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Determinants of technology adoption: The case of Airbus Project 42

MSc Management Engineering

Final Dissertation

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Abstract

Technological progress is reaching unprecedented speeds and milestones around the world, leading to profound changes in daily life and society. In parallel with these advances and as a direct consequence, barriers to cross-border trade continue to fall. In such an environment, it is of utmost importance to understand the multi-layered differences that cause diverse social groups in different regions of the world to perceive and accept the same newly introduced technology differently. Recognising the relevance and complexity of this context, BlueSky, research and development division of Airbus, has launched Project 42. The aim of the project is to understand the determinants of the process of new technology adoption and to create a multi-agent system that can simulate this process and support business decisions by predicting the behaviour of different social and demographic groups in the face of the introduction of new disruptive technologies in the market. To achieve this goal, (1) a literature review was conducted, then (2) a sustainability pillar-based framework was proposed to model the agents of the multi-agent system, and (3) a Serious Game was designed and developed to improve the modelling of the agents and collect relevant information about socio-cultural differences in the process of innovation adoption. This dissertation reports on the author's contribution to Project 42, which is still ongoing. Future results (i.e. the dissemination of the Serious Game and the related data collection) may be published in a new research paper.

Keywords: Technology adoption, Sustainability, Multi-Agent System, Design Thinking, Serious Game

Contents

Introduction

Background information and relevance of the research

The aim of this paper is to report on my contribution to Project 42 during my time in Toulouse, France.

Project 42 is an initiative of BlueSky, the research and development department of Airbus, which aims to discover innovative technologies that are of strategic importance for the future of the Group. The aviation industry is evolving rapidly (Shparberg & Lange, 2022) and more new forms of travel are expected to enter the market in the next decade than in the last century (McKinsey, 2020). Airbus, which as Europe's largest and the world's leading aerospace company has always focused on the aviation industry, now recognises the importance of understanding the human dynamics involved in adopting new technologies.

Understanding the complex dynamics of the acceptance process for new technologies is critical for several reasons. From a business perspective, this understanding can inform where investments should be made to avoid wasting resources on products that will not succeed in the marketplace (Godoe & Johansen, 2012). Furthermore, the introduction of new technologies can have a significant impact on society (Jasanoff, 2016), for example by changing the way people work, communicate and interact with each other. So, from a societal perspective, understanding acceptance factors can help identify potential challenges and benefits associated with the technology and inform policy decisions related to its adoption. New technologies can also have an impact on the environment (Cai, 2021), for example by reducing carbon emissions, improving energy efficiency and reducing waste (Chauhan et al., 2022). Understanding the adoption process can help identify potential environmental benefits and challenges associated with the technology and inform policy decisions related to its adoption (Marcus, 2019). In short, knowledge of the complex dynamics and drivers of new technologies adoption can be of paramount importance to businesses, individuals, policy makers and society. It can inform decision-making around investment, policy and innovation, and lead to better outcomes for society as a whole.

Research objective

Project 42 aims to create a tool for understanding the dynamics of the adoption process of new technologies. This would provide Airbus with important information on consumer behaviour at the time of the introduction of an innovation. In today's globalised environment, where technological growth is exponential, a forecasting tool that provides insights into these dynamics can lead to a significant competitive advantage.

The tool used to achieve this goal is a multi-agent system, a computer-based system consisting of several agents that can be used to create a complex model of society (Dornhaus et al., 2002). Agents are autonomous, intelligent entities that are characterised by certain properties and interact with each other. This system would offer the possibility to simulate complex scenarios in which new technologies are hypothetically introduced and to show the different behaviour of the modelled agents after the occurrence of such an event (i.e. the introduction of a new technology).

In order to build the multi-agent system, relevant data are needed on the basis of which the agents can be modelled. Thus, data have been collected from more than 70 countries on the adoption rate of electric vehicles (an innovation related to sustainability and the mobility industry), as well as data on economic, social, political, environmental and cultural indicators (based on the 5 pillars of sustainability). However, this framework has some limitations, in particular the data are not owned by Airbus and there is no guarantee that these data will continue to be made available over time.

To overcome these limitations, a Serious Game based on the methodology of Design Thinking was developed following two workshops. The purpose of the Serious Game is to collect meaningful data on the willingness to adopt innovations in different geographical and demographic groups. The data collected will be used to achieve two goals:

- To provide the multi-agent system with meaningful and robust data to refine the modelling of the agents and accurately evolve them over time.
- To examine the data collected and, as in the case of the Moral Machine, to verify that its clustering matches that available in the literature.

The first point is of particular interest to Airbus, as it enhances the tool developed by BlueSky to predict consumer behaviour and effectively introduce innovations to the market. The second point, on the other hand, is of academic relevance and more of scientific interest as it can provide relevant information about different social groups.

Overview of the structure of the dissertation

The following dissertation provides a review of the current literature on the adoption of new technologies. A synthesis was made to list the main factors that drive consumers in the process of innovation adoption and that people use as criteria for evaluating technologies. It then shows how the weighting of each criterion has changed over time, with sustainability becoming an increasingly important issue. It then delves into this topic by describing the concept of sustainability and how it has evolved over time, its growing importance (underlined by the Sustainable Development Goals) and its pillars. Finally, it shows how the different awareness of this issue in different social groups can lead to different behaviours in the adoption of new technologies.

Based on the considerations that emerged from the literature review, and in particular on the increasing importance of the issue of sustainability, the methodological section presents the sustainability framework that was created to collect the data required for the development of the multi-agent system. The framework, which serves as the data set for the multi-agent system, considers more than 70 countries and consists of 3 significant indicators for each pillar of sustainability (economic, social, political, environmental and cultural) that are associated with the adoption rate of electric vehicles. The limitations of this model are presented as well as the proposed solution to overcome them, namely the development of a Serious Game. This section describes the workshops organised to develop this Serious Game, the Moral Machine case used as a successful example in the literature, and the Design Thinking method used to co-create the game.

The findings section presents the correlation matrix obtained from the data collected in the sustainability framework, which forms the basis for the development of the multi-agent system. Furthermore, the developed Serious Game is presented and its objectives, design and dynamics are described in detail. Finally, the next steps for the continuation of Project 42, which is still ongoing at the time of publication of this dissertation, are summarised.

1 Literature review

The following chapter aims to analyse the factors that lead individuals to adopt new technologies and how they evaluate them. First, the different criteria are presented and supported with relevant examples. It then looks at how people's weighting of factors has changed over time, with particular emphasis on the growing importance of sustainability in evaluating technologies. The chapter delves deeper into the concept of sustainability by introducing weak and strong sustainability approaches and linking them to the discussion on solutionism. This theoretical excursus is then linked to the research objective of the paper, which aims to investigate the extent to which the spread of these different approaches in different social groups can serve as an early indicator of the willingness to accept new technologies. This hypothesis is tested in the next part of the paper, which deals with methodological analysis.

1.1. Disruptive technologies in a globalised world

Airport for flying taxis and drones powered by a hydrogen generator as a clean alternative to fuel (Alnuaimi, 2021). Surgically implanted bionic eyes to artificially replace the corneas of blind people (Bahar et al., 2022). Living concrete capable of healing structural damage and safely processing air pollution as the basis for the greener cities of tomorrow (Riley et al., 2019). Smartwatches that run on the natural sweat of the human body without using toxic materials to manufacture and dispose of batteries (Mercier & Wang, 2020).

These innovations are just the tip of the iceberg of the future that awaits us. Technological advances around the world are reaching unprecedented speeds and milestones that will fundamentally change both daily life and important societal systems (National Intelligence Council, 2021). In parallel with and as a direct effect of some of these advances, particularly the revolution in information technology (Garrett, 2000), barriers to cross-border trade continue to fall – with some exceptions such as during the Covid 19 pandemic and in the context of political conditions in some eastern states (Altman & Bastian, 2022). The market is increasingly global, both at the supply chain and retail level (OECD, 2022). Large distributors, such as Amazon.com and eBay (Hamilton et al., 2011), have created efficient networks that are able to distribute products at ever lower costs and times. We live in an increasingly globalised and barrier-free environment (Clegg et al., 2003), where the exchange of resources from one part of the planet to another is easy and frequent (Federico & Tena-Junguito, 2016). When a new product or service is launched, it can be available anywhere in the world.

In summary, two main trends underline the analyses:

- Rapid and exponential growth in technological advancement
- Increasingly comprehensive and feasible globalisation of markets

In such an environment, it is of utmost importance to understand the cultural, social, economic, political and psychological differences that cause different social groups in different regions of the world to perceive and accept the same newly introduced technology differently.

The adoption of new disruptive technologies by individuals, organisations and societies is a complex process that is influenced by a number of factors, including the characteristics of the technology itself, the context in which it is introduced and the attitudes and behaviours of individuals and organisations considering its adoption (Rogers, 1995). It is of paramount importance to consider how people perceive and judge technologies, as we run the risk of rejecting technologies that could improve social well-being or, conversely, introducing technologies that could have negative social consequences without noticing this in time (Hidalgo et al., 2021). For example, as reported in the book 'How People Judge Machines' by César Hidalgo (2021), a medical diagnostic tool that is not perfect but more accurate than human doctors may be rejected if machine errors are judged or published with a strong negative bias.

The following section analyses the different determinants that drive the process of adoption of new technologies and how these factors have changed and continue to change over time.

1.2. Determinants of new technologies adoption

This section analyses the criteria that lead people to adopt new technologies. A synthesis was made by analysing the existing literature and deriving the main factors that people have used to evaluate technologies over the years.

There are several criteria by which people judge past and present technologies. The following list attempts to capture all the different factors that are relevant to people's adoption of innovations. Each item on the list is then examined individually with specific references to existing literature and an attempt is made to link it to case studies that illustrate and depict the importance of the item in a real technology adoption process.

The main purpose of the following list is to provide a comprehensive overview of the key factors that people consider both consciously and unconsciously when assessing and evaluating new technologies.

Factors for evaluating and judging technologies:

1. **Usefulness**
   - Effectiveness: The extent to which a technology can fulfil its intended purpose or function and how well it compares to other technologies or alternatives (Cambridge Dictionary, 2023).
   - Reliability: The ability of a technology to perform its intended function consistently without failure or error and to deliver accurate and consistent results (Doty, 1989).

2. **Availability**
   - Affordability: the extent to which a technology is accessible and affordable to users (Cambridge Dictionary, 2023a), and its cost relative to the perceived value or benefit it provides.
   - Accessibility: the ease with which a technology can be accessed (Cambridge Dictionary, 2023a), used and adopted by users, including factors such as trialability, observability (Rogers, 1995), organisational factors and versatility (Cambridge Dictionary, 2023d) of the technology.

3. **Ease of use**
   - Usability: the extent to which a technology is easy for users to use (Cambridge Dictionary, 2023d), navigate and understand, and the degree

of satisfaction and enjoyment users experience when using it (Davis, 1989).

- Required behavioural change: the extent to which the adoption of a new technology requires individuals to modify their established behaviors, norms, habits, and traditions (Kleijnen et al., 2009).

4. **Social factors**
   - Social influence: the extent to which social norms and influences affect the adoption and use of a technology, including factors such as perceived social norms, social pressures and cultural values (Ajzen, 1991).

5. **Ethical and legal considerations**
   - Security and privacy: the extent to which a technology protects users' data, privacy and security, and how it complies with ethical and legal considerations and regulations.

6. **Safety**
   - Safety: the extent to which a technology is safe to use and how it manages perceived risks or potential harm to users, including physical, psychological and emotional safety (Shoemaker & Shoaf, 1975).

7. **Environmental aspects**
   - Sustainability: the extent to which a technology meets the needs of the present without compromising the ability of future generations to meet their own needs (United Nations Brundtland Commission, 1987).

The importance of the criteria listed may vary depending on the technology and the context in which it is used (Kline & Rosenberg, 1986). Furthermore, some criteria may be more important than others depending on the perspective of the person or organisation assessing the technology (Bijker et al., 2012).

It is important to note that the factors used to evaluate past technologies may differ from those used to evaluate current technologies, and that the relative importance or weighting of each criterion may have changed over time. In the past, more weight may have been given to criteria such as effectiveness and reliability, as the focus was on whether the technology performed the intended task well. More recently, however, criteria such as safety, sustainability (Frey et al., 2023; Glavič & Lukman, 2007), and ethical and legal implications (IBM-Harris Poll Survey, 2019) have become more important.

One of the main differences between the criteria of the past and the present is the increasing emphasis on the ethical and social implications of new technologies (Owen & Pansera, 2019; Jasanoff, 2016). While in the past the main focus was on whether a technology works well, today there is a greater awareness of the potential negative impacts of a technology on society, such as job displacement (Ivanov et al., 2020), invasion of privacy (Uchidiuno et al., 2018), etc. Another difference is the increasing importance of sustainability and environmental impacts (Verbeke et al., 2007). Today, there is a growing awareness of the need to minimise the environmental impact of new technologies and design them to be economically viable in the long term. This was explicitly recognised in the United Nations Sustainable Development Goals adopted in 2015.

Overall, the weighting and importance of the various criteria used to evaluate new technologies have changed over time, reflecting changes in societal values, advances in technology and changes in the global economic and political landscape. In the continuation of this work, we will focus in particular on the increasing attention to the issue of sustainability, as this is definitely a key factor in the acceptance of new technologies today, as has already been emphasised. First, however, an in-depth analysis of each of the above factors will be undertaken, reviewing the current literature on the subject and using a use case as an example of the importance of the criterion in a real adoption process.

1.2.1. Usefulness

Usefulness is a criterion for evaluating technology that refers to the extent to which the technology is perceived as useful or beneficial by its users. According to the Technology Acceptance Model (TAM) proposed by Davis in 1989, perceived usefulness is one of the key factors that determine whether a person accepts and uses a technology. Perceived usefulness is defined as "the extent to which a person believes that using a particular system would improve his or her job performance" (Davis, 1989). Perceived usefulness is determined by several factors, such as the technology's ability to improve productivity, reduce costs, open up new opportunities, increase efficiency or improve quality of life. The usefulness of a technology is also influenced by the user's previous experience and expectations, as well as the context in which the technology is used. Studies have shown that perceived usefulness is a crucial factor in technology adoption and use. For example, a study by Venkatesh and Davis (2000) found that perceived usefulness significantly influenced users' intention to use a new information system. Similarly, Sun and Zhang (2006) found that perceived usefulness was positively related to user satisfaction and continued use of mobile services.

Usefulness is a criterion used to assess the extent to which a technology can meet the needs of its users and provide tangible benefits. It includes the subcategories of effectiveness and reliability, both of which are critical in determining the overall usefulness of a technology. Effectiveness is the measure of a technology's ability to fulfil its intended purpose or function (Cambridge Dictionary, 2023) and how well it compares to other technologies or alternatives, which includes performance, time, productivity and efficiency gains. For example, a software programme may be considered effective if it meets the needs of its users and helps them achieve their goals efficiently. On the other hand, a product that does not fully achieve its intended purpose or does not perform as well as competing alternatives may be considered ineffective. On the other hand, reliability refers to the ability of a technology to perform its intended function consistently and accurately without failure or error (Doty, 1989). For example, a medical device that consistently provides accurate readings is considered reliable, while one that does not may be considered unreliable and potentially dangerous. In combination, effectiveness and reliability help determine the overall utility of a technology and its potential for adoption and diffusion.

Case study: the personal computer (PC)

An example of a technology that has been adopted in the past because of its usefulness is the personal computer (PC). In the 1970s and 1980s, the PC emerged as a new technology that promised to revolutionise the way people worked and communicated (Press, 1993). Originally developed for hobbyists and computer enthusiasts (Fichman, 1992), the PC quickly became popular in the business world because of its usefulness in increasing productivity and efficiency (Gilchrist et al., 2001). The usefulness of the PC was evident in its ability to automate manual tasks such as data entry, calculations and document creation. This enabled businesses to process information faster and more accurately than ever before. In addition, the PC facilitated communication within and outside the company by providing new tools for email, instant messaging and video conferencing: "the computer screen is a window to this world" (Harasim, 1993). As PC became more widely used, its usefulness grew as software developers created new applications to meet the needs of different industries and tasks. PC also helped democratise access to information and technology (Rogers & Malhotra, 2000) so that small businesses and individuals could compete on a level playing field with larger organisations (Ives & Learnmonth, 1984). Overall, the usefulness of PC was a key factor in its widespread adoption and continued success, demonstrating the importance of effectiveness as a criterion for evaluating new technologies.

