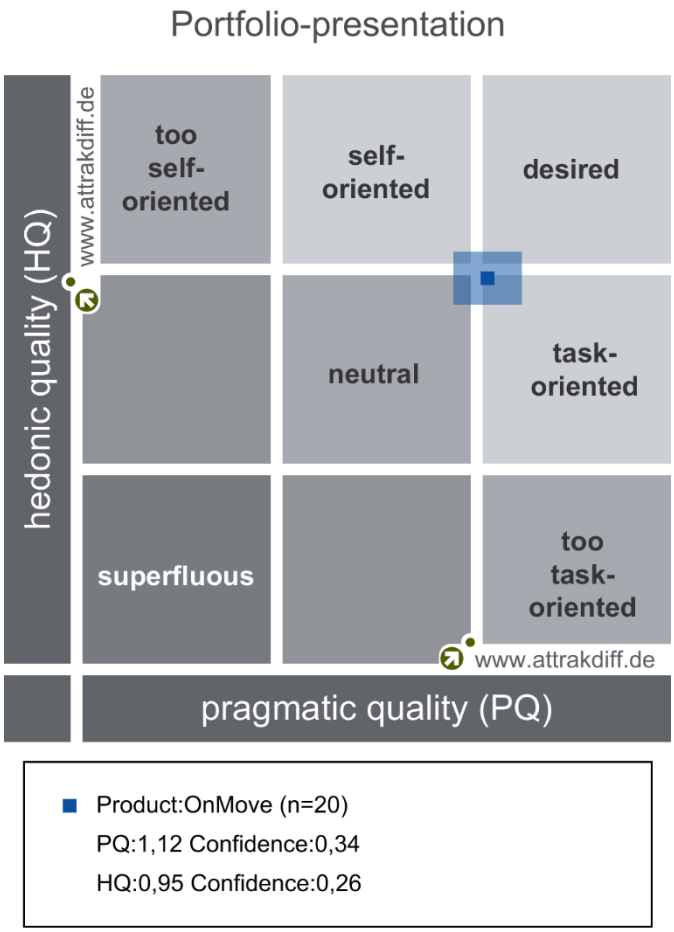

Figure 29 - Portfolio-Presentation

4 Conclusions

As urban transport systems face challenges in providing effective services, new approaches to transportation are emerging. One approach to address this challenge is using shared mobility services (such as bike sharing and ride-sharing, among others), especially in combination with traditional public transport. Hence, this combination of transport systems is a substitute for private vehicles. This is particularly relevant amongst academic campus users (students, teachers and other workers). It is, thus, important to create mechanisms and services that promote a more sustainable and active mobility among such users.

4.1 Main Contributions

By combining the concepts of Gamification, Mobility, and Sustainability, the implementation of the OnMove V2 app was aimed, thus allowing to incentivizeusers to adopt more sustainable and active means of transportation. Therefore, the developing of the OnMove mobility app was initated by defining its architecture. Afterwards, it was included all the technical features and functionalities identified in the literature and through interactions with experts. To perform a usability test and improve the app's attractiveness and ease of use, we also tested its user experience.

It was possible to identify that gamification aims to make tasks more enjoyable, increase motivation, and encourage positive behaviours by integrating game design principles such as points, badges, and leaderboards. The development of gamification frameworks, including their benefits, challenges, and potential applications, has been studied and analyzed, and we found that while the effectiveness of gamification remains an ongoing debate, it has shown promising results in various fields and has the potential to revolutionize how tasks and challenges can be approached in the future.

Upon concluding the study, it was possible to identificy what we believe to be the most effective GDE/Frameworks to apply to a Mobility as a Service platform, especially for use in an academic environment, providing the basis for the development of the second MaaS smartphone application called OnMove, developed under the Smart Living Society activity of the TECH project.

4.2 Research limitations

Given the time and budget constraints of the project, as well as the requirements inherent in developing the OnMove application, we could not test the application regularly with different types of users. As the Alto-Minho Regional Transport Authority limited the data-sharing, obtaining it from different transport operators required additional effort. At the same time, we did not ensure the development of all gamification techniques

in the app; however, we identified all the necessary components. In particular, integrating gamification, mobility, well-being, and sustainability proved more challenging than initially anticipated.

4.3 Future developments

The next step in this project would be to apply the findings about gamification to the already developed mobile application called OnMove as a new module that would operate parallel to the system. By doing so, we will be able to analyze the effects of gamification by measuring user engagement and longevity in the app, solidifying our findings. Chapter 2, Tables 7 and 8 reference the gamification elements to be applied.

Adding quests, personalized goal tracking, virtual rewards and social features (scoreboards and friends) will hopefully provide the users with the extra motivation needed to adopt more sustainable and healthier means of transportation. At the same time, the contribution mechanism and the cheating prevention methods will aid in keeping the users active and involved with the app. It is important to define the implementation methodology (duration of the field study, sample size, among other variables) before the next step.

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Appendixes

a. Appendix 1 – Health Survey

The following survey was developed by the ESS-IPP, as presented below.

Data de nascimento:_____

Massa corporal (em kilogramas, exemplo: se pesar 71 kilogramas, escreva apenas 71) : _____

Altura (em metros, exemplo: se medir 1,76 metros, escreve apenas 1,76)

Já teve alguma uma doença cardiovascular, respiratória e metabólica?

- Sim
- Não
- Não sei o que são doenças cardiovasculares, respiratórias e metabólicas

- **Se já teve/tem alguma uma doença cardiovascular, respiratória e metabólica, indique qual:**
- **Algum dos seus familiares (pais ou irmãos) teve enfarte do miocárdio, ou foi submetido a revascularização coronária ou morte súbita antes dos 55 anos em familiares masculinos de 1o grau ou antes dos 65 em familiares femininos de 1o grau? ***
  - Sim
  - Não
  - Não sei
- **É fumador:**
  - Sim
  - Não
  - Não sei
- **Sofre de colesterol alto? (LDL≥130mg/dL, HDL<40mg/dL, medicação lipidica, cholesterol total ≥200 mg/dL) ***
  - Sim
  - Não
  - Não sei
- **Sofre de diabetes? Ou Pre-diabetes?**
  - Sim

- Não
- Não sei

Table 9 - Survey

Leia as 7 perguntas abaixo cuidadosamente e responda com sinceridade, assinalando SIM ou NÃO
1) O médico alguma vez disse que tem problema de coração _ **OU** tensão alta_?
2) Sente dor no peito em repouso, ao fazer suas atividades quotidianas comuns **OU** ao praticar atividade física?
3) Perde o equilíbrio devido a tontura **OU** ficou inconsciente nos últimos 12 meses? Responda **NÃO** se a tontura estiver associada a respiração rápida e/ou profunda (inclusive durante exercícios intensos).
4) Foi diagnosticado com alguma outra condição crônica de saúde (que não seja tensão alta ou doença cardíaca)? **Liste as condições e aqui:**_____
5) Está a tomar medicamentos prescritos pelo médico para uma condição crônica de saúde? **Liste as condições e os medicamentos e aqui:**_____
6) Atualmente tem (ou teve nos últimos 12 meses) um problema ósseo, articular ou de tecidos moles (músculo, ligamento ou tendão) que poderia se agravar se tornasse mais ativo fisicamente? Responda **NÃO** se tiver tido um problema que **hoje não limita mais a sua capacidade** de fazer atividade física. **Liste as condições e aqui:**_____
7) O médico alguma vez disse que só deveria fazer atividade física sob supervisão médica?
Se respondeu NÃO a todas as perguntas acima, está livre para fazer atividade física. Por favor assine a DECLARAÇÃO DO PARTICIPANTE. **DECLARAÇÃO DO PARTICIPANTE**

Se for menor de idade ou precisar do consentimento de um responsável, o seu pai, mãe, responsável legal ou criador também assinar este formulário.