1.2.2. Availability

Availability is the criterion that refers to the ease with which the technology can be obtained and accessed. Technologies that are difficult to obtain or require a lot of effort to use are less likely to be adopted than those that are easy to access and use. This criterion can be divided into two subcategories: Affordability and Accessibility. Affordability refers to the cost of acquiring and using the technology, including the purchase price, maintenance costs and other expenses associated with its use (Cambridge Dictionary, 2023a). Technologies that are too expensive are often only available to the wealthy, while technologies that are affordable to the masses are more likely to be adopted. On the other hand, accessibility encompasses the ease of access to the technology, including factors such as trialability and observability (Rogers, 1995). A technology that is affordable and easily accessible is more likely to be adopted and used by a greater number of people. However, other factors such as compatibility with existing complementary devices, systems and organisational factors, as well as the versatility of the technology, i.e. its ability to adapt to changing needs (Davis, 1989) and to be used in different contexts, can also influence the availability of a technology.

Overall, the concept of availability is crucial to the success of a technology, as it can strongly influence its acceptance and use by potential users. A technology that is too expensive or difficult to access may not be considered or may be overlooked, regardless of its potential benefits or effectiveness. In contrast, a technology that is affordable, accessible, compatible and versatile is more likely to be adopted and integrated into a user's daily routine or organisational processes.

It is important to note that the availability of technology is important for a variety of reasons. Not only does it increase the number of people who can use a technology, but it can also help to reduce the digital divide and increase equality of opportunity (Fuchs, 2009). Access to technology can have a significant impact on education (Light, 2009), employment and economic opportunities, especially in developing countries (Doong & Ho, 2012).

Case study: Gutenberg's printing press

The widespread introduction of the printing in the 15th century is a prime example of a technology that was historically introduced because of its advantages in availability. Before the advent of printing, books had to be copied by hand by scribes (Dewar, 1998), which made them expensive and limited their availability to a small group of elites. The invention of printing by Johannes Gutenberg in the mid-15th century revolutionised the production of books by making it possible to print multiple copies quickly and cheaply (Kreis, 2004). This increased the availability of books, made them accessible to a wider audience and led to a rise in literacy rates across Europe. The availability advantage of the printing press also played a key role in the success of the Protestant Reformation, as it enabled the mass production and dissemination of Martin Luther's writings and ideas (Rubi, 2011). Printing enabled the spread of knowledge and ideas on a previously unimaginable scale and led to cultural, religious and political changes that shaped the modern world. The availability of printed material played a crucial role in the spread of the Reformation, the Scientific Revolution and the Enlightenment, among other movements (Eisenstein, 1985). The availability of the printing press was thus a key factor in its widespread use and transformative effect on society.

1.2.3. Ease of use

When evaluating a technology, ease of use is a critical criterion. It refers to how straightforward and user-friendly a technology is, and it is often influenced by the level of usability and the required behavioural change. Usability refers to the extent to which a technology is easy for users to use, navigate and understand (Davis, 1989), while required behavioural change refers to the degree to which an individual must modify their behaviour or habits to use the technology effectively. These concepts are directly related to ease of use, as a technology with high usability and minimal required behavioural change is likely to be easier to use. In this section, we will explore the concepts of usability and required behavioural change, and how these factors can influence the adoption of new technologies.

The concept of usability encompasses several aspects, such as the simplicity and intuitiveness of the user interface, the ease with which the use of the technology can be learned and remembered, and the efficiency and satisfaction of completing tasks with the technology. Davis (1989) argues that usability is a multidimensional construct that can be assessed in terms of the interface, simplicity and manageability of a technology. Interface refers to the way in which the technology presents information and allows interaction with the user. This includes factors such as the layout, design and navigation of the technology. Simplicity refers to the ease with which users can understand and use the technology, including how easily users can learn to use it and how intuitive it is. Manageability, on the other hand, refers to the extent to which the technology can be maintained and updated over time, and the extent to which users can control and adapt the technology to their needs.

The International Standards Organization (ISO) defines usability as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use". In other words, usability focuses on how well a technology can be used by intended users to achieve their goals with ease and satisfaction.

Usability is an essential criterion for technology adoption as it can greatly influence user acceptance and satisfaction. A technology that is difficult or frustrating to use can lead to lost productivity, increased user errors and resistance, or abandonment of the technology. On the other hand, a technology that is easy and enjoyable to use can increase user satisfaction, increase productivity and facilitate adoption and diffusion of the technology (Nielsen, 1993). According to Nielsen, "Usability is a quality attribute that assesses how easy user interfaces are to use. The word "usability" also refers to methods for improving ease-of-use during the design process". The expert has identified five quality components that contribute to the overall usability of a technology. These are: Learnability, Efficiency, Memorability, Error and Satisfaction (Nielsen, 2012). Learnability refers to how easy it is for users to learn how to use the technology ("to accomplish basic tasks the first time they encounter the design"); efficiency refers to the speed and ease with which users can complete tasks once they have learned how to use the technology; memorability refers to how easily users can remember how to use the technology after a period of non-use (skill re-establish proficiency); errors refer to the frequency and severity of mistakes users make when using the technology; and satisfaction refers to the extent to which users are satisfied with the technology ("how pleasant it is to use the design").

A second crucial aspect affecting the ease of a technology is the behavioural change required. In their famous work on Prospect Theory, Kahneman and Tversky (1979) analyse the role of the individual adopter in the process of innovation diffusion. According to them, the adoption of an innovation depends on two main dimensions: the required behavioural change and the (perceived) benefits of the innovation. Decision-makers compare the gains and losses associated with a choice, but it is difficult to convince them to adopt an innovation because they would not rationally compare it with their old solution. This leads to consumer resistance, which can hinder the adoption and diffusion of new technologies. Similarly, Kleijnen et al. (2009) identify two main sets of antecedents for consumer resistance: the extent of change required (in terms of established behaviours, norms, habits and traditions) and psychological conflicts or problems with the consumer's prior belief structure. Therefore, a technology that requires minimal behavioural change is more likely to be adopted, as this reduces the perception of loss associated with the adoption of a new technology.

In summary, the concept of ease of use is critical to the successful adoption and use of a technology. This criterion includes the sub-criteria of usability and required behavioural change. A technology with high usability that requires little behavioural change is more likely to be perceived as user-friendly by its potential users and consequently adopted. The successful adoption of a technology depends not only on its functionality, but also on its ease of use, which in turn can influence the user's attitude towards the technology. Therefore, ease of use has a direct influence on the degree of acceptance and adoption by users

Case study: Apple Macintosh and the graphical user interface (GUI)

An example of technology adopted for its ease of use is the Apple Macintosh, introduced in 1984 (Guterl, 1984). Unlike its competitors at the time, the Macintosh offered a graphical user interface (GUI) that allowed users to interact with the computer through icons and menus rather than text-based commands.

The first GUI was developed in the 1970s by the Xerox Palo Alto Research Center (PARC) (Barnes, 2010). Before the GUI, computers were operated through command line interfaces that required users to type in complex code to perform tasks. The GUI replaced this with a user-friendly visual interface that used icons, windows and menus to help users interact with the computer. This greatly simplified the use of the computer and made it accessible to a greater number of people. The GUI was eventually adopted by Apple for the Macintosh computer in 1984 and played an important role in popularising personal computers.

The graphical user interface made the Macintosh much more accessible to the average user who may have had no experience with computers or programming languages. The Macintosh's user interface was also designed to be intuitive and user-friendly, with features such as the mouse, drag-and-drop functionality, and the ability to use multiple programmes simultaneously (Jansen, 1998). These design choices made the Macintosh much easier to learn and use than other computers of the time and helped establish Apple as a major player in the personal computer market.

Today, the principles of usability and user-centred design remain important in the development of new technologies (Juàrez-Ramìrez, 2017; ISO 9241-210:2019). Companies such as Apple and others have recognised the importance of making their products as simple as possible for all users (Sheppard et al., 2018; Reckon, 2022).

1.2.4. Social factors

Social influence is a crucial criterion for evaluating the adoption of new technologies. It refers to the influence that social factors and interactions have on an individual's decision to adopt a new technology, namely "the degree to which an individual perceives that important others believe he or she should use the new system" (Venkatesh et al., 2003).

As Rogers (1995) noted, the decision-making process of potential adopters is influenced and driven by the social structures in which the adopters are embedded. This applies to the social phenomenon of bandwagon effect, i.e. the extent to which demand for a good is increased by the fact that others also consume the same good (Leibenstein, 1950). This type of behaviour is particularly pronounced for network goods (when a critical mass is to be reached). This concept is close to the psychological concept of herd behaviour, i.e. the situation in which a potential user adopts an innovation if many other actors socially close to him adopt it, regardless of the quality of the innovation or, as Banerjee (1992) says, "even regardless of individual information suggesting something else". The basic idea underlying both phenomena is to observe the behaviour of others in order to eliminate uncertainty.

The role of social influence in technology adoption decisions is complex and subject to a variety of conditional influences. Social influence affects individual behaviour through three mechanisms: compliance, internalisation and identification (Venkatesh & Davis 2000; Warshaw 1980). The mechanism of conformity involves individuals simply changing their intention in response to social pressure, i.e. intending to conform to social influence, while internalisation and identification refer to the change in the individual's belief structure and/or the individual's response to possible social status gains.

According to social influence theory, people's attitudes and beliefs are influenced by their interactions with others, and these interactions can affect their perceptions of the usefulness, ease of use and overall value of a technology (Davis, 1989). This includes the influence of social norms (Ajzen, 1991), which cause people to conform to the behaviour of those around them, especially those they consider credible or trustworthy (Deutsch & Gerard, 1955).

Following the psychological perspective, social influence can be divided into three main categories: informational influence, normative influence and compliance. Informational influence is when a person adopts a new technology because they believe it will give them information or knowledge they did not have before (Deutsch & Gerard, 1955). Normative influence is when a person adopts a new technology because it is seen as socially acceptable or desirable (Cialdini & Trost, 1998). Compliance occurs when a person adopts a new technology because of the pressure or influence of others, regardless of their personal beliefs or preferences (Kelman, 1958).

In summary, social influence is a crucial factor in the adoption of new technologies. It is the influence that social factors and interactions have on a person's decision to adopt a new technology.

Case study: Facebook

An example of a technology that has spread in the past through social influence is Facebook. When Facebook first launched in 2004, it was only available to users with a Harvard email address (Wilson et al., 2012). However, as more universities were added to the platform, Facebook's social influence began to grow. The social networking site quickly became a popular way for students to connect and communicate with each other, and it was not long before it spread beyond universities and into the mainstream.

Facebook's success can largely be attributed to the social impact it had on its users (Perez-Vega et al., 2016). As more and more people used the platform, it became a widely accepted way to connect with friends, family and acquaintances online. The first users of Facebook were mainly university students who shared the platform with their fellow students, which started a domino effect. Facebook's social influence led to a bandwagon effect that encouraged adoption (Fu et al., 2012), even though there were already established social networks like Myspace and Friendster that offered similar features. As more and more people joined, those who were not yet on the platform were encouraged to join so as not to miss out on social connections and updates. Facebook became the norm and anyone who did not have a Facebook account was a social outlier.

The case study on Facebook adoption shows how important social influence is for technology adoption. Facebook's success can be partly attributed to the informational influence that resulted from its widespread use by university students. This created a social norm for using the platform (Vorvoreanu, 2009), leading to increased pressure to adapt and adopt the technology. As the user base grew, the platform also became more useful, reliable and available, contributing to its continued success.

The concept of social influence can be understood as the influence that other people have on a person's beliefs, attitudes and behaviours (McDonald & Crandall, 2015). In the case of technology adoption, social influence can take different forms, such as normative influence, where individuals conform to the expectations of a group, or informational influence, where individuals rely on the expertise of others to make decisions. These social factors are closely related to the perceived usefulness, ease of use and availability of a technology, as people often adopt technologies that match their social context and expectations (Rogers, 1995). In this context, the role of social influence is crucial to understanding technology adoption. It highlights the importance of considering social dynamics and group norms when developing and adopting new technologies.

1.2.5. Ethical and legal considerations

Ethical and legal considerations are essential in the adoption of any technology (Manning et al., 2023; Lin et al. 2020; Thompson, 2021). Ethical considerations refer to issues of morality such as fairness, equality and justice (Killen, 2018), while legal considerations refer to compliance with laws and regulations (Cambridge Dictionary, 2023). These two factors are critical to the social acceptance of a technology and the legal and regulatory environment in which it is deployed (Sharma & Safa, 2022). In addition, security and privacy concerns must be carefully considered when introducing technologies (Johnson et al., 2020). Security refers to measures taken to protect technology systems and infrastructures from unauthorised access, theft and other forms of malicious activity (Bacon, 2021). Privacy, on the other hand, involves protecting individuals' personal information and data from unauthorised access, use and disclosure (The World Bank, n.d.).

As technology becomes more widespread, ethical and legal considerations become increasingly important. The rapid development of technology has led to ethical and legal considerations in several areas, including intellectual property rights, data protection and cybersecurity (Shackelford, 2016). For example, the use of artificial intelligence (AI) raises concerns about ethical issues such as bias, fairness and accountability (Varona & Suàrez, 2022). These concerns need to be addressed to ensure that the use of AI is ethical and complies with legal requirements. Similarly, the use of any technology must comply with applicable laws and regulations. For example, the use of drones is subject to various legal and regulatory requirements, including obtaining the necessary permissions and complying with data protection regulations (EASA, 2020). Failure to comply with legal and regulatory requirements can lead to significant consequences, including legal liability and reputational damage. Furthermore, the introduction of technologies must be accompanied by measures to ensure security and data protection (Johnson et al., 2020). Security threats such as cyber-attacks can compromise the integrity and confidentiality of information systems and cause significant damage. Privacy concerns such as unauthorised access to data and misuse of personal information must also be considered. Failure to address security and privacy concerns can lead to legal liabilities, financial loss and reputational damage.

In summary, ethical and legal considerations are essential in the adoption of technology. As technology advances, it becomes increasingly important to address these considerations along with security and privacy concerns.

Case study: Electronic Health Record (EHR) system in the United States

An example of technology that was historically adopted due to ethical and legal considerations is the electronic health record (EHR) system. The adoption of EHRs in the United States was accelerated by the Health Information Technology for Economic and Clinical Health (HITECH) Act (Kadakia et al., 2021), which was passed in 2009 as part of the American Recovery and Reinvestment Act (American Speech-Language-Hearing Association, n.d.). The HITECH Act provided incentives for healthcare providers to adopt EHRs and included provisions to protect the privacy and security of patient health data (HIIPA Journal, 2023).

Prior to the adoption of EHRs, patient health records were typically kept in paper form, which posed significant security and privacy risks (Menachemi & Collum, 2011). Paper records could easily be lost or stolen, and healthcare providers often had difficulty sharing patient data with other providers, which could lead to medical errors or delays in care. The adoption of EHRs not only improved the security and privacy of patient data, but also enabled more efficient sharing of patient data between healthcare providers, leading to improved quality of care.

The adoption of EHRs also had ethical implications. For example, EHRs gave patients greater access to their own health information and more control over their healthcare decisions. This greater transparency and patient ownership is consistent with the ethical principles of autonomy and beneficence in health care (Chopra & McMahon, 2011). In addition, by adopting EHRs, healthcare providers have been able to demonstrate that they meet the legal requirements for maintaining the privacy and security of patients' health information, as outlined in the Health Insurance Portability and Accountability Act (HIPAA).

The adoption of EHRs in the United States has thus been driven by a combination of ethical and legal considerations, as well as security and privacy concerns.

1.2.6. Safety

Safety is an important criterion in the adoption of technologies and refers to the degree of protection from harm or danger that a technology provides. According to Shoemaker and Shoaf's (1975) definition, safety includes both physical and non-physical harm, such as psychological or emotional harm. In addition, the authors state that perceived risk associated with the introduction of a new technology is a crucial factor in resistance to innovation.

The concepts of perceived risk and acceptable risk are important to consider in the new technologies adoption process new technologies from a safety perspective. Perceived risk refers to the extent to which a user believes that a particular technology may cause harm or negative consequences (Lim, 2003). The importance of this concept was highlighted by Mitchell (1999), who stated that perceived risk is a stronger explanation for consumer behaviour, as consumers are motivated to avoid mistakes rather than maximise benefits when making purchases.