Eu, abaixo-assinado, li, compreendi satisfatoriamente e preenchi este questionário. Reconheço que esta indicação para a prática de atividade física é valida por no máximo 12 meses a partir da data do preenchimento, e será invalidada caso minha condição de saúde mude. Reconheço também que o estabelecimento onde irei praticar a atividade física pode guardar uma cópia deste formulário para registro. Neste caso, manterá a confidencialidade do mesmo, respondendo às leis e regulamentações aplicáveis.

*NOME:*_____

_____*Data:*_____

*ASSINATURA:*_____

_____*TESMUNHA:* _____

ASSINATURA DO PAI/MÃE/RESPONSÁVEL/CUIDADOR:

_____

_____

Se respondeu **SIM** a uma ou mais perguntas, PREENCHA AS SEGUINTES QUESTÕES

PAR-Q+ em português

1. **Tem artrite, osteoporose ou problemas na coluna?**

   Se a resposta for positiva, responda às perguntas 1a-1c, Se **NÃO**__ salte para a pergunta 2

1a. Tem dificuldade em controlar sua condição com medicamentos ou outros tratamentos prescritos por médicos? (Responda NÃO se não tiver a tomar medicamentos ou fazendo outros tratamentos no momento)

1b. Tem problemas articulares que causam dor, uma fratura recente ou fratura causada por osteoporose ou cancro, vertebra deslocada, (como espondilolistese) e/ou espondilólise/defeito de pars interarticulares (fratura do anel ósseo na parte posterior da coluna vertebral)?
1c. Recebeu injeções de esteroides ou tomou comprimidos de esteroides regularmente por mais de 3 meses?
2. Tem algum tipo de cancro? Se a resposta for positiva, responda às perguntas 2a-2b, Se **NÃO**__ salte para a pergunta 3
2a. O seu diagnóstico de câncer inclui algum destes tipos: pulmão/broncogénico, mieloma múltiplo (câncer de células plasmáticas), cabeça e/ou pescoço?
2.b Está recebendo tratamento para o câncer (como quimioterapia ou radioterapia)?
3. Tem algum problema cardíaco ou cardiovascular? Isto inclui doença arterial coronariana, insuficicencia cardíaca, anormalidade do ritmo cardíaco? Se a resposta for positiva, responda às perguntas 3a-3d, Se **NÃO**__ salte para a pergunta 4
3.a Tem dificuldade em controlar sua condição com medicamentos ou outros tratamentos prescritos por médicos? (Responda **NÃO** se não estiver a tomar medicamentos ou fazendo outros tratamentos no momento)
3.b Tem batimentos cardíacos irregulares que requerem acompanhamento médico (como fibrilação arterial, contração ventricular prematura)?
3.c Tem insuficiência cardíaca crónica?
3.d Foi diagnosticado com doença coronária (cardiovascular) e não praticou atividades físicas regulares nos últimos 2 meses?
4. Tem tensão alta? Se a resposta for positiva, responda às perguntas 4a-4b, Se **NÃO**__ salte para a pergunta 5

4.a Tem dificuldade em controlar sua condição com medicamentos ou outros tratamentos prescritos por médicos(Responda **NÃO** se não estiver a tomar medicamentos ou fazendo outros tratamentos no momento)
4.b Tem tensão arterial em repouso igual ou superior a 160/90 mmHg com ou sem medicação? (Responda **SIM** se não souber a sua tensão arterial em repouso)
5. **Tem algum problema metabólico?** Isto inclui diabetes tipo 1, diabetes tipo 2, pré-diabetes Se a resposta for positiva, responda às perguntas 5a-5e, Se **NÃO**__ salte para a pergunta 6
5a. Costuma ter dificuldade em controlar os seus níveis de açúcar no sangue com a alimentação, com medicamentos, ou com outros tratamentos prescritos por médicos?
5b. Costuma ter sinais e sintomas de pouco açúcar no sangue (hipoglicemia) após exercícios e/ou durante suas atividades quotidianas? Sinais de hipoglicemia podem incluir tremores, nervosismo, irritabilidade fora do comum, transpiração excessiva, tontura, confusão mental, dificuldade para falar, fraqueza ou sonolência.
5c. Tem algum sinal ou sintoma de complicações do diabetes, como doença cardíaca ou vascular e/ou complicações que afetem os seus olhos, rins **OU** perda de sensibilidade nos pés e dedos dos pés?
5d. Tem outros problemas metabólicos (como diabetes gestacional, doença renal crônica ou problemas no fígado?)
5e. Planeja fazer, num futuro próximo, exercícios que são mais intensos ou vigorosos?
6. **Tem problemas de saúde mental ou dificuldade de aprendizagem?** Isto inclui Alzheimer, transtorno de ansiedade, detensão, demência, transtorno alimentar, transtorno psicótico, disfunção intelectual, síndrome de Down Se a resposta for positiva, responda às perguntas 6a-6b, Se **NÃO**__ salte para a pergunta 7