Acceptable risk, on the other hand, refers to the level of risk that users are willing to tolerate in return for the benefits of the technology (Kaplan & Garrick, 1981). The concept of social acceptance of new technologies is closely related to the concept of 'acceptable risk'. However, this concept is difficult to quantify and cannot be readily associated with the adoption of innovations because it is contextual and depends on the activities to which it applies. (Otway and Von Winterfeldt, 1982).

In the context of technology adoption, perceived risk and acceptable risk are closely related to the concept of trust (Lim, 2003). Users are more likely to adopt new technologies if they trust that the technology is safe and reliable (Stewart, 1999; Kim & Prabhakar, 2000; Mayer et al-, 1995). This trust can be influenced by factors such as the reputation of the company or person developing the technology, the transparency of the development process, and the extent of regulation or oversight that ensures safety.

When it comes to technology and its adoption, safety can be assessed by evaluating the risks and potential harms associated with the use of a particular technology and the measures taken to mitigate those risks. Ensuring safety is important not only for protecting users, but also for maintaining public trust in the technology and promoting its widespread adoption (Lang & Hallman, 2005). Safety considerations are therefore a crucial aspect in the design, development and introduction of new technologies and in the whole process of adoption of innovations by society.

Case study: Automobiles – Airbags, seat belts and anti-lock braking systems (ABS)

An example of a technology that was historically adopted because of its safety benefits is the airbag. The airbag was developed in the 1950s (Meier, 2012), but it was not until the 1980s that it became a standard safety feature in automobiles. The decisive factor for the adoption of the airbag was the concern for the safety of motor vehicles and the need to reduce the number of fatalities and injuries in car accidents. Studies had proven that consumers were willing to pay for airbags (Mannering & Winston, 1995). Airbags have been shown to significantly reduce the risk of serious injury or death in crashes (Pintar et al., 2000), and their adoption was driven by the desire to make cars safer for drivers and passengers.

The introduction of seat belts in the 1960s was also a major safety improvement that initially met with resistance from many drivers (Gantz & Henkle, 2002). However, as the benefits of the seat belt became more apparent, it became more widely accepted and is now standard equipment in all cars. The National Highway Traffic Safety Administration (NHTSA), in agreement with traffic safety researchers, finds that seat belts reduce the likelihood of dying in a crash by 45% and the likelihood of being injured by 50%.

Finally, the introduction of anti-lock braking systems (ABS) in the 1980s and 1990s was driven by concerns about car safety and the need to reduce accidents caused by skidding and loss of control (Gowda et al., 2019). ABS have been shown to reduce the risk of accidents and improve overall vehicle safety (Burton et al., 2004). The adoption of ABS was driven by the desire to improve driver and passenger safety and it has become a standard feature in modern cars (Brauer, 2011).

In summary, the adoption of some relevant new technologies in the automotive industry has been driven by concerns about safety, and advances in safety features have played an important role in reducing the perceived risks associated with vehicle use. The airbag, seat belts and anti-lock brakes are examples of safety features that were initially viewed with scepticism, but have become standard features in modern automobiles due to their proven effectiveness in reducing the risk of serious injury or death in crashes (Mackay, 1991). These safety features have been instrumental in increasing the popularity of cars as a primary mode of transport, as people feel safer with this technology and this influences the vehicle purchase process (Koppel et al., 2008). By reducing the perceived risks associated with car use, advances in safety have contributed to the growth and development of the automotive industry, making it one of the most important industries in the world.

1.2.7. Environmental aspects

Environmental aspects are a decisive criterion for the adoption of new technologies. Sustainable development has become an increasingly important concept for organisations, governments and society as a whole (Global Investors for Sustainable Development Alliance, 2019). Sustainability means meeting the needs of the present without compromising the ability of future generations to meet their own needs (United Nations Brundtland Commission, 1987).

In the context of technology adoption, sustainability does not only mean that the technology should be environmentally friendly, i.e. that it should minimise negative impacts on the environment throughout its life cycle, from production to disposal (Pajula et al., 2017), but this concept encompasses several interrelated dimensions. As the United Nations General Assembly highlighted in the 2030

Agenda for Sustainable Development (2015) with the 17 Sustainable Development Goals (SDGs), these dimensions include economic, environmental, social, cultural and political aspects.

The economic dimension refers to "practices that support long-term economic growth without negatively impacting social, environmental, and cultural aspects of the community" (University of Mary Washington, 2017). The social dimension refers to recognising and dealing with the impact of an enterprise on individuals, whether positive or negative. Building and maintaining good relationships and interactions with stakeholders is crucial. Businesses directly or indirectly impact the well-being of employees, supply chain workers, customers and surrounding communities, so there is a need to proactively manage these impacts (United Nations Global Compact, 2023). The environmental dimension assesses the "the ability to maintain an ecological balance in our planet's natural environment and conserve natural resources to support the wellbeing of current and future generations" (Microsoft, n.d.). The cultural dimension refers to the ability to maintain or improve values and beliefs despite external pressures. This characteristic is seen as conducive and driving sustainable development and plays a central role in sustainable development initiatives (Bouronikos, 2022). The political dimension assesses the policies, regulations and governance structures that influence the adoption and implementation of the technology and the distribution of its benefits and costs among different stakeholders (Neves et al., 2022). Understanding and balancing these different dimensions of sustainability are critical to the long-term viability and acceptance of new technologies.

Adopting sustainable technologies can help companies reduce their environmental impact (Burgeon & Hovsepian, 2018), improve their reputation

(Darko et al., 2017) and secure competitive advantage (Shahzad et al., 2022). Moreover, the adoption of sustainable technologies not only benefits businesses but also contributes to a more sustainable society as a whole (Pearce et al., 1989). By adopting environmentally friendly technologies, companies can help reduce the negative impacts of their operations on society, such as air pollution and resource depletion (Omer, 2008). In addition, sustainable technologies can improve the overall quality of life of individuals (Steg & Gifford, 2005) by increasing the availability and quality of resources such as water and energy. Adopting sustainable technologies is not only an economic imperative, but also a social responsibility that can lead to a more just and equitable society. Therefore, companies should also consider societal benefits when making decisions about the adoption of sustainable technologies, as this can have a positive impact on their reputation, stakeholder relations and long-term success.

Given the fundamental importance of sustainability in shaping the future of our society and planet, in the next sections of this paper we will focus on using it as a key criterion for assessing the introduction of new technologies. This decision is motivated by the growing relevance and urgency of sustainability as we face unprecedented environmental and social challenges that require immediate and effective action (Silvestre & Ţîrcă, 2019). Yet despite its importance, sustainability is often overlooked in the technology adoption literature, which has traditionally focused on criteria such as usefulness, availability and ease of use. This paper aims to fill this gap by highlighting the growing importance of sustainability as a key factor for innovation adoption in recent years and contributing to a better understanding of the complex relationship between technology and sustainability.

Case study: Wind turbines

The adoption of sustainable technologies is a critical component in addressing the pressing environmental challenges facing our planet. A notable example of a technology introduced for its sustainability benefits is the wind turbine. Wind energy was initially seen as a fringe technology with limited potential to generate large amounts of energy, so interest fluctuated (Johansen, 2021). However, as the world increasingly shifts towards renewable energy sources, wind energy has become a significant and rapidly growing component of the global energy mix (Allamehzadeh, 2016). According to the International Energy Agency (IEA), wind energy will become the largest source of electricity generation in Europe by 2027, surpassing both coal and gas (Deign, 2018).

The adoption of wind turbines can be traced back to the 1980s, when the concept of sustainable development gradually took hold. Denmark was one of the first countries to turn to wind energy (Johansen, 2021). In 1981, the Danish Wind Turbine Manufacturers Association was established (Danish Wind Industry Association, 2001) and a concerted effort was made to promote the adoption of wind energy as a means of reducing dependence on fossil fuels and promoting sustainability. These efforts have been driven by a combination of government action and citizen initiatives, with small wind turbines being installed on farms and in rural communities across the country (Krohn, 2022).

The reason for the adoption of wind power is the benefits of sustainability. Wind power is a clean and renewable energy source that produces no greenhouse gas emissions or other harmful pollutants (Peri & Tal, 2020). It also provides an alternative to fossil fuels, which are a finite resource and subject to price fluctuations and supply disruptions (Bhattacharyya, 2009). In addition to reducing greenhouse gas emissions and promoting energy independence, wind energy has also created jobs (Blanco & Rodrigues, 2009) and spurred economic growth in many regions (Pfaffenberger et al., 2006).

Today, wind energy is an established technology. Wind turbines are installed in more than 110 countries, accounting for a growing share of global energy production (Bojek, 2022). The success of wind energy in underlines the importance of sustainability as a key criterion for the adoption of this technology.

1.3. The growing importance of sustainability

Following on from the previous paragraph on environmental aspects, it is worth noting that the growing awareness of the impact of human activities on the environment and the urgent need to address climate change and grand societal challenges in general has brought the issue of sustainability to the forefront of the political and social agenda (Meadowcroft, 1999). The concept of sustainability has evolved from a narrow focus on environmental concerns to a broader consideration of economic, social, political and cultural issues (Hajian & Kashani, 2021). The United Nations Sustainable Development Goals (SDGs) provide a comprehensive framework for sustainable development that addresses a wide range of issues such as poverty, education, gender equality, health and climate change mitigation (United Nations General Assembly, 2015). In this context, it is crucial to understand the concept of sustainability and its different dimensions in order to assess the impact of new technologies on society and the environment and how sustainability can influence the process of adopting new technologies. Organisations, governments and individuals are increasingly recognising the importance of adopting sustainable technologies to reduce their impact on the environment (Burgeon & Hovsepian, 2018), improve their competitiveness

(Shahzad et al., 2022) and contribute to the overall well-being of society (Weaver et al., 2000). In this context, it is important to understand the relationship between sustainability and the adoption of new technologies, and this is the aim of the following section.

This section gives a comprehensive overview of sustainability with its many dimensions and its importance in our society. The definition of sustainability is given by examining the evolution of this concept, from its origins as an environmental concern to its broader definition today. The relevance of sustainability in today's world is then highlighted, with particular reference to the United Nations' Sustainable Development Goals (SDGs) and the current status of their achievement. The following sections then highlight the different dimensions of sustainability, including economic, social and environmental aspects, as well as political and cultural factors that influence sustainable development. Ultimately, this chapter aims to provide a comprehensive understanding of sustainability and highlight its importance for the adoption of new technologies and its role in shaping the future of our society and planet.

1.3.1. An Overview of Sustainability

Definition of Sustainability

Sustainability is a complex and multi-faceted concept (Mariotti, 2017) that refers to the ability to maintain a balance between economic, social, environmental, political and cultural factors in order to meet the needs of present and future generations (Santander Universidades, 2022). It is about finding a way to achieve economic growth and development without compromising the ability of future generations to meet their own needs (United Nations Brundtland Commission, 1987). Sustainability is about ensuring that our current activities do not have a negative impact on the planet or its resources, but rather preserve them for future generations. This includes addressing issues such as climate change, biodiversity loss, pollution and resource depletion (Baste & Watson, 2022). Sustainability also aims to promote social equity, justice and prosperity and recognises that economic growth and development must be accompanied by social progress and improved quality of life for all (Steg & Gifford, 2005).

At its core, sustainability recognises the interconnectedness of economic, social, environmental, political and cultural systems and seeks to promote their long-term health and viability (Hristov, 2022; Zen et al., 2012). Achieving sustainability requires a holistic approach that considers the complex interactions between these systems (The World Bank, 2021). This includes integrating sustainability principles into all aspects of decision-making, from the individual to the organisational and societal levels. It also includes promoting sustainable practises in areas such as energy use, transport, land use, agriculture and waste management (Tubiello et al., 2021). To achieve sustainability, it is important to adopt a holistic and integrated approach that takes into account economic, social, environmental, political and cultural factors (World Bank, 2021). This requires the involvement of a wide range of stakeholders, including government officials, civil society organisations, businesses and community groups, to ensure that sustainability policies and practises are based on the values and priorities of local communities (Valentin & Spangenberg, 2000). In this way, we can create a more sustainable future for ourselves and for future generations.

In summary, sustainability is a multi-faceted concept that aims to promote the economic, social, environmental, political and cultural well-being of present and future generations. It recognises the interconnectedness of these different systems and seeks to promote their long-term health and viability through the adoption of sustainable practises and policies.

The evolution of the concept

The concept of sustainability has multiple roots that can be traced back to various movements of the 1960s and 1970s. Kidd (1992) identifies six distinct but interconnected strands of thought: ecological, environmental, biosphere, technology critique, 'No Growth-Slow Growth' and ecodevelopment roots. At this time, there was growing concern about environmental degradation, pollution and resource depletion (Jabbour & Flachsland, 2017), which was reflected in the creation of the United Nations Environment Programme (Ivanova, 2007). Activists began to call for a more holistic approach to environmental management that considered the long-term health of the planet (Prescott & Logan, 2019).

One of the most important early works on sustainability was Rachel Carson's book "Silent Spring," published in 1962, which alerted readers to the harmful effects of pesticides on the environment (Carson, 2002). This book helped kick-start the environmental movement and sparked a public discussion about the need for more sustainable practises (Griswold, 2012).

In the 1970s, the concept of sustainable development emerged as politicians and activists recognised the need to balance economic growth with environmental protection (Du Pisani, 2006). in 1972, the United Nations held the first Conference on the Human Environment in Stockholm (United Nations, n.d.), bringing together representatives from around the world to discuss environmental issues and set the course for future environmental policy.

in 1987, the Brundtland Commission, also known as the World Commission on Environment and Development, published a report entitled "Our Common Future" (United Nations Brundtland Commission, 1987), in which it defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". This report helped popularise the concept of sustainable development and set the course for future international environmental policy.

In the 1990s and 2000s, the concept of sustainability was further developed and expanded as policy makers and activists recognised the need to consider social and economic factors alongside environmental concerns (Purvis et al., 2019). The United Nations Sustainable Development Goals (SDGs), adopted in 2015, reflect this broader approach to sustainability and include targets on poverty reduction, education, gender equality and clean energy, in addition to environmental goals (United Nations General Assembly, 2015).

Today, sustainability has become a central theme of both public policy and private sector initiatives (Nidumolu et al., 2009), as governments, businesses and individuals recognise the need to address the complex environmental, social, economic, political and cultural challenges facing the world (Leal Filho et al., 2019). This has led to the development of a range of sustainability initiatives, including green technologies (Zhang, 2013), sustainable agricultural practises (Hall & Dorai, 2010), green building standards (Bungau et al., 2022) and sustainable transport (United Nations, 2021), to name a few.

Sustainable Development Goals (SDGs)

The Sustainable Development Goals (SDGs) represent a global commitment to end poverty, protect the planet and ensure prosperity for all. Adopted by the United Nations General Assembly in 2015, the SDGs build on the Millennium Development Goals (MDGs) and provide a comprehensive framework for sustainable development. The SDGs cover a wide range of issues, from poverty and hunger to climate action and partnerships for the goals. Achieving the SDGs will require the combined efforts of governments, international organisations, civil society and the private sector. Progress towards these goals will be closely monitored through a set of indicators. The SDGs provide a roadmap for creating a more equitable, sustainable and prosperous world, and their importance cannot be overstated in our current context of global challenges and uncertainties.

Here is a more detailed overview of the SDGs (United Nations General Assembly, 2015):

1. **No Poverty**: "*End poverty in all its forms everywhere*".
2. **Zero Hunger**: "*End hunger, achieve food security and improved nutrition, and promote sustainable agriculture*".
3. **Good Health and Well-being**: "*Ensure healthy lives and promote well-being for all at all ages*".
4. **Quality Education**: "*Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all*".
5. **Gender Equality**: "*Achieve gender equality and empower all women and girls*".
6. **Clean Water and Sanitation**: "*Ensure availability and sustainable management of water and sanitation for all*".
7. **Affordable and Clean Energy**: "*Ensure access to affordable, reliable, sustainable, and modern energy for all*".

8. **Decent Work and Economic Growth**: "*Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all*".
9. **Industry, Innovation and Infrastructure**: "*Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation*".
10. **Reduced Inequalities**: "*Reduce inequality within and among countries*".
11. **Sustainable Cities and Communities**: "*Make cities and human settlements inclusive, safe, resilient, and sustainable*".
12. **Responsible Consumption and Production**: "*Ensure sustainable consumption and production patterns*".
13. **Climate Action**: "*Take urgent action to combat climate change and its impacts*".
14. **Life Below Water**: "*Conserve and sustainably use the oceans, seas, and marine resources for sustainable development*".
15. **Life on Land**: "*Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation, and halt biodiversity loss*".
16. **Peace, Justice, and Strong Institutions**: "*Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels*".
17. **Partnerships for the Goals**: "*Strengthen the means of implementation and revitalize the global partnership for sustainable development*".

The SDGs are supported by a wide range of stakeholders, including governments, international organisations, civil society and the private sector (United Nations Development Group, 2016). Progress towards the SDGs is measured by a set of indicators developed through a collaborative process involving governments, international organisations, civil society and other stakeholders (United Nations Economic Commission for Europe, 2020).

By 2023, progress towards the Sustainable Development Goals (SDGs) is uneven (United Nations, 2022). While some notable achievements have been made in areas such as poverty reduction and access to education and health care, many of the goals are falling by the wayside. The COVID -19 pandemic has further highlighted the urgency and complexity of the challenges facing the world and undermined progress towards the SDGs in many countries (Lekagul et al., 2022). Achieving the SDGs by 2030 will require significant efforts from all stakeholders, including innovative partnerships, new technologies and ambitious policies (United Nations, n.d.). However, there are also reasons for optimism, such as the growing awareness and mobilisation around sustainability issues (Yamane & Kaneko, 2021) and the potential of new solutions and approaches (United Nations Inter-Agency Task Team on Science, Technology and Innovation for the SDGs and UNIDO, 2022). Overall, the SDGs provide an important framework for addressing the most pressing global challenges and building a better future for all.

The Sustainable Development Goals (SDGs) provide a comprehensive framework for sustainable development that encompasses a wide range of issues that are interconnected and complex. The SDGs underscore the multidimensional nature of the sustainability challenge and emphasise the need for an integrated and holistic approach that takes into account economic, social, environmental, political and cultural factors. In the following sections, each dimension of sustainability is examined in depth. Looking at each dimension in detail can contribute to a better understanding of the complexity of sustainability challenges and the different perspectives of different stakeholders.

1.3.2. Sustainability Dimensions

Sustainability is a concept that is becoming increasingly important and has found its way into various areas of our society. With growing concerns about climate change, biodiversity loss and social inequality, sustainable development is more urgent than ever. Sustainable development involves the integration of economic, social, political, environmental and cultural aspects of society. These dimensions are closely interlinked, as demonstrated by the 17 Sustainable Development Goals (SDGs). The United Nations SDGs provide a framework for global sustainable development efforts, as explained in the previous section. The SDGs recognise the importance of the different dimensions of sustainability and include specific targets to achieve sustainable development. In this response, the next sections define and explain each of these dimensions of sustainability, highlighting their relationship to the SDGs.

Economic Sustainability

The economic dimension of sustainability involves the efficient use of resources to produce and distribute goods and services. It includes the practises and policies that promote economic growth, development and prosperity. The SDGs emphasise the importance of economic growth for sustainable development and call for inclusive and sustainable economic growth (SDG 8). The SDGs also emphasise the need to promote sustainable industrialisation and innovation (SDG 9) and to ensure sustainable consumption and production patterns (SDG 12). The SDGs promote sustainable agriculture that aims to end hunger, achieve food security and improve nutrition (SDG 2).

Economic sustainability aims at economic growth while minimising negative impacts on the environment and society. This dimension includes the adoption of sustainable business practises that take into account the long-term impacts of economic activities. This also includes the use of renewable resources and the adoption of sustainable technologies.

Social Sustainability

The social dimension of sustainability focuses on the well-being of individuals and communities. It addresses the creation of social systems that promote equality, social justice and human rights. The SDGs recognise the importance of social sustainability for sustainable development and emphasise the need to eradicate poverty (SDG 1), reduce inequality (SDG 10), promote access to education (SDG 4) and ensure access to health care (SDG 3). The SDGs also call for the promotion of peaceful and inclusive societies (SDG 16), gender equality and the empowerment of all women and girls (SDG 5), and the protection of cultural heritage through participatory and inclusive cities and communities (SDG 11).

This dimension recognises the interconnectedness of social and economic systems and aims to create a balance between the two. Social sustainability includes promoting healthy and safe communities, protecting human rights and ensuring basic needs such as food, shelter and healthcare.

Sustainability and the Environment

The environmental dimension of sustainability focuses on the conservation and protection of the natural environment. It includes the management of natural resources such as water, land and forests, and the reduction of environmental degradation. The SDGs recognise the importance of environmental sustainability and emphasise the need to protect and restore terrestrial and marine ecosystems (SDG 14 and 15), combat climate change (SDG 13) and ensure access to clean water and sanitation (SDG 6). In addition, the SDGs emphasise the importance of ensuring affordable, reliable, sustainable and modern energy for all (SDG 7).

Environmental sustainability aims to protect and preserve the natural environment for future generations. This includes adopting sustainable practises such as reducing carbon emissions, minimising waste and promoting the use of renewable energy.

Public Policies and Sustainability

The political dimension of sustainability involves the creation of policies and governance systems that promote sustainability. It recognises the role of government and other political actors in promoting sustainable development. The SDGs emphasise the importance of political sustainability and call for the promotion of effective, accountable and inclusive institutions (SDG 16) that can implement sustainable development policies. The SDGs also emphasise the need to promote partnerships for sustainable development (SDG 17) between governments, civil society and the private sector.

Political sustainability means creating democratic and participatory systems that involve citizens in decision-making processes. This includes adopting policies that promote sustainable resource use and environmental protection.

Cultural Dimension of Sustainability

The cultural dimension of sustainability involves the preservation of cultural diversity and heritage. It recognises the importance of cultural practises, traditions and values for sustainable development. The SDGs recognise the importance of cultural sustainability and call for the promotion of cultural diversity and the protection of cultural heritage (SDG 11).

Cultural sustainability aims to ensure that cultural heritage is protected and preserved for future generations. This includes promoting cultural diversity, protecting cultural landscapes and developing cultural industries.

Final remarks

The Sustainable Development Goals (SDGs) provide a comprehensive framework for sustainable development that recognises the multi-faceted nature of sustainability and includes the integration of economic, social, political, environmental and cultural dimensions. Each of these dimensions is critical to achieving sustainable development. Economic sustainability involves the efficient use of resources to produce and distribute goods and services. Social sustainability focuses on the well-being of individuals and communities. Political sustainability involves the creation of policies and systems of governance that promote sustainability. Environmental sustainability focuses on the conservation and protection of the natural environment. Cultural sustainability involves the preservation of cultural diversity and heritage. Together, these dimensions provide a framework for sustainable development that promotes the well-being of current and future generations.

These dimensions and the SDGs form a framework for sustainable development that recognises the interdependence of economic, social, political, environmental and cultural sustainability. Achieving sustainable development requires a comprehensive approach that addresses all these dimensions in an integrated and balanced manner. By adopting the SDGs, countries and organisations can work towards a common goal and track their progress towards sustainable development. It is important to recognise that progress in one dimension of sustainability can have positive or negative impacts on other dimensions. Therefore, to achieve sustainable development, societies must strive for a balanced and integrated approach that takes into account the different needs and perspectives of all stakeholders.

1.4. Sustainability and Adoption: Perceptions and Approaches

In the previous sections, the concept of sustainability has been thoroughly analysed. Its evolution over time has been examined and a holistic approach has been adopted, taking into account the various economic, social, environmental, political and cultural dimensions as reflected in the 17 Sustainable Development Goals (SDGs). The increasingly important role of this theme in the context of the dynamics of the process of adopting new technologies was also highlighted. Sustainability has become a crucial issue for the adoption of new technologies as it is directly related to the long-term environmental, economic and social impacts of technology use and also has political and cultural implications. It is therefore important to understand how sustainability considerations affect people in the process of adopting new technologies.

This section examines the relationship between the adoption of innovations and sustainability. In particular, it explores how people's different approaches to sustainability issues may influence their adoption of new technologies. Two different sustainability concepts are analysed in this section, namely the weak sustainability approach and the strong sustainability approach. Weak sustainability assumes that natural and human-made capital are interchangeable, while strong sustainability claims that natural capital cannot be replaced by human-made capital (Ayres et al., 1998; Dietz & Neumayer, 2007)). These concepts are then associated with the concept of solutionism. The concept of solutionism is the belief that technological solutions can solve social and environmental problems (Morozov, 2013). By analysing these concepts, this section will shed light on the complex interplay between innovation adoption and sustainability.

1.4.1. Weak and strong sustainability approaches

Sustainability is a multi-faceted concept that is the subject of intense debate among academics, policy-makers and practitioners. One of the most fundamental debates in the sustainability literature concerns the appropriate relationship between economic growth, the environment and social progress (Raudsepp-Hearne et al., 2010). This debate is usually framed within the distinction between weak and strong sustainability concepts (Ang & Van Passel, 2012).

Weak sustainability assumes that natural and human-made capital are interchangeable and therefore the loss of natural capital can be compensated by the accumulation of human-made capital (Ayres et al., 1998). In other words, it assumes that natural resources can be replaced by technological advances and that economic growth can continue indefinitely without harming the environment. This approach focuses on the conservation of the total stock of resources and accepts some depletion of natural capital as long as it is replaced by man-made capital. This approach focuses primarily on the conservation of the total stock of resources rather than on the conservation of natural resources per se.

On the other hand, strong sustainability asserts that natural capital cannot be replaced by human-made capital (Ayres et al., 1998). This approach emphasises the importance of the environment as a fundamental component of sustainable development and argues that economic growth must be based on the conservation and enhancement of natural resources. Strong sustainability is based on the premise that the economy and the environment are interdependent and that economic development cannot be achieved without protecting and improving the natural environment. This approach focuses on the conservation and protection of natural capital, including non-renewable resources, and on maintaining the integrity of ecosystems and biodiversity. This approach would prioritise the conservation of natural resources rather than replacing them with human-made capital.

The concepts of weak and strong sustainability have important implications for the adoption of new technologies. A weak sustainability approach may signal a more positive attitude towards innovation and technological change, believing that technological advances can offset environmental degradation. In contrast, a strong sustainability approach may indicate a more cautious attitude towards the adoption of new technologies, suggesting that many technological solutions are not environmentally sustainable in the long run. When judging technologies, a weak sustainability approach would tend to focus on whether the technology enables the substitution of non-renewable resources with man-made capital, while a strong sustainability approach would focus on whether the technology preserves and protects natural capital and biodiversity. For example, a technology that aims to reduce greenhouse gas emissions but still relies on non-renewable resources would be considered more environmentally friendly under a weak sustainability approach, but less environmentally friendly under a strong sustainability approach.

The prevalence of weak or strong sustainability attitudes in different social groups may be a predictor of their attitudes towards the adoption of new technologies. While individuals with weak sustainability attitudes may be more willing to adopt new technologies that are not necessarily in line with long-term sustainability goals, individuals with strong sustainability attitudes may be more resistant to adopting new technologies that they believe will have negative impacts on the environment or social well-being. Therefore, understanding how prevalent these attitudes are across different social and demographic groups may be critical to understanding and anticipating the behaviour of these groups following the introduction of a new technology into the market. As will be presented in the sequel, the methodological part of this dissertation aims to develop the necessary tools to try to capture and quantify these socio-cultural differences.

1.4.2. Solutionism

Solutionism is a concept closely related to the concepts of weak and strong sustainability. It is the belief that technological solutions can solve social and environmental problems without fully considering the potential risks and trade-offs associated with adopting these solutions (Morozov, 2013). This approach often focuses on finding quick fixes rather than addressing the underlying systemic problems that contribute to social and environmental challenges. This attitude can lead to technology being used for technology's sake, rather than considering whether it is the most appropriate or effective solution to a particular problem. In the context of sustainability, the concept of solutionism can have different implications depending on whether weak or strong sustainability concepts are used. This can lead to the adoption of new technologies that may not be suitable in the long term.

People who have weak sustainability attitudes may be more inclined towards a solutionist approach, seeing natural and human-made capital as interchangeable and believing that technological innovations can compensate for the depletion of natural resources. These people may be more inclined to adopt new technologies presented as solutions to environmental or social problems without fully considering their potential long-term impacts. For example, a company may adopt a new technology that reduces its carbon footprint without addressing other systemic problems such as overconsumption or unsustainable production practises.

On the other hand, people who have strong sustainability attitudes may be more critical of a solutionist approach. They see natural capital as irreplaceable and argue for more holistic and systemic solutions that address the root causes of environmental degradation and social inequality. These people may be more sceptical of technological solutions and more inclined to focus on systemic changes that address the root causes of social and environmental problems. They are more likely to consider the potential trade-offs associated with the adoption of new technologies and prefer solutions that are more holistic and long-term.

From these considerations, it can be deduced that the concept of solutionism is also related to people's inclination to adopt new technologies. People who hold a solutionist view may be more enthusiastic about adopting new technologies and less concerned about their possible negative effects, believing that technological solutions can mitigate or solve these problems. They may be more inclined to adopt new technologies without thoroughly weighing their potential risks and drawbacks. This can lead to the adoption of technologies that have negative social and environmental impacts in the long run. For example, the adoption of genetically modified crops may be seen as a solution to food shortages, but may also have negative impacts on the environment, such as the loss of biodiversity or the development of resistant pests. In addition, the concept of solutionism can also have broader societal implications, as it can influence the policy and investment decisions of governments and organisations. Solutionist approaches can lead to a preference for technological innovations over more systemic and transformative solutions, which can undermine the achievement of long-term sustainability goals.

On the other hand, people who are more critical of a solutionist approach may be more cautious about the adoption of new technologies and require more comprehensive information and evidence about their potential environmental and social impacts. These individuals are often more inclined to adopt strong sustainability concepts and are likely to assess the potential environmental and social impacts of new technologies from a broader and more holistic perspective. They tend to consider the trade-offs between the economic, social and environmental outcomes associated with the adoption of new technologies and the potential long-term consequences of their use. These people are more inclined to seek alternative solutions that prioritise natural resources and respect ecological limits than to rely exclusively on technological solutions. They may also be more interested in promoting social and environmental justice and addressing systemic problems rather than just the symptoms of the problem.

Overall, the prevalence of solutionist attitudes in different social groups may be a predictor of different attitudes towards the adoption of new technologies. Those who favour solutionism are more likely to see new technologies as the solution to environmental and social problems, while those who are critical of this approach are more likely to take a cautious and comprehensive approach to assessing the potential impact of new technologies.

In summary, the concept of solutionism stands for the belief that technology can solve social and environmental problems. This belief is closely linked to weak sustainability, while it is at odds with strong sustainability. The concepts of weak and strong sustainability offer different approaches to the management of natural resources and the impact of technology use on the environment. The prevalence of these attitudes in different social groups may be a predictor of different attitudes towards the adoption of new technologies. Therefore, understanding the prevalence of solutionist attitudes, alongside weak and strong sustainability approaches, is crucial to understanding people's attitudes towards the adoption of new technologies. This also proves particularly important when considering the recent findings of Hidalgo (2021), who states that people judge humans based on their intentions, while they judge machines based on their outcomes. This means that the introduction of a technology whose impact on sustainability proves to be positive should lead to greater acceptance of the technology itself. However, the impact on sustainability is perceived differently depending on the attitude of the person making the judgement (as was already highlighted in the distinction between weak and strong approaches to sustainability). The remainder of this dissertation, which transitions into the section on methodological research, explains the tools developed to capture and quantify the extent to which these attitudes are prevalent across different social and demographic groups, which is the main objective of Airbus.

2 Research methodology

In the previous chapter, the literature on the adoption of innovations was analysed. It highlighted the importance of the topic, the main factors guiding people in adopting a new technology and the growing importance of the concept of sustainability in this process.

BlueSky, the Airbus division whose aim is to research and discover new and innovative technologies that could be of strategic importance to the Group in the future, wants to test the validity of these hypotheses. The aim is to create an operational tool that will allow the company to understand if, when and which social group would be willing to accept a new technology on the market. This tool could give the company a significant competitive advantage in the face of the rapid and exponential growth of technological progress (National Intelligence Council, 2021) and an increasingly globalised market (OECD, 2022).