6a. Tem dificuldade em controlar sua condição com medicamentos ou outros tratamentos prescritos por médicos? (Responda **NÃO** se não estiver a tomar medicamentos ou fazendo outros tratamentos no momento)
6b. Tem síndrome de Down **E** problemas da coluna que afetam nervos ou músculos?
7. **Tem alguma doença respiratória?** Isto inclui doença pulmonar obstrutiva crónica, asma, hipertensão arterial pulmonar Se a resposta for positiva, responda às perguntas 7a-7d, Se **NÃO**__ salte para a pergunta 8
7a. Tem dificuldade em controlar sua condição com medicamentos ou outros tratamentos prescritos por médicos? (Responda **NÃO** se não estiver a tomar medicamentos ou fazendo outros tratamentos no momento)
7b. O médico alguma vez disse que tem baixos níveis de oxigênio no sangue em repouso ou durante exercício e/ou que precisa de terapia de oxigênio suplementar?
7c. Se asmático atualmente apresenta sintomas como sensação de aperto no peito, respiração sibilante, dificuldade em respirar, tosse constante (mais de 2 dias/semana) ou usou medição de resgate mais 2 vezes na última semana?
7d. O médico alguma vez disse que tem tensão alta nos vasos sanguíneos dos pulmões?
8. **Tem alguma lesão na medula espinhal?** Isto inclui tetraplegia e paraplegia Se a resposta for positiva, responda às perguntas 8a-8c, Se **NÃO**__ salte para a pergunta 9
8a. Tem dificuldade em controlar a sua condição com medicamentos ou outros tratamentos prescritos por médicos? (Responda **NÃO** se não estiver a tomar medicamentos ou fazendo outros tratamentos no momento)
8b. Costuma apresentar tensão arterial baixa em repouso a ponto de causar tonturas e/ou desmaios?

8c. O médico alguma vez mencionou que apresenta surtos repentinos de tensão arterial (reconhecidos como disreflexia autonômica)
9. **Já teve derrame cerebral?** Isto inclui ataque isquémico transitório ou acidente vascular cerebral Se a resposta for positiva, responda às perguntas 9a-9c, Se **NÃO**__ salte para a pergunta 10
8a. Tem dificuldade em controlar a sua condição com medicamentos ou outros tratamentos prescritos por médicos? (Responda **NÃO** se não estiver a tomar medicamentos ou fazendo outros tratamentos no momento)
9b. Tem dificuldade para caminhar ou mobilidade comprometida?
9c. Sofreu um derrame ou teve comprometimento nos nervos ou músculos nos últimos 6 meses?
10. **Tem qualquer outro problema de saúde não listado acima, ou tem dois ou mais problemas de saúde?** Se tiver outras condições, responda às perguntas 10a-10c, Se **NÃO**__ leia as recomendações da página 4
10a. Sofreu de escurecimento de visão, desmaio ou perda de consciência como resultado de lesão na cabeça nos últimos 12 meses **OU** teve uma concussão cerebral diagnosticada nos últimos 12 meses?
10b. Tem algum problema de saúde que não está listada (como epilepsia, problemas neurológicos, problemas renais)
10c. Tem atualmente dois ou mais problemas de saúde? LISTE OS SEU(S) PROBLEMA(S) DE SAÚDE:_____ _____ E RESPETIVO(S) MEDICAMENTO(S) AQUI:_____ _____
Se respondeu NÃO a todas as perguntas ADICIONAIS sobre problemas de saúde, está apto a tornar-se mais ativo fisicamente – Assine a DECLARAÇÃO DO PARTICIPANTE. Se respondeu SIM a alguma questão deverá consultar o seu médico.