In light of these considerations, BlueSky launched Project 42, which aims to model human behaviour at different population levels (from the individual to civilisation) in order to predict sociological and psychological behaviour, including unconscious behaviour, over different time horizons in response to potential future changes triggered by Airbus. From a technological point of view, instead of a classical model-based systems engineering (MBSE) approach, where the models are already defined and described (Dornhaus et al., 2002), an evolutionary and massively decentralised multi-agent system was envisaged. With the right levers and social assumptions, the system should develop the appropriate (unconscious) behaviour and thus be a disruptive simulation tool of utmost importance for the development of the company.

2.1. Multi-agent system (MAS)

2.1.1. Theory

A multi-agent system (MAS) is a distributed system consisting of multiple autonomous agents that interact with each other and their environment. Each agent is able to perceive its environment, reason about it, and take actions to achieve its goals, which may or may not conflict with the goals of the other agents in the system (Cardoso & Ferrando, 2021). MAS is an active area of research in artificial intelligence, computer science, robotics, and many other fields because it provides the ability to model and simulate complex systems involving multiple entities with different goals.

Agents and agent architectures

An agent is an autonomous entity that can sense its environment using sensors and act using effectors (Rossetti & Liu, 2005). Agents can be classified into different types based on their capabilities, communication and collaboration. Reactive agents, for example, respond to changes in their environment, while deliberative agents reason about their goals and plans before taking action (Doran et al., 1997). Communication between agents can be done through different methods, such as message passing, shared memory or broadcasting (Abd Alrahman & Piterman, 2021). Collaboration between agents can be achieved through negotiation, coordination or competition (Elghamrawy, 2021).

The architecture of an agent is the set of components and processes that enable it to perform its functions. The most common agent architectures are Reactive, Deliberative and Hybrid (Doran et al., 1997). Reactive agents consist of a set of sensors that sense the environment and a set of effectors that perform actions in response to stimuli. Deliberative agents use an internal representation of the world and reason about their goals and plans to select appropriate actions. Hybrid agents combine reactive and deliberative architectures to achieve robustness and flexibility.

MAS and multi-agent system architectures

A multi-agent system (MAS) is a collection of agents that interact with each other and their environment to achieve their individual goals and the collective goals of the system. A MAS can be organised in different architectures depending on the degree of coordination and communication between the agents. The most common MAS architectures are Centralized, Hierarchical, Heterarchical, and Distributed (Salvador Palau et al., 2019).

In a Centralized MAS there is a single agent who acts as the central coordinator for all other agents. The central agent has access to all information about the system and can make decisions on behalf of the other agents. In Decentralised MAS, on the other hand, there are several agents who communicate and coordinate with each other to achieve their goals. Each agent has a partial overview of the system and makes decisions based on its local information. Distributed MASs have multiple agents that communicate and coordinate with each other without a central authority. Agents in a distributed MAS are autonomous and can make decisions based on their local information and the messages they receive from other agents.

Applications of multi-agent systems

MASs have many applications in various fields, including robotics, transportation, finance, healthcare and social sciences. Some examples of MAS applications are:

- *Robotic systems*: multi-robot systems can be used for tasks such as search and rescue, surveillance and exploration. MASs enable robots to coordinate their actions and exchange information to achieve their goals.
- *Transportation systems*: MASs can be used to control traffic flow and optimise routes for vehicles. Agents can control traffic lights, communicate with vehicles and provide information to drivers.
- *Finance*: MASs can be used to model and simulate financial markets and predict trends. Agents can represent investors, traders and institutions and make decisions based on market data and analysis.
- *Healthcare*: MAS can be used to monitor the health of patients and provide personalised care. Agents can represent patients, doctors and caregivers and coordinate their actions to optimise patient outcomes.
- *Social sciences*: MAS can be used to simulate and study complex social phenomena such as crowd behaviour, opinion formation and cooperation. Agents can represent individuals, groups and organisations and simulate their interactions and dynamics.

In summary, a multi-agent system (MAS) is a distributed system consisting of multiple autonomous agents that interact with each other and their environment to achieve their individual goals and the collective goals of the system. MASs have different agent architectures and system architectures depending on the degree of coordination and communication required between the agents. MASs have applications in many fields, including robotics, transportation, finance, healthcare and social sciences, as they can model and simulate complex systems involving multiple entities with different goals. As research into MAS continues to progress, it can be expected to see further developments and applications of this technology in the coming years.

2.1.2. MAS to predict innovation adoption dynamics

Project 42 aims to develop a multi-agent system (MAS) to model human behaviour at different population levels and predict the adoption of new technologies. By developing a MAS, capable of simulating the behaviour of individuals, groups and societies, it is hoped to gain valuable insights into the factors that influence the adoption of new technologies. This model can take into account factors such as social influence, cultural norms, economic incentives and demographic characteristics of populations to predict the propensity of social groups to adopt new technologies. The capabilities of this MAS include the ability to simulate and test different scenarios and strategies for introducing new technologies into the market. The development of such MAS requires interdisciplinary research involving experts from the fields of artificial intelligence, sociology, economics and psychology. By harnessing the potential of MAS to model human behaviour, the risks associated with the introduction of new technologies can be anticipated and mitigated while maximising their benefits to individuals and society.

A multi-agent system can contribute to understanding the acceptance of new technologies in several ways:

- *Modelling complex social systems*: A multi-agent system can be used to model the interactions between different stakeholders in a society, such as individuals, businesses and government organisations. This can help to understand how different groups react to new technologies and how these new technologies may be adopted or rejected.

- *Simulate the diffusion of technologies*: A multi-agent system can be used to simulate the diffusion of new technologies in a population. This can help to understand how different factors, such as the characteristics of the technology, the behaviour of individuals and the structure of the social network, influence the rate of adoption.
- *Identifying key influencers*: A multi-agent system can be used to identify the key influencers in a network that can help or hinder the adoption of new technologies. This can help to understand how the behaviour of certain individuals may influence the overall adoption of a technology.
- *Exploring the impact of policies*: A multi-agent system can be used to explore the impact of different policies on the uptake of new technologies. This can help to understand how different incentives, regulations and subsidies can influence the adoption of new technologies.

Overall, multi-agent systems can be a powerful tool for understanding the complex dynamics of technology acceptance. They shed light on how different factors interact to influence adoption rates and identify key factors that promote or hinder adoption.

Design of the system

The development of a multi-agent system (MAS) to model the complex process of innovation adoption involves several important steps:

- The system must be designed with an appropriate agent architecture to represent the behaviours of individuals, groups and societies. This architecture must be flexible and adaptable to accommodate different degrees of complexity and heterogeneity of populations.
- The system must be able to model the diffusion of innovations over time, taking into account factors such as social influence, communication networks and demographic characteristics. This requires the development of algorithms and models to represent the different stages of the innovation adoption process, such as awareness, interest, evaluation, testing and adoption.
- The system must include feedback loops and learning mechanisms to simulate the dynamic nature of the innovation adoption process. This includes the use of data-driven methods to validate and refine the model and to identify key factors that influence the adoption of new technologies.
- The system must be able to simulate and test different scenarios and strategies to promote innovation adoption. This requires the integration of decision-making algorithms to model the behaviour of policy makers, regulators and companies, as well as the interactions between different stakeholders.
- The MAS needs to be validated and evaluated against real data to assess its accuracy and predictive power. This requires the use of statistical and machine learning techniques to compare the simulation results with empirical data and to identify the strengths and weaknesses of the model.

The role of data

Data is necessary to create a multi-agent system, train the agents and enable them to make decisions based on the information they receive from the environment

(Wood & DeLoach, 2001). Data is critical in the development of a multi-agent system (MAS) for several reasons.

Data can be used to train and validate the agent models and algorithms used in MAS. Machine learning and statistical techniques are used to extract patterns and insights from real data, which can then be used as a basis for designing agent behaviour and interactions. In addition, the data is also important for the calibration and validation of MAS itself. This involves comparing the simulation results of MAS with empirical data to assess their accuracy and predictive power. By using real data, researchers can test MAS under different scenarios and determine the strengths and weaknesses of the model. In addition, the data can serve as the basis for decision-making algorithms in MAS. By analysing data on the behaviour and preferences of individuals and groups, MAS can simulate the decision-making processes of policymakers, regulators and businesses, and identify the most effective strategies to promote the adoption of innovations. Finally, the data can be used to test and evaluate different scenarios and strategies to promote the adoption of innovations. By using data-driven simulation methods, MAS can identify the potential impact of different policies and marketing campaigns on the adoption of new technologies and enable evidence-based decision-making.

Overall, data are an essential part of developing a MAS to model innovation adoption. They enable researchers to develop accurate and effective agent models, validate and calibrate the MAS, develop decision algorithms, and test and evaluate different scenarios and strategies. Since it is not possible to have a priori data on the adoption of a future technology and its acceptance, the next section outlines the starting hypothesis to overcome this problem and work with data in the development of the system.

2.1.3. Dataset: A Sustainability Framework

The previous sections have explained the theory of multi-agent systems, demonstrated their usefulness in predicting readiness to adopt new technologies, and provided guidance on system design and the importance of data. In particular, the problem of using data on the adoption of future technologies, as this data cannot be measured a priori. To address this problem, the following assumption was made in consultation with BlueSky:

"The adoption rate of electric vehicles (EVs) in different states can be (at least partially) representative of the adoption rate of a generic innovation."

The rationale for this hypothesis is:

- *Innovative nature of EVs*: electric vehicles are a relatively innovative technology: although they have been around for more than a century, adoption and interest in the technology has increased in recent years
- *Availability of data*: There is already data on EV penetration that can be used as time series.
- *Proximity to industry*: EVs are an innovation in the field of mobility and therefore fall within the specific interest of Airbus as a main business area
- *Sustainability dimension*: EVs are an innovation closely linked to the issue of sustainability, a driver for the growing interest in the adoption of new technologies

Based on this assumption, the following methodology was applied. Data on the market penetration of electric vehicles was collected for over 70 countries.

Then the 5 pillars of sustainability identified in the literature and described in the previous chapter were considered: Economic, Social, Public Policy, Environmental and Cultural. For each of these dimensions, a search was made for significant indicators for which there was evidence in the existing literature of a possible correlation with EV penetration. Finally, a mathematical correlation analysis was conducted to test the relationship between adoption rates and these indicators. The rest of this section explains the different indicators and presents the data collected. In the next chapter on the findings, the correlation matrix obtained is presented. Finally, some critical points related to the analysis and the solutions undertaken to overcome them are presented.

EV adoption rate

The following table shows the share of plug-in EVs in new car sales (2021) for different countries. The countries have been sorted in random order, but starting with the country with the highest rate, Norway.

Table 2.1: EV adoption rate by country

Country	EV adoption
Norway	86,2%
UK	18,6%
France	18,3%
China	15,0%
Italy	9,3%
Colombia	7,1%
Canada	6,6%
US	4,0%

Australia	2,4%
Japan	1,2%
Rwanda	0,001%
Iceland	71,7%
Sweden	43,3%
Denmark	35,2%
Finland	30,8%
Netherlands	29,8%
Germany	26,0%
Switzerland	22,5%
Belgium	18,4%
Ireland	15,7%
Austria	9,5%
Spain	7,8%
New Zealand	5,5%
Republic of Korea	6,8%
Brazil	0,4%
India	0,1%
Indonesia	0,5%
Mexico	0,3%
Russia	0,1%
Philippines	0,3%
Turkey	0,6%
Thailand	0,6%
South Africa	0,1%
Egypt	0,04%

Argentina	0,01%
Azerbaijan	1,6%
Belarus	1,3%
Bosnia and Herzegovina	1,7%
Bulgaria	3,5%
Chile	0,8%
Costa Rica	4,4%
Croatia	4,3%
Cyprus	1,8%
Czechia	3,1%
Estonia	3,0%
Georgia	3,4%
Greece	8,7%
Hong Kong	38,8%
Hungary	6,8%
Israel	8,3%
Jordan	13,3%
Kazakhstan	0,1%
Latvia	4,1%
Lithuania	3,4%
Luxembourg	18,7%
Malaysia	0,2%
Malta	2,9%
Morocco	0,1%
North Macedonia	3,1%
Poland	4,1%

Portugal	0,0%
Romania	8,5%
Serbia	1,2%
Singapore	8,6%
Slovakia	2,6%
Slovenia	3,0%
Sri Lanka	2,8%
Taiwan	3,4%
Ukraine	2,2%
United Arab Emirates	2,0%
Uruguay	3,9%

Economic indicators

The indicators assigned to the economic pillar are as follows:

- **Gross National Income per capita (GNI)** (United Nations, 2021): GNI per capita based on Purchasing Power Parity (PPP). PPP GNI is the gross national income (GNI) converted into international dollars using purchasing power parity exchange rates. An international dollar has the same purchasing power against GNI as a US dollar in the United States. GNI is an alternative to gross domestic product (GDP) as a measure of wealth. It calculates income instead of production. GNI is the sum of the value added of all resident producers plus all product taxes (less subsidies) that are not included in the valuation of production, plus net receipts of primary income (compensation of employees and property income) from abroad. The hypothesis underlying this indicator is that income significantly influences the decision to adopt innovations (Escamilla et al., 2019).

- **Gini coefficient** (The World Bank, 2022): The Gini coefficient stands for the inequality of income and wealth within a nation or a social group. A Gini coefficient of 0 expresses perfect equality where all values are equal, while a Gini coefficient of 1 (or 100%) expresses the maximum inequality between values. The literature highlights that there is a strong relationship between income inequality and innovation performance in different countries (Botta, 2017).

- $\frac{BERD}{GERD}$ (OECD, 2020): Business enterprise expenditure on R&D (BERD) represents the component of GERD made by units belonging to the business enterprise sector. It is a measure of intramural R&D expenditure within the business enterprise sector during a given reference period. Gross domestic expenditure on R&D (GERD) is the total intramural expenditure on R&D performed domestically during a given reference period. $\frac{BERD}{GERD}$ is the ratio of private R&D funding to total R&D funding and could be an indicator of a country's innovation capacity and generally of a healthy business environment.

Table 2.2: GNI, GINI and $\frac{\text{BERD}}{\text{GERD}}$ by country

Country	Gross national income	GINI	$\frac{\text{BERD}}{\text{GERD}}$
Norway	$ 64.660	27,7%	54,3%
UK	$ 45.225	35,1%	67,4%
France	$ 45.937	32,4%	65,9%

China	$	17.504	38,2%	76,6%
Italy	$	42.840	35,2%	61,8%
Colombia	$	14.384	54,2%	
Canada	$	46.808	33,3%	53,7%
US	$	64.765	41,4%	75,3%
Australia	$	49.238	34,3%	51,0%
Japan	$	42.274	32,9%	78,7%
Rwanda	$	2.210	43,7%	
Iceland	$	55.782	26,1%	67,9%
Sweden	$	54.489	29,3%	71,7%
Denmark	$	60.365	27,7%	61,6%
Finland	$	49.452	27,7%	67,0%
Netherlands	$	55.979	29,2%	66,6%
Germany	$	54.534	31,7%	66,6%
Switzerland	$	66.933	33,1%	67,5%
Belgium	$	52.293	27,2%	73,7%
Ireland	$	76.169	30,6%	74,5%
Austria	$	53.619	30,2%	70,3%
Spain	$	38.354	34,3%	55,6%
New Zealand	$	44.057	32,5%	61,7%
Republic of Korea	$	44.501	31,4%	79,1%
Brazil	$	14.370	48,9%	
India	$	6.590	35,7%	
Indonesia	$	11.466	37,9%	
Mexico	$	17.896	45,4%	21,5%
Russia	$	27.166	36,0%	56,6%

Philippines	$	8.920	42,3%	
Turkey	$	31.033	41,9%	64,8%
Thailand	$	17.030	35,0%	
South Africa	$	12.948	63,0%	31,0%
Egypt	$	11.732	31,5%	
Argentina	$	20.925	42,3%	36,1%
Azerbaijan	$	14.257	26,6%	
Belarus	$	18.849	24,4%	
Bosnia and Herzegovina	$	15.242	33,0%	
Bulgaria	$	23.079	40,3%	
Chile	$	24.563	44,9%	33,5%
Costa Rica	$	19.974	49,3%	
Croatia	$	30.132	28,9%	
Cyprus	$	38.188	31,2%	
Czechia	$	38.745	25,3%	61,0%
Estonia	$	38.048	30,8%	55,0%
Georgia	$	14.664	34,5%	
Greece	$	29.002	33,1%	46,1%
Hong Kong	$	62.607	53,3%	
Hungary	$	32.789	30,0%	76,5%
Israel	$	41.524	38,6%	88,9%
Jordan	$	9.924	33,7%	
Kazakhstan	$	23.943	27,8%	
Latvia	$	32.803	34,5%	30,9%
Lithuania	$	37.931	35,3%	48,2%
Luxembourg	$	84.649	34,2%	54,3%

Malaysia	$ 26.658	41,1%	
Malta	$ 38.884	31,0%	
Morocco	$ 7.303	39,5%	
North Macedonia	$ 15.918	33,0%	
Poland	$ 33.034	30,2%	62,8%
Portugal	$ 33.155	32,8%	57,0%
Romania	$ 30.027	34,8%	59,0%
Serbia	$ 19.123	34,5%	
Singapore	$ 90.919	34,5%	60,9%
Slovakia	$ 30.690	23,2%	54,1%
Slovenia	$ 39.746	24,4%	73,3%
Sri Lanka	$ 12.578	39,3%	
Taiwan		34,0%	
Ukraine	$ 13.256	25,6%	
United Arab Emirates	$ 62.574	26,0%	
Uruguay	$ 21.269	40,2%	

Social indicators

The indicators assigned to the social pillar are as follows:

- **Gender Inequality Index (GII)** (United Nations, 2021): The Gender Inequality Index is a composite measure of gender inequality that includes three dimensions: reproductive health, empowerment and the labour market. A low GII score indicates low inequality between women and men and vice versa. The literature reports that there is a strong relationship between income inequality and innovation (Anfinsen et al., 2019).

- **Social Progress Index** (Social Progress Imperative, 2022): Consisting of several dimensions, the Social Progress Index can be used as a measure of success and provides a holistic, transparent, outcome-based measure of a country's well-being that is independent of economic indicators. The framework consists of 3 main domains: basic human needs, foundations of well-being, opportunities. For each domain, 4 different dimensions are analysed in more detail. Mihai (2017) stated that social progress depends on the ability to create and adopt innovations. The hypothesis is that countries with higher levels of social progress should be more able to adopt innovations.

- **Human Development Index (HDI)** (United Nations, 2021): The Human Development Index (HDI) is a summary measure of average performance on key dimensions of human development:
  - a long and healthy life: health dimension (measured by life expectancy at birth)
  - being knowledgeable: education dimension (number of years of schooling per adult at age 25 & expected number of years of schooling per child at school entry)
  - have an adequate standard of living: standard-of-living dimension (gross national income per capita)

  As Lin (1991) found, the probability of adopting a new technology is positively related to the level of education.

Table 2.3: GII, Social Progress Index and HDI by country

Country	Gender inequalities	Social Progress Index	HDI
Norway	0,016	90,74%	0,961

UK	0,098	86,13%	0,929
France	0,083	86,07%	0,903
China	0,192	65,74%	0,768
Italy	0,056	85,23%	0,895
Colombia	0,424	69,83%	0,752
Canada	0,069	88,17%	0,936
US	0,179	84,65%	0,921
Australia	0,074	87,83%	0,951
Japan	0,083	88,19%	0,925
Rwanda	0,388	52,18%	0,534
Iceland	0,043	89,54%	0,959
Sweden	0,023	89,42%	0,947
Denmark	0,013	90,54%	0,948
Finland	0,033	90,46%	0,940
Netherlands	0,025	88,97%	0,941
Germany	0,073	88,72%	0,942
Switzerland	0,023	90,26%	0,962
Belgium	0,048	87,22%	0,937
Ireland	0,074	87,69%	0,945
Austria	0,053	88,05%	0,916
Spain	0,057	85,35%	0,905
New Zealand	0,088	87,26%	0,937
Republic of Korea	0,067	86,47%	0,925
Brazil	0,390	71,26%	0,754
India	0,490	60,19%	0,633
Indonesia	0,444	66,67%	0,705

Mexico	0,309	70,84%	0,758
Russia	0,203	71,99%	0,822
Philippines	0,419	67,46%	0,699
Turkey	0,272	66,59%	0,838
Thailand	0,333	69,80%	0,800
South Africa	0,405	69,95%	0,713
Egypt	0,443	58,73%	0,731
Argentina	0,287	78,64%	0,842
Azerbaijan	0,294	63,26%	0,745
Belarus	0,104	71,49%	0,808
Bosnia and Herzegovina	0,136	71,23%	0,780
Bulgaria	0,210	76,81%	0,795
Chile	0,187	80,78%	0,855
Costa Rica	0,256	80,65%	0,809
Croatia	0,093	82,32%	0,858
Cyprus	0,123	83,18%	0,896
Czechia	0,120	85,10%	0,889
Estonia	0,100	86,16%	0,890
Georgia	0,280	74,43%	0,802
Greece	0,119	82,44%	0,887
Hong Kong			0,952
Hungary	0,221	78,21%	0,846
Israel	0,083	83,17%	0,919
Jordan	0,471	67,32%	0,720
Kazakhstan	0,161	71,21%	0,811
Latvia	0,151	82,46%	0,863

Lithuania	0,105	83,71%	0,875
Luxembourg	0,044	87,48%	0,930
Malaysia	0,228	74,08%	0,803
Malta	0,167	84,52%	0,918
Morocco	0,425	64,04%	0,683
North Macedonia	0,134	72,74%	0,770
Poland	0,109	80,17%	0,876
Portugal	0,067	84,75%	0,866
Romania	0,282	76,89%	0,821
Serbia	0,131	75,80%	0,802
Singapore	0,040	83,76%	0,939
Slovakia	0,180	81,29%	0,848
Slovenia	0,071	84,19%	0,918
Sri Lanka	0,383	69,22%	0,782
Taiwan	0,045		0,907
Ukraine	0,200	74,17%	0,773
United Arab Emirates	0,049	70,70%	0,911
Uruguay	0,235	80,27%	0,809

Public policy indicators

The indicators assigned to the public policy pillar are as follows:

- **R&D tax incentives** (OECD, 2020): Indirect government support through R&D tax incentives (in millions of US dollars). Li et al. (2021) found that financial incentives play a central role in the decision-making process for innovation adoption.

- **Energy mix ratio** (Our World in Data, 2020): The energy mix is the distribution of the different primary energy sources consumed in a given geographical area - coal, oil, gas, nuclear or renewables. It is usually a combination of some, if not all, of these sources. This balance of energy sources is becoming increasingly important as countries seek to shift from fossil fuels to low-carbon energy sources (nuclear or renewables, including hydropower, solar and wind). The energy mix represents the ratio between renewable and non-renewable energy sources. Some countries are more committed to renewable energy as they enact more laws and environmentally friendly policies. It can have a symbolic effect on citizens by signalling the positive benefits of an innovation and encouraging them to buy it (Ingeborgrud & Ryghaug, 2019).

- **Global Innovation Index, Institutions Component** (World Intellectual Property Organization, 2021): The Global Innovation Index (GII) tracks recent global innovation trends against the backdrop of an ongoing COVID -19 pandemic, slowing productivity growth and other evolving challenges. It provides insight into the world's most innovative economies by assessing the innovation performance of some 132 economies while identifying innovation strengths and weaknesses. One of the pillars of this index is that of institutions, which represent the policy and regulatory environment. Policies and institutions influence the use of innovation, and government policy is a key factor (International Energy Agency, 2022; Palmer, 2021).

Table 2.4: R&D tax incentives, Energy mix ratio, Institutional GII by country

Country	R&D Tax Incentives	Energy mix ratio	Institutional GII
Norway	$ 376	0,716	92,6
UK	$ 7.914	0,171	86,6
France	$ 6.634	0,123	83,4
China	$ 7.888	0,149	64,4
Italy	$ 2.780	0,176	75,5
Colombia	$ 13	0,312	66,2
Canada	$ 1.916	0,293	90,1
US	$ 23.336	0,091	87,6
Australia	$ 1.558	0,129	88,3
Japan	$ 3.860	0,114	88,8
Rwanda		0,096	67,0
Iceland	$ 25	0,869	86,8
Sweden	$ 70	0,480	88,8
Denmark	$ 102	0,393	88,8
Finland	$ 17	0,332	93,3
Netherlands	$ 1.226	0,115	88,9
Germany		0,185	84,3
Switzerland		0,367	87,3
Belgium	$ 1.030	0,082	80,8
Ireland	$ 652	0,176	84,3
Austria	$ 786	0,363	86,2
Spain	$ 330	0,214	77,5
New Zealand	$ 27	0,402	90,7
Republic of Korea	$ 1.791	0,035	79,5

Brazil	$ 745	0,389	60,6
India		0,090	64,4
Indonesia		0,067	51,2
Mexico	$ 21	0,104	61,0
Russia	$ 2.019	0,136	63,1
Philippines		0,109	56,3
Turkey	$ 256	0,165	56,0
Thailand	$ 17	0,054	64,2
South Africa	$ 10	0,034	66,8
Egypt		0,062	49,3
Argentina	$ 0,3	0,102	52,8
Azerbaijan		0,022	65,5
Belarus		0,010	57,8
Bosnia and Herzegovina			59,5
Bulgaria		0,115	69,8
Chile	$ 18	0,265	72,7
Costa Rica			63,1
Croatia	$ 0,3	0,283	69,8
Cyprus		0,068	80,4
Czechia	$ 117	0,065	76,9
Estonia		0,143	81,1
Georgia			76,2
Greece	$ 15	0,194	69,2
Hong Kong		0,001	88,1
Hungary	$ 65	0,068	71,7
Israel		0,051	76,2

Jordan			64,4
Kazakhstan		0,040	69,8
Latvia	$ 1	0,239	78,9
Lithuania	$ 13	0,095	76,4
Luxembourg		0,042	79,8
Malaysia		0,081	72,3
Malta	$ 4		73,9
Morocco		0,076	61,6
North Macedonia		0,148	68,9
Poland	$ 91	0,068	73,2
Portugal	$ 446	0,313	80,4
Romania	$ 9	0,175	68,1
Serbia			69,3
Singapore		0,004	95,1
Slovakia	$ 27	0,098	72,8
Slovenia	$ 50	0,188	82,9
Sri Lanka		0,214	47,5
Taiwan		0,030	
Ukraine		0,061	56,2
United Arab Emirates		0,011	78,4
Uruguay			70,3

Environmental indicators

The indicators assigned to the environmental pillar are as follows:

- **Energy independence** (The World Bank, 2015): net energy imports (% of energy consumption) representing the availability of energy resources. It indicates the extent to which an economy relies on imports to meet its energy needs.

- **Access to water sources** (Our World in Data, 2021): Proportion of people who do not have access to an improved water source. The definition of an improved drinking water source includes "piped water on premises (piped household water connection located inside the user's dwelling, plot or yard), and other improved drinking water sources (public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs, and rainwater collection)". Note that access to drinking water from an improved source does not guarantee that the water is safe or sufficient, as these characteristics are not tested at the time of collection. However, improved drinking water technologies are more likely to provide safe drinking water and prevent contact with human excreta than those designated as unimproved.

- **CO2 emissions per capita** (The World Bank, 2019): contribution of the average citizen of each country by dividing total emissions by population. An environmentally friendly attitude influences the adoption of innovations, as lifestyle and identity influence consumers' choice of green technologies. A correlation has been found between commitment to environmental protection and the adoption of these technologies (Ingeborgrud & Ryghaug, 2019).

Table 2.5: Energy independence, water sources access and CO2 emissions by country

Country	Energy independence	Water sources access	CO2 emissions
Norway	-581%	0,00%	6,7
UK	35%	0,00%	5,2
France	44%	0,00%	4,5
China	15%	4,92%	7,6
Italy	76%	0,08%	5,3
Colombia	-274%	2,32%	1,6
Canada	-73%	0,78%	15,4
US	7%	0,12%	14,7
Australia	-190%	0,03%	15,2
Japan	93%	0,92%	8,5
Rwanda		17,26%	0,1
Iceland	12%	0,00%	4,5
Sweden	25%	0,17%	3,4
Denmark	2%	0,00%	5,1
Finland	45%	0,00%	7,4
Netherlands	35%	0,00%	8,4
Germany	61%	0,00%	7,9
Switzerland	50%	0,00%	4,4
Belgium	80%	0,00%	8,1
Ireland	86%	2,60%	7,2
Austria	64%	0,00%	7,3
Spain	71%	0,07%	5,1
New Zealand	19%	0,00%	6,8
Republic of Korea	81%	0,07%	11,8

Brazil	12%	0,55%	2,1
India	34%	4,53%	1,8
Indonesia	-103%	6,73%	2,3
Mexico	-5%	0,32%	3,5
Russia	-84%	2,39%	11,8
Philippines	46%	3,03%	1,3
Turkey	75%	0,96%	4,8
Thailand	42%	0,00%	3,8
South Africa	-14%	3,34%	7,5
Egypt	-7%	0,32%	2,5
Argentina	14%		3,7
Azerbaijan	-310%	2,91%	3,5
Belarus	87%	0,09%	6,1
Bosnia and Herzegovina	23%	0,06%	6,4
Bulgaria	37%	0,99%	5,6
Chile	65%	0,00%	4,8
Costa Rica	50%	0,00%	1,6
Croatia	46%		4,1
Cyprus	94%	0,23%	6,0
Czechia	32%	0,12%	9,0
Estonia	-3%	0,41%	7,7
Georgia	69%	2,65%	2,7
Greece	64%	0,00%	5,6
Hong Kong	99%	0,00%	
Hungary	58%	0,00%	4,7
Israel	65%	0,00%	6,9

Jordan	97%	0,91%	2,4
Kazakhstan	-117%	2,62%	11,5
Latvia	45%	0,54%	4,0
Lithuania	75%	1,99%	4,2
Luxembourg	96%	0,12%	15,3
Malaysia	-6%	2,55%	7,9
Malta	98%	0,00%	3,3
Morocco	91%	4,33%	2,0
North Macedonia	52%	0,62%	4,0
Poland	29%	0,03%	7,8
Portugal	77%	0,09%	4,3
Romania	17%	0,00%	3,8
Serbia	29%	0,46%	6,6
Singapore	98%	0,00%	8,3
Slovakia	61%	0,00%	5,7
Slovenia	49%	0,50%	6,5
Sri Lanka	50%	7,18%	1,1
Taiwan			
Ukraine	27%	0,40%	3,9
United Arab Emirates	7%	0,03%	19,3
Uruguay	44%	0,00%	1,9

Cultural indicators

The indicators assigned to the cultural pillar are derived from the Hofstede Insights (2023) components and are as follows:

- **Individualism**: The fundamental issue of this dimension is the degree of interdependence that a society maintains between its members. It is about whether people's self-concept is defined in terms of "I" or "we". In individualistic societies, people should only care about themselves and their immediate family. In collectivist societies, people belong to a group that takes care of them in return for their loyalty.

- **Uncertainty avoidance**: Uncertainty avoidance has to do with the way a society deals with the fact that the future can never be known: Should we try to control the future or just let it happen? This uncertainty causes fear, and different cultures have learned to deal with this anxiety in different ways. The extent to which members of a culture feel threatened by ambiguous or unknown situations and have created beliefs and institutions that try to avoid them is reflected in the evaluation of uncertainty avoidance. As explained earlier, the perceived risk associated with the introduction of a new technology is a crucial factor in the adoption of innovations (Shoemaker & Shoaf, 1975).

- **Long-term orientation**: This dimension describes how each society needs to maintain some connection to its own past while dealing with the challenges of the present and the future, with societies prioritising these two existential goals differently. Normative societies that score low on this dimension, for example, prefer to maintain time-honoured traditions and norms while treating social change with suspicion. High-scoring cultures, on the other hand, take a more pragmatic approach: they promote frugality and efforts at modern education as preparation for the future. Kahneman and Tversky (1979) noted that one of the most important dimensions on which the process of innovation adoption depends is the behavioural change required.