DECLARAÇÃO DO PARTICIPANTE

Pedimos a todos os que preencham o PAR-Q+ que leiam e assinem a declaração abaixo.

Se for menor de idade ou precisar do consentimento de um responsável, o pai, mãe, responsável legal ou criador também assinar este formulário.

Eu, abaixo-assinado, li, compreendi satisfatoriamente e preenchi este questionário. Reconheço que esta indicação para a prática de atividade física é valida por no máximo 12 meses a partir da data do preenchimento, e será invalidada caso minha condição de saúde mude. Reconheço também que o estabelecimento onde irei praticar a atividade física pode guardar uma cópia deste formulário para registo. Neste caso, manterá a confidencialidade do mesmo, respondendo às leis e regulamentações aplicáveis.

*NOME:*_____

_____*Data:*_____

*ASSINATURA:*_____

_____*TESMUNHA:* _____

ASSINATURA DO PAI/MÃE/RESPONSÁVEL/CUIDADOR:

_____

_____

b. Appendix 2 – Unitary Tests

Unitary Backend Tests

- Current User Details

```
it('respondes with details about the current user', async () => {
    const cookie = await global.signin();

    const response = await request(app).get('/api/users/currentuser').set('Cookie', cookie).send().expect(200);

    expect(response.body.email).toEqual('teste@teste.com');
});

it('respondes with null if not autehnticated', async () => {
    const response = await request(app).get('/api/users/currentuser').send().expect(200);
    expect(response.body.currentUser).toEqual(undefined);
});
```

Figure 30 - Current User Details and Authentication Check.

- Signup

```
it('returns a 201 on successfull signup', async () =>
    request(app)
        .post('/api/users/signup')
        .send({
            email: 'teste@teste.com',
            password: 'asdf',
            name: 'teste',
        })
        .expect(201));

it('returns a 400 with an invalid email', async () =>
    request(app)
        .post('/api/users/signup')
        .send({
            email: 'testedasda',
            password: 'asdf',
        })
        .expect(400));

it('returns a 400 with an invalid password', async () =>
    request(app)
        .post('/api/users/signup')
        .send({
            email: 'testedasda',
            password: '',
        })
        .expect(400));
```

Figure 31 - Signup Tests (1)

```
it('returns a 400 with empty fields', async () => {
    await request(app)
        .post('/api/users/signup')
        .send({
            email: 'email@e,masd.pt',
        })
        .expect(400);

    await request(app)
        .post('/api/users/signup')
        .send({
            password: 'asddff',
        })
        .expect(400);
});

it('disallows duplicate emails', async () => {
    await request(app)
        .post('/api/users/signup')
        .send({
            email: 'teste@teste12.com',
            password: 'asdf',
            name: 'teste',
        })
        .expect(201);
    await request(app)
        .post('/api/users/signup')
        .send({
            email: 'teste@teste12.com',
            password: 'asdf',
            name: 'teste',
        })
        .expect(400);
});

it('sets a cookie after a successfull signup', async () => {
    const cookie = await global.signin();
    expect(cookie).toBeDefined();
});
```

Figure 32 - Signup Tests (2).

- SignIn

```
it('fails when a email does not exist is supplied', async () => {
  await request(app)
    .post('/api/users/signin')
    .send({
      email: 'teste2@teste.com',
      password: 'asdfg',
    })
    .expect(400);
});

it('fails when an incorrect password is supplied', async () => {
  await request(app)
    .post('/api/users/signup')
    .send({
      email: 'teste@teste.com',
      password: 'asdf',
    })
    .expect(400);

  await request(app)
    .post('/api/users/signin')
    .send({
      email: 'teste@teste.com',
      password: 'fdsfsdf',
    })
    .expect(400);
});
```

Figure 33 - User Sign in Tests (1).

```
it('respondes with a cookie with valid credentials', async () => {
  await request(app)
    .post('/api/users/signup')
    .send({
      email: 'teste@teste.com',
      password: 'asdf',
      name: 'easdasfsda',
    })
    .expect(201);

  const response = await request(app)
    .post('/api/users/signin')
    .send({
      email: 'teste@teste.com',
      password: 'asdf',
    })
    .expect(200);
  expect(response.get('Set-Cookie')).toBeDefined();
});
```

Figure 34 – User Sign in Tests (2).

- SignOut

```
it('clears the cookie after signing out', async () => {
    await request(app)
        .post('/api/users/signup')
        .send({
            email: 'teste@teste.com',
            password: 'asdf',
            name: 'easdasfsda',
        })
        .expect(201);

    const response = await request(app).post('/api/users/signout').send({}).expect(200);

    expect(response.get('Set-Cookie')[0]).toEqual(
        'express:sess=; path=/; expires=Thu, 01 Jan 1970 00:00:00 GMT; httponly'
    );
});
```

Figure 35 - Sign Out Cookie Test

- List Created Vehicles

```
const createVehicle = async () => {
  const cookie = await signin();

  return request(app)
    .post('/api/vehicles')

    .set('Cookie', cookie)
    .send({
      carModel: 'asdsadsad',
      type: 'asfdasf',
      capacity: '5',
    })
    .expect(201);
};

it('can fetch a list of vehicles', async () => {
  await createVehicle();
  await createVehicle();
  await createVehicle();

  const response = await request(app).get('/api/vehicles').send().expect(200);

  expect(response.body.length).toEqual(3);
});
```

Figure 36 - Lists the test of the created vehicles.

- New Vehicle Test

```
it('has a route handles listening to /api/vehicles post requests', async () => {
  const response = await request(app).post('/api/vehicles').send({});

  expect(response.status).not.toEqual(404);
});

it('it can be only accessed if user is signed in', async () => {
  await request(app).post('/api/vehicles').send({}).expect(401);
});

it('return a status other than 401 if user is signed in', async () => {
  const cookie = await signin();
  const response = await request(app)
    .post('/api/vehicles')

    .set('Cookie', cookie)
    .send({});

  expect(response.status).not.toEqual(401);
});
```

Figure 37 - New Vehicle Tests (1).

```
it('return an error if a invalid type is provided', async () => {
  const cookie = await signin();
  await request(app)
    .post('/api/vehicles')
    .set('Cookie', cookie)
    .send({
      carModel: 'testeModelo',
      capacity: '5',
      type: '',
    })
    .expect(400);

  await request(app)
    .post('/api/vehicles')
    .set('Cookie', cookie)
    .send({
      carModel: 'testeModelo',
      capacity: '5',
    })
    .expect(400);
});
it('creates a vehicle with valid inputs', async () => {
  const cookie = await signin();
  let tickets = await Vehicle.find({});
  expect(tickets.length).toEqual(0);
  await request(app)
    .post('/api/vehicles')
    .set('Cookie', cookie)
    .send({
      carModel: 'testeModelo',
      capacity: '5',
      type: 'asdasf',
    })
    .expect(201);

  tickets = await Vehicle.find({});
  expect(tickets.length).toEqual(1);
  expect(tickets[0].type).toEqual('asdasf');
});
```

Figure 38 - New Vehicle Tests (2).

- Show Vehicles Through Provided ID

```
it('returns 404 if the vehicle is not found', async () => {
  const id = new mongoose.Types.ObjectId().toHexString();
  await request(app).get(`/api/vehicles/${id}`).send().expect(404);
});

it('returns a vehicule if it is found', async () => {
  const cookie = await signin();
  const carModel = 'asdsadsad';
  const type = 'asfdasf';
  const capacity = '5';
  const response = await request(app)
    .post('/api/vehicles')
    .set('Cookie', cookie)
    .send({
      carModel,
      type,
      capacity,
    })
    .expect(201);

  const vehicleResponse = await request(app).get(`/api/vehicles/${response.body.id}`).send().expect(200);
});
```

Figure 39 - Show Vehicles through provided ID Test.