Table 2.6: Individualism, Uncertainty avoidance and Long-term orientation by country

Country	Individualism	Uncertainty avoidance	Long term orientation
Norway	69	50	35
UK	89	35	51
France	71	86	63
China	20	30	87
Italy	76	75	61
Colombia	13	80	13
Canada	80	48	36
US	91	46	26
Australia	90	51	21
Japan	46	92	88
Rwanda			
Iceland	60	50	28
Sweden	71	29	53
Denmark	74	23	35
Finland	63	59	38
Netherlands	80	53	67
Germany	67	65	83
Switzerland	68	58	74
Belgium	75	94	82
Ireland	70	35	24
Austria	55	70	60

Spain	51	86	48
New Zealand	79	49	33
Republic of Korea	18	85	100
Brazil	38	76	44
India	48	40	51
Indonesia	14	48	62
Mexico	30	82	24
Russia	39	95	81
Philippines	32	44	27
Turkey	37	85	46
Thailand	20	64	32
South Africa	65	49	34
Egypt	37	55	42
Argentina	46	86	20
Azerbaijan	22	88	61
Belarus	25	95	81
Bosnia and Herzegovina	22	87	70
Bulgaria	30	85	69
Chile	23	88	31
Costa Rica	15	86	
Croatia	33	80	58
Cyprus			
Czechia	58	74	70
Estonia	60	60	82
Georgia	41	85	38
Greece	35	100	45

Hong Kong	25	29	61
Hungary	80	82	58
Israel	54	81	38
Jordan	30	65	16
Kazakhstan	20	88	85
Latvia	70	63	69
Lithuania	60	65	82
Luxembourg	60	70	64
Malaysia	26	36	41
Malta	59	96	47
Morocco	46	68	114
North Macedonia	22	87	62
Poland	60	93	38
Portugal	27	99	28
Romania	30	90	52
Serbia	25	92	52
Singapore	20	8	72
Slovakia	52	51	77
Slovenia	27	88	49
Sri Lanka	35	45	45
Taiwan	17	69	93
Ukraine	25	95	86
United Arab Emirates	36	66	22
Uruguay	36	98	26

2.1.4. Limitations of the model

As the findings will show, the collection of these data and the correlation analysis between the different indicators is a fundamental achievement for the development of the multi-agent system. Nevertheless, there are two main reasons why the analysis of these indicators is necessary but not sufficient for Airbus:

- Some data, especially those related to the cultural domain, do not seem to be very robust
- The data are not owned by Airbus, but are provided by international bodies, so their availability in the long term is not guaranteed.

It would be crucial for BlueSky to create their own database that they could draw on to run and develop their model with robust and proprietary data. The second methodological part therefore concerns the development of a serious game that can be used to collect large amounts of data over time, belonging to Airbus and providing culturally specific information.

Therefore, work continued on the conception and design of this Serious Game, in particular by organising two workshops (with the theme 'Cultural determinants of the adoption of new technologies'). However, it is important to emphasise from the outset that the success of this second part, i.e. the development of the Serious Game, has led to a change of course in the definition of BlueSky's objectives, with the development of the Serious Game becoming a main objective in itself and not just as a function of the multi-agent system.

The Serious Game aims to collect large amounts of demographic data on the willingness to accept innovative technologies in daily life. The original plan was to use the data collected through the Serious Game as the engine for the multi-agent system. However, as the project evolved, the Serious Game became a goal in itself due to its multiple possibilities, as will be shown in the following sections of this dissertation.

2.2. Serious game

2.2.1. Premise

The original goal of Project 42, initiated by BlueSky, was to develop a multi-agent system that simulates the dynamics and behaviour of individuals and social groups in the complex process of adopting new technologies.

Data is necessary to create a multi-agent system, train the agents and enable them to make decisions based on the information they receive from the environment (Wood & DeLoach, 2001). It is important to note that the quality and reliability of the data is critical to the performance of the multi-agent system. It is important to pre-process and validate the data to ensure that it is accurate and relevant to the problem at hand. Collecting data through a serious game can be an effective way to gather qualitative data on the adoption of new technologies.

A serious game designed to collect data on the adoption of new technologies could include tasks and scenarios that simulate the use and adoption of the technology and be used to collect data on players' attitudes, behaviours and decision-making processes. Using a serious game to collect data on the adoption of new technologies has several advantages:

- It can provide a more engaging and interactive way of collecting data, which can increase participation and the quality of the data collected.

- It can simulate real-life scenarios and behaviours, which can provide more accurate and relevant data than traditional survey methods.
- It allows data collection in a controlled environment, which can reduce noise in the data and improve the quality of the data collected.
- It enables large-scale data collection by reaching a large audience.

However, it should be noted that developing a serious game to collect data requires a significant amount of resources and expertise. It is important to ensure that the game is well designed, tested and validated before it is used for data collection. And it is important to ensure that the data collected is reliable and collected ethically.

The project started with the intention of developing a multi-agent system and using a serious game to collect data. However, the serious game has since become a goal in its own right. Using a serious game to collect data on the acceptance of new technologies can provide valuable cultural and social insights and can also be used to segment different markets by clustering the results.

The following sections explain the methods used to develop the serious game. In particular, they describe the two workshops that were organised to achieve this goal. In the first workshop, a first draft of the Serious Game was created using the Design Thinking approach in a co-creation process with the workshop participants, a group of international students. This first proposal was then revised and improved before being proposed to BlueSky. The Airbus department found this first proposal so satisfactory that they asked to focus on further improvements to the proposal. The second workshop therefore focused on presenting the serious game to the participants, a group of international professors and experts. After playing a first beta version of the application, the participants gave feedback and provided ideas on how to further improve the game. In the next chapter on the results, the serious game is presented and described in detail, including the specifications and a link to the prototype of the application.

2.2.2. Workshop I: Co-creating the Serious Game

To design and develop the serious game, it was decided, together with BlueSky, to use a qualitative approach by organising workshops with international participants. The internationality of the participants is a feature worth highlighting, as the aim of these workshops was to gather relevant insights that highlight cultural differences.

Specifically, two workshops were planned:

- a first workshop whose participants were to be international students
- a second workshop with international professors and experts

The decision to separate students and professors/experts was based on several considerations. First, it was to prevent students from participating less actively in the workshop when professors were present. Secondly, it was easier to organise the students' agendas than those of the professors/experts and a date could be set earlier. This made it possible to hold a first workshop also with a a beta test, in order to present oneself at a possible second one in the presence of professors with more material already created and to be better prepared.

The first workshop was attended by 10 students from 6 countries (France, India, Italy, Cameroon, Brazil and Spain) and was structured as follows:

- Presentation of the Moral Machine serious game, which the guests were allowed to play to show a successful case from which they could draw inspiration for the final objective
- Short presentation of the sustainability framework developed for the Airbus Multi-Agent System
- Open discussion on the factors that guests believe lead to their culture adopting or not adopting an innovation
- Co-design phase of the serious game using a design thinking approach (students first work individually, then in pairs and finally in groups, presenting and critiquing their work each time)

The outcome of this first workshop was the first draft of a possible Serious Game and various ideas that later led to its improvement. After refining this first draft, the results were presented to Airbus, who were very satisfied with the outcome. They therefore suggested that the second workshop should focus on improving this first proposal instead of trying to develop a new game from scratch. In the following section, the different parts of the workshop are explained in more detail and the most important results are presented.

The Moral Machine Experiment

The first part of the workshop included the presentation of the successful Moral Machine case to give participants an idea of what to expect from the workshop by experiencing a real case. Moral Machine is a multilingual online serious game that can be used to collect large-scale data on how citizens want autonomous vehicles to solve moral dilemmas related to unavoidable accidents (Awad et al., 2018). It enabled the collection of 39.61 million decisions from 233 territories.

With the rapid development of artificial intelligence, concern has arisen about how machines will make moral decisions (Bonnefon et al., 2016). In this context, Moral Machine has been proposed as an experimental online platform to explore the moral dilemmas faced by autonomous vehicles. Users are shown unavoidable accident scenarios with two possible outcomes, depending on whether the autonomous vehicle swerves or stays on its course as it is about to crash and cannot find a trajectory that would save everyone involved. Should it swerve on a teenager crossing the road to save its three elderly passengers? Autonomous vehicles will have to decide how to share the risk of damage between different road users.

The accident scenarios are created by Moral Machine, considering 9 factors:

1) People vs. pets
2) Action (on course) vs. non-action (swerving)
3) Passengers vs. pedestrians
4) More human lives vs. few human lives
5) Men vs. women
6) Young vs. older
7) Lawful crossing vs. carelessness
8) Fitter vs. less fit
9) Higher vs. lower social status

After completing the 13-accident session, users can fill out a survey (to collect their data) and are geolocated (to cluster them). With Moral Machine, it was possible to collect data from millions of people around the world, which would have been almost impossible to achieve with standard academic survey methods and also very costly (Awad et al., 2018).

Workshop participants expressed different views on the game:

- Pro:
  - *"In general, it is a pleasant experience to play this game."*
  - *"The game is super-intuitive and it is easy to get into the situation."*
  - *"The morality of autonomous vehicles is a hot topic that we will certainly have to deal with in the coming years."*
  - *"The connection between technologies and morality is really interesting."*

- Pain points:
  - *"The biggest dilemma would be if you yourself and/or your loved ones were in the car - killing strangers is 'easier'.".*
  - *"The game is more 'interesting' than 'entertaining'."*
  - *"A game where you have to kill people is quite difficult to play."*
  - *"Sometimes players respond by considering only one parameter (e.g. saving more lives), but then the outcome is one based on other factors (e.g. by saving more lives, I killed more children)."*

The success factors of the game can be divided into two dimensions:

- *Emotional dimension*:
- It says something about “you”: when someone plays, they end up with an outcome that reflects your preferences/ethical values.
- It has the power of a good story (storytelling).
  - It is the story about the future as people imagine it, and in the meantime, people build it by telling the story (emotional appeal).

  - "*Asimov's laws were a storytelling tool whose goal was to create good stories by showing how difficult it is to create moral machines with a dozen lines of code. And yet we do not have the luxury of giving up on creating moral machines.*"
  - "*Never in human history have we allowed a machine to autonomously decide who should live and who should die in a fraction of a second and without real-time monitoring.*"
- It opens a discussion: there is not one right answer, it is about finding a compromise, discussing. So the player is enticed to share the game with friends and spread it around.

- *Practical dimension*:
  - Simplicity: it is easy to understand and play, it is a visual tool (and if needed there is a button for a written explanation). But at the same time it collects a lot of information (the 9 dimensions).
  - In the beginning, there was a clearly defined problem of collective importance (reconciling moral algorithms with human values in anticipation of a future in which autonomous vehicles will be ubiquitous throughout the world) - importance of the problem framing.

The cultural dimension in the adoption of innovations

The intermediate part of the workshop aimed to get information from the participants about their thoughts on the crucial cultural factors in the process of adopting new technologies. After each participant had time to reflect, a discussion was opened to give participants the opportunity to share and provide as much food for thought as possible. The results of the open discussion can be summarised as follows: The most important factors for the introduction of innovations that emerged in the cross-cultural comparison:

- Budget and economic availability
- Performance of the innovation
- Social impact of the innovation (extent)
- Adoption of the innovation depends on the needs of the population
- Approval of the government
- Educational level of adopters
- Attitude of adopters (conservative, metropolitan vs. rural, etc.)
- Emotional dimension touched by the innovation

These factors will then serve as the basis for the co-creation process of the serious game in the next and final phase of the workshop.

Co-creation of Serious Game

Building on the findings of the previous two phases (in terms of methodology with regard to the Moral Machine case, in terms of content with regard to the identified cultural drivers), the final phase of the workshop aimed to develop a Serious Game using a Design Thinking approach and a co-creation process among the participants.

The Design Thinking methodology includes the following phases:

- *Envisioning* ("Me"): individual work, starting from one's own will ("People will never love a product that you do not love"). After each person has individually developed an idea, it is presented to all participants in a short pitch.

- *Sharing* (from "Me" to "Pair"): Each participant pairs with another participant based on similarity and complementarity of ideas. Through a sparring method, an idea is then presented again, combining the two original ideas through a process of creative critique. The idea is presented again to the whole group.
- *Clashing* (from "Pair" to "Circle"): Repeating the initial process, 3 pairs join together to form a Circle of 6 people. This Circle discusses each idea again and tries to get the best out of each idea by challenging the underlying assumptions and aiming for a solid final synthesis.

Through these various steps, participants conceived, proposed, modified and refined several potential Serious Games and critiqued each other to eventually converge on a final solution. This proposed Serious Game was then revised and is presented in the Findings chapter.

As anticipated, BlueSky was so pleased with the proposed version that it proposed to focus on improving it, creating a beta prototype and basing the second workshop on improving it, as reported in the next section.

2.2.3. Workshop II: Improving the Serious Game

The second workshop was attended by international professors and experts, namely 11 people from 10 different countries (France, Italy, Egypt, Algeria, Iceland, Venezuela, Poland, Czech Republic, Tunisia and Lebanon). As mentioned in the previous section, the original aim of the workshop, namely the joint development of the serious game, was already achieved with the first working group. This second workshop, in consultation with BlueSky, was therefore about gathering feedback and improving the first proposal.

Again, the starting point was to present the successful case of the Moral Machine to give the participants an overview of the research subject and the intended goal. Again, an open discussion arose around two main questions:

- "*What did you feel when you answered the Moral Machine questions?*"
- "*How do you explain the success of this experience?*"

Here is some feedback on the participants' opinions about this successful game, which were collected afterwards:

- Nora: *"I feel uncomfortable when I have to make a decision because it is not in accordance with my morals to do so. In my opinion, the reasons for the success of the game are the fact that it's close to science fiction, which attracts attention, and because it raises the burning question of morality and science (an innovation can have negative effects on our lives, which is interesting)".*
- Firas: *"I do not feel uncomfortable, the outcome was always death, I had no alternative. Humans make the rules for the machine, and the rules are set (once set, they become socially accepted in the long run). The important and challenging process will be to correct these rules".*
- Anna: *"I am not uncomfortable, this is a psychological test like many others. It is a theoretical choice that has nothing to do with a real decision. There are differences between measuring behaviour and decision making. It is about saving people versus other people, I prefer to decide in faith. On the other hand, when it comes to humans versus animals, I believe we should kill the animals. In my opinion, the reason for the success of the game is the application of a very old moral*

dilemma (the trolley problem), but in a practical and modern way. For me, this game has a problem: I am not sitting in the trolley, and it would be different if I were included in the scenario. Another success factor is that participants are not paid and give immediate feedback. The good design of the game has led to virality and tremendous scientific results".

- Jesus: *"I do not feel uncomfortable, it's just a game. In my opinion, something is missing in this test: skin colour, religion, etc. They could have improved the experience by including these perspectives. The game would have been stronger if relatives were included in the scenarios".*
- Paul: *"I did not feel comfortable, mainly because of the title. Morality is mainly about people, not machines. I did not understand my point of view in the game: Who am I? Am I the pilot? If I am not the pilot, am I God? I think reality is much more complex than black and white, and this test is too simplistic. The dichotomy is too simplistic: just go left or go right".*
- Abdelghaffar: *"I did not feel comfortable, it's difficult to decide. Sometimes I think of other solutions, but I am forced to choose between the only two proposals".*
- Nicolas: *"I do not feel uncomfortable. It's interesting to answer a questionnaire that I think says something about you in the end. And it stimulates exchange: I want to know what my wife, my friends think about this issue".*
- Simona: "*In my opinion, there are several reasons for the success of the survey. First of all, the division into only two possibilities is well visualised and makes the game easy. Then each player can choose their own point of view and that opens up many perspectives. You slip into the shoes you want. The game is not too long and at the end you get a surprising result. After seeing the result, I feel a positive attitude".*

- Peter: *"In my opinion, the reason for success is that it is a game. Once you start, it becomes easier. If you involve relatives, it would not be a game anymore, it would not be fun. The anonymity and non-sequitur are important"*.
- Hoda: *"I do not feel comfortable with it. It is a game, but it is too exhausting. It is not as much fun as a game"*.

After this first phase of open discussion, the sustainability framework on which the project is based was briefly presented again and the connection between the importance of the issue of sustainability and the dynamics of the introduction of new technologies was explained. Finally, the demo version of the serious game was offered to the participants so that they could play the game, give feedback to improve the game and develop game scenarios together.

The next chapter on the research results presents all the results obtained, including the beta demo of the serious game, which was refined thanks to the feedback received during this second workshop.

3 Findings

This chapter presents the main findings that emerged from the processes described earlier. In particular, two main results were obtained.

First, using the data collected in the sustainability framework on the adoption rate of e-vehicles and the main indicators related to the pillars of sustainability, it was possible to perform a correlation analysis to verify the relationship between these indicators and to boost the multi-agent system.

Secondly, the Serious Game that emerged from the organisation and implementation of the two workshops will be described in detail and its design and game dynamics will be presented.