- Update Vehicle Information

```
it('returns a 404 if the provided id does not exist', async () => {
  const cookie = await signin();

  const id = new mongoose.Types.ObjectId().toHexString();
  await request(app)
    .put(`/api/vehicles/${id}`)
    .set('Cookie', cookie)
    .send({
      carModel: 'testeModelo',
      capacity: '5',
      type: 'volvo',
    })
    .expect(404);
});

it('returns a 400 if the user provides an invalid type', async () => {
  const cookie = await signin();

  const response = await request(app).post('/api/vehicles').set('Cookie', cookie).send({
    carModel: 'testeModelo',
    capacity: '5',
    type: 'volvo',
  });

  await request(app)
    .put(`/api/vehicles/${response.body.id}`)
    .set('Cookie', cookie)      You, 18 seconds ago • Uncommitted changes
    .send({
      carModel: 'testeModelo',
      capacity: '5',
      type: '',
    })
    .expect(400);

  await request(app)
    .put(`/api/vehicles/${response.body.id}`)
    .set('Cookie', cookie)
    .send({
      location: 'alskdfjj',
      type: '',
    })
    .expect(400);
});
```

Figure 40 - Update Vehicle Information Test (1).

```
it('updates the vehicle provided valid inputs', async () => {
  const cookie = await signin();

  const response = await request(app).post('/api/vehicles').set('Cookie', cookie).send({
    carModel: 'testeModelo',
    capacity: '5',
    type: 'volvo',
  });

  await request(app)
    .put(`/api/vehicles/${response.body.id}`)
    .set('Cookie', cookie)
    .send({
      carModel: 'testeModelo2',
      capacity: '5',
      type: 'bmw',
    })
    .expect(201);

  const vehicleResponse = await request(app).get(`/api/vehicles/${response.body.id}`).send();

  expect(vehicleResponse.body.carModel).toEqual('testeModelo2');
  expect(vehicleResponse.body.type).toEqual('bmw');
});
```

Figure 41 - Update Vehicle Information Test (2).

- New Routes Tests

```
it('has a route handles listening to /api/routes post requests', async () => {
  const response = await request(app).post('/api/routes').send({});

  expect(response.status).not.toEqual(404);
});

it('it can be only accessed if user is signed in', async () => {
  await request(app).post('/api/routes').send({}).expect(401);
});

it('return a status other than 401 if user is signed in', async () => {
  const cookie = await signin();
  const response = await request(app).post('/api/routes').set('Cookie', cookie).send({});

  expect(response.status).not.toEqual(401);
});

it('return an error if a invalid userId is provided', async () => {
  const cookie = await signin();
  await request(app)
    .post('/api/routes')
    .set('Cookie', cookie)
    .send({
      location: '',
      type: 'asdf',
    })
    .expect(400);

  await request(app)
    .post('/api/routes')
    .set('Cookie', cookie)
    .send({
      type: 'fdsfsdf',
    })
    .expect(400);
});
```

Figure 42 - New Routes Tests (1).

```
it('return an error if a invalid type is provided', async () => {
  const cookie = await signin();
  await request(app)
    .post('/api/routes')
    .set('Cookie', cookie)
    .send({
      location: 'dsf2354324',
      type: '',
    })
    .expect(400);

  await request(app)
    .post('/api/routes')
    .set('Cookie', cookie)
    .send({
      location: 'dsf2354324',
    })
    .expect(400);
});
```

Figure 43 - New Routes Test (2).

```
it('creates a ride with valid inputs', async () => {
  const cookie = await signin();
  let tickets = await Route.find({});
  expect(tickets.length).toEqual(0);
  await request(app)
    .post('/api/routes')
    .set('Cookie', cookie)
    .send({
      startLocation: {
        details: { lat: 123, lng: 456 },
        name: 'Start Location Name',
      },
      type: 'ESS',
      vehicleId: '60ed58dde9bf430019f5482e',
      state: 'AVAILABLE',
      endLocation: {
        details: { lat: 789, lng: 101 },
        name: 'End Location Name',
      },
      estimatedTime: '20 minutos',
      description: 'boa',
      startDate: 'Wed Nov 16 2021 17:05:14 GMT+0100 (Hora de verão da Europa Ocidental)',
      rating: 5,
      capacity: 15,
    })
    .expect(201);

  tickets = await Route.find({});
  expect(tickets.length).toEqual(1);
  expect(tickets[0].type).toEqual('ESS');
});      You, 2 minutes ago • Uncommitted changes
```

Figure 44 - New Routes Test (3).

- Show Routes Tests

```
it('returns 404 if the route is not found', async () => {
  const id = new mongoose.Types.ObjectId().toHexString();
  await request(app).get(`/api/routes/${id}`).send().expect(404);
});

it('returns a vehicule if it is found', async () => {
  const location = 'ESS';
  // const type = 'asfdasf';
  // const availableTime = 'teste';
  // const status = 'Available';

  const cookie = await signin();
  const response = await request(app)
    .post('/api/routes')
    .set('Cookie', cookie)
    .send({
      startLocation: {
        details: { lat: 123, lng: 456 },
        name: 'ESS',
      },
      type: '2',
      vehicleId: '60ed58dde9bf430019f5482e',
      state: 'AVAILABLE',
      endLocation: {
        details: { lat: 789, lng: 101 },
        name: 'End Location Name',
      },
      estimatedTime: '20 minutos',
      description: 'boa',
      startDate: 'Wed Nov 16 2021 17:05:14 GMT+0100 (Hora de verão da Europa Ocidental)',
      rating: 5,
      capacity: 15,
    })
    .expect(201);
  const rideResponse = await request(app).get(`/api/routes/${response.body.id}`).send().expect(200);

  expect(rideResponse.body.startLocation.name).toEqual(location);
});
```

Figure 45 - Show Routes Test

- Update Routes Tests

```
it('returns a 404 if the provided id does not exist', async () => {
  const id = new mongoose.Types.ObjectId().toHexString();
  const cookie = await signin();
  await request(app)
    .put(`/api/routes/${id}`)
    .set('Cookie', cookie)
    .send({
      startLocation: {
        details: { lat: 123, lng: 456 },
        name: 'ESS',
      },
      type: '2',
      vehicleId: '1',
      state: 'AVAILABLE',
      endLocation: {
        details: { lat: 789, lng: 101 },
        name: 'End Location Name',
      },
      estimatedTime: '20 minutos',
      description: 'boa',
      startDate: 'Wed Nov 16 2021 17:05:14 GMT+0100 (Hora de verão da Europa Ocidental)',
      rating: 5,
      capacity: 15,
    })
    .expect(404);
});
```

Figure 46 - Update Routes Tests (1).

```
it('updates the route provided valid inputs', async () => {
  const cookie = await signin();

  const response = await request(app)
    .post('/api/routes')
    .set('Cookie', cookie)
    .send({
      startLocation: {
        details: { lat: 123, lng: 456 },
        name: 'Start Location Name',
      },
      type: 'ESS',
      vehicleId: '60ed58dde9bf430019f5482e',
      state: 'AVAILABLE',
      endLocation: {
        details: { lat: 789, lng: 101 },
        name: 'End Location Name',
      },
      estimatedTime: '20 minutos',
      description: 'boa',
      startDate: 'Wed Nov 16 2021 17:05:14 GMT+0100 (Hora de verão da Europa Ocidental)',
      rating: 5,
      capacity: 15,
    });

  await request(app)
    .put(`/api/routes/${response.body.id}`)
    .set('Cookie', cookie)
    .send({
      type: '100',
      availableTime: 'teste',
      state: 'unavailable',
    })
    .expect(201);

  const rideResponse = await request(app).get(`/api/routes/${response.body.id}`).send();

  expect(rideResponse.body.type).toEqual('100');
  expect(rideResponse.body.availableTime).toEqual('teste');
  expect(rideResponse.body.state).toEqual('unavailable');
});      You, now • Uncommitted changes
```

Figure 47 - Update Routes Tests (2).