3.1. Sustainability Framework: Correlation Matrix

The previous chapter described the sustainability framework that was created for the development of the multi-agent system. Based on the hypothesis that the adoption rate of electric vehicles can be (at least partially) representative of the adoption rate of an innovation in general (and in particular in the field of mobility as it is in the interest of Airbus), data was collected on more than 70 countries regarding the adoption rate of electric vehicles and economic, social, political, environmental and cultural indicators (provided by international organisations such as the OECD, UN, etc.). The indicators were selected based on the different pillars of sustainability, looking for correspondences between the chosen indicator and the adoption and diffusion of innovations in the existing literature.

Based on the collected data, it was possible to perform a correlation analysis to determine the actual relationship between the adoption rate of EVs and the selected indicators. The table below shows the values found:

Table 3.1: Correlation analysis, EVs adoption rate

Pillar	Indicator	EVs adoption rate
Economic	Gross national income	0,53
	GINI	-0,22
	BERD / GERD	0,21
Social	Gender inequalities	-0,43
	Social Progress Index	0,49
	HDI	0,48
Public Policy	R&D Tax Incentives	-0,05
	Energy mix ratio	0,69
	Institutional GII	0,53
Environmental	Energy independence	-0,34
	Water sources access	-0,21
	CO2 emissions	0,04
Cultural	Individualism	0,36
	Uncertainty avoidance	-0,38
	Long term orientation	-0,10

Grouping the different indicators and looking at their values as a whole and comparing them with the adoption rate of electric vehicles results in the following cluster correlation matrix:

Table 3.2: Cluster Correlation Matrix

Cluster Correlation Matrix	
Economic	0,32
Social	0,47
Political	0,42
Environmental	0,20
Cultural	0,28

Finally, the distribution of the correlation values of the individual indicators is shown in the graph below, where the rare outliers can be easily seen (values that are close to zero in terms of absolute value indicate a low correlation, while values that tend towards 1 in terms of absolute value indicate a high correlation).

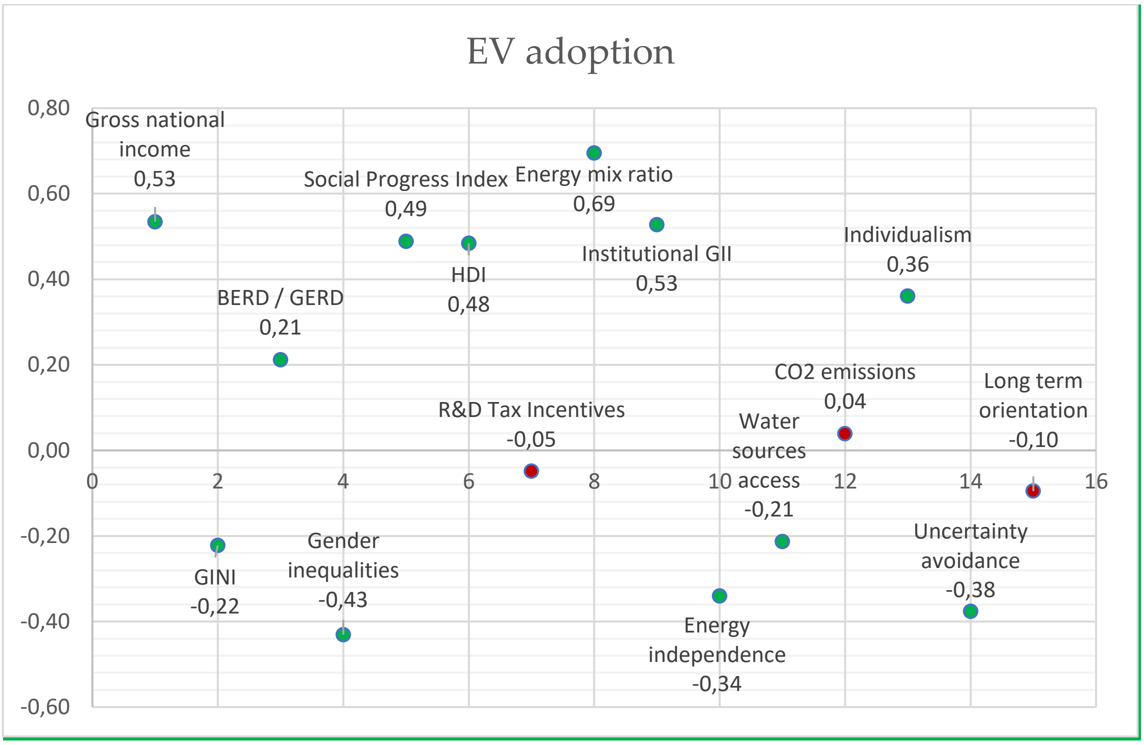

Figure 3.1: Outliers

As already suspected by analysing the literature, there seems to be an interesting correlation between EVs adoption and the selected indicators based on the sustainability pillars. Only a few outliers, highlighted in red in the graph, show a greater uncertainty in the correlation between these factors. This opens the possibility to further investigate the correlation with the individual indicators in the future.

Furthermore, it was also possible to observe the mutual correlation between the different indicators themselves. This step is crucial for Airbus as it provides a mathematical basis for modelling the multi-agent system). The full correlation matrix with all values can be found in Appendix B. The multi-agent system developed from this matrix is the work and property of Airbus and is not the subject of this research.

3.2. Serious Game: Should a machine…?

The previous chapter described the co-creation process that led to the development of the serious game through a design thinking approach. This section presents the results achieved, namely the design and dynamics of the serious game, the planned scenarios and the reward system conceived as a result page.

3.2.1. Objective

As mentioned earlier, the original aim of the Serious Game was to collect data that would feed into the multi-agent system and serve as a kind of engine for its operation. However, after its conception and development, the potential of the Serious Game seemed so great that it became an objective in itself, as it is a tool that can potentially collect large amounts of cultural information of high scientific value. The goal is to aspire to the achievements of the Moral Machine game described above.

The Serious Game was thus designed to collect a large amount of data on cultural aspects of innovation adoption and to reveal the cultural tendencies of populations in relation to the potential integration of new technologies, such as artificial intelligence. The ultimate question to be answered by this game is the following:

"Are technologies seen as a solution or part of the problem in building a sustainable world?"

At the beginning of the experience, players are introduced through a brief description of the game, which is only useful for cautionary purposes due to its intuitive dynamics. At the end of the game, players are then asked if they would like to participate in the survey and provide some of their demographic data, as was the case with the Moral Machine.

Through the designed game dynamics, user-friendly gameplay and the developed reward system, the aim is to create a viral game that spreads quickly and is able to collect data from players all over the world. These aspects are explained in more detail in the following section.

3.2.2. Design and dynamics

The Serious Game is called "**Should a machine...?**". Players are presented with different scenarios that show what could be done with new technologies in the future. In each scenario, a machine replaces a human. Machines could substitute nurses, governors, teachers... Where will the players draw the line? What will they find acceptable or not? Players can answer the proposed question and express their preference for the corresponding scenario with a simple 'swipe' mechanism, similar to the well-known application 'Tinder'.

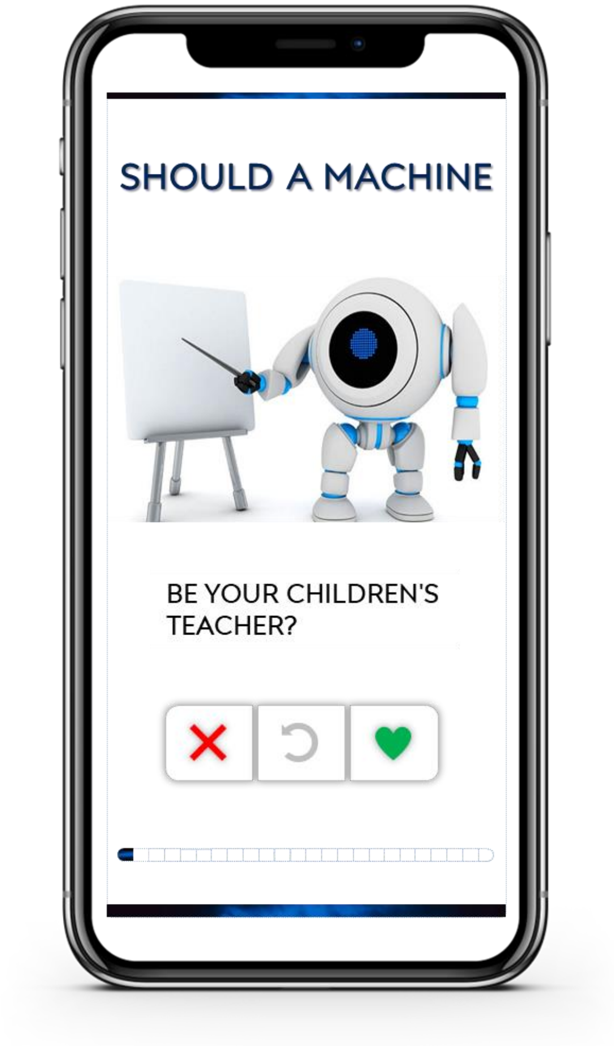

Figure 3.2: "Should a machine…?" Serious Game (sample scenario)

In terms of architecture, each scenario is associated with a Sustainable Development Goals (SDGs) value behind the first, "front-end" layer (one presented to the players). The SDGs are divided into 4 groups:

- *Economic*: Poverty, Nutrition, Workplace
- *Social*: Health, Education, Equality
- *Political*: Justice, Infrastructures & Cities, Collaboration
- *Environmental*: Energy, Production & Consumption, Climate Change

By answering the questions with "Yes" or "No", the players increase their score in relation to the group of the respective scenario. At the end, the player is shown a different result depending on his answer, as it will be shown in the section "Results page and reward system"

3.2.3. Assessment of scenarios and questions

One of the most important critical issues in the development of this Serious Game concerns the design of the scenarios. The questions posed to the players need to be unbiased, meaningful and related to the SDG scenarios they are linked to.

Here is the list of questions created and their corresponding assignment to one of the SDGs:

- **Poverty** (income, wealth)
  1. *Should a machine manage your taxes?*
  2. *Should a machine propose a project for the rehabilitation /requalification of run-down urban areas ("slums")?*
  3. *Should an algorithm decide on the recipients of financial aid?*
  4. *Should a machine decide on the "right" inflation rate?*
  5. *Should a machine decide on your maximum income?*
  6. *Should a machine decide that you have to give money away to the poor?*
  7. *Should a machine choose people to kill based on their income?*
  8. *Should a machine decide whether you can have children?*
  9. *Should a machine set a car quota for you per year?*

- **Nutrition** (hunger, water)
  1. *Should a machine control your schedule for drinking water and allow you to do it only when it deems necessary?*
  2. *Would you trust a diet plan created by a machine for your parents who suffer from obesity?*
  3. *Should a machine distribute food and water equally to society in the event of famine?*
  4. *Should a machine do your grocery shopping based on your health?*
  5. *Should a machine inform you about the quality and health of your food?*
  6. *Should a machine decide whether you can eat something?*
  7. *Should a machine manage a school canteen?*
  8. *Should a machine make a new, balanced energy drink?*

- **Health** (health & well-being, hygiene)
  1. *Should a machine perform open-heart surgery on you?*
  2. *Should a machine visit your grandmother and take care of her?*
  3. *Should an algorithm decide on every citizen's health insurance?*
  4. *Should a machine visit the elderly to combat loneliness in case of illness?*
  5. *Should a machine do your grocery shopping based on your health and not your preferences?*
  6. *Should a machine take care of your partner's emotional care?*
  7. *Should a machine decide on euthanasia if your health is not good enough?*
  8. *Should a machine decide on your abortion?*
  9. *Should a machine pick up your children from school?*

- **Education**
  1. *Should a machine write a book about you?*
  2. *Should a machine be the teacher for your children?*
  3. *Should a machine correct a student's essay?*
  4. *Should a machine be an anti-cheating system?*
  5. *Should a machine act as a tutor in school?*
  6. *Should a machine be the nanny for your children?*
  7. *Should a machine do homework with your children?*
  8. *Should a machine set up the annual school programme?*

- **Equality** (gender equality, economic and social)
  1. *Should a machine decide on your sexual preferences?*
  2. *Should a machine help a disabled person with rehabilitation?*
  3. *Should a machine/algorithm select the best candidates for a job by analysing their CVs?*
  4. *Should a machine judge a person in court without bias?*
  5. *Should a machine calculate your salary based on your actual worth?*
  6. *Should a machine calculate your salary based on your real worth?*
  7. *Should a machine be a representative of a civil rights movement?*
  8. *Should a machine suggest sexual orientation to teenagers?*
  9. *Should a machine decide who should be promoted in a company?*

- **Energy**
  1. *Would you trust a machine to run a nuclear power plant near your home?*
  2. *Should a machine decide on the right energy mix for a country?*

3. *Should a machine build smart windows that generate electricity and regulate heat/light?*
4. *Should a machine fully automate the mining of hazardous chemicals?*
5. *Should a machine move polluting activities into space and mine asteroids?*
6. *Should a machine regulate the heat and light in your home to reduce their impact?*
7. *Should a machine decide to whom the energy produced in your country is distributed?*
8. *Should a machine run a hydro-wind power plant?*

- **Production and consumption (oceans, land, production and consumption)**

1. *Should a machine control your electricity/water consumption during the day to prevent exceeding a certain limit? (Switch off if consumption is too high and switch on again later)*
2. *Should a machine create an artificial coral reef to replace the dying natural reef?*
3. *Should a machine check food stocks at home and buy the necessary items?*
4. *Should a machine produce food?*
5. *Should a machine set up mining areas/activities?*
6. *Should a machine produce and cook your food?*
7. *Should a machine artificially change the ecosystem in harsh areas?*
8. *Should a machine flush only when needed?*

- **Climate change**

1. *Should a machine clean the beaches of rubbish?*

2. *Should a machine artificially create clouds?*
3. *Could machine-controlled drones clean the air?*
4. *Should a machine fly drone patrols to monitor vulnerable areas?*
5. *Should a machine artificially replace a flooded island?*
6. *Should a machine determine which and where green spaces should be created in a city?*
7. *Should a machine create an evacuation plan for hurricanes?*
8. *Should a machine create blocks of ice to artificially replace glaciers?*

- **Workplace**
  1. *Would you work in the metaverse?*
  2. *Should a machine organise work groups by selecting the people in them?*
  3. *Should a machine evaluate applications for a job?*
  4. *Should a machine accept that a machine automatically replies to my email?*
  5. *Should a machine accept that a machine evaluates my performance?*
  6. *Should a machine evaluate candidates in a hiring process?*
  7. *Should a machine be your colleague?*
  8. *Should a machine be your boss?*

- **Infrastructure and cities** (housing, transport, etc.)
  1. *Should a machine managed by a third party be your housekeeper?*
  2. *Should a machine be a public transport driver?*
  3. *Should a machine design an important bridge (from design to construction)?*
  4. *Should a machine be responsible for maintenance?*
  5. *Should a machine democratise VTLOs?*

6. *Should a machine build a distribution network for batteries for electric cars?*
7. *Should a machine be responsible for the maintenance of public infrastructure?*
8. *Should a machine be an aeroplane pilot?*

- **Justice and safety**
  1. *Should a machine be your bodyguard?*
  2. *Should a machine arrest someone for a crime?*
  3. *Should a machine fight in the army?*
  4. *Should a machine replace a judge?*
  5. *Should a machine be a lawyer?*
  6. *Should a machine make an emergency call after receiving a phone call?*
  7. *Should a machine be a fireman?*
  8. *Should a machine determine the sentence?*

- **Collaboration** (cooperation, community)
  1. *Should a machine replace you at a meeting with friends?*
  2. *Should a machine be the president/decision-maker in your favourite sports club?*
  3. *Should a machine control and count the ballots in an election?*
  4. *Should a machine be a governor?*
  5. *Should a machine vote for you by studying your preferences?*
  6. *Should a machine select an entrepreneur instead of running tenders?*
  7. *Should a machine select start-ups in which public institutions can invest?*
  8. *Should a machine select congressmen by studying their CVs?*

In the first prototype of the game, the sample of questions was created for illustrative purposes only, but still needs to be verified to be scientifically valid. In particular, the use of advanced techniques such as self-assessment manikin (SAM), valence and arousal (and possibly avoidance) techniques using bipolar sliding semantic scales, and in general the deepening of important cross-cultural research methods is planned for the second phase of the development of the Serious Game (outside the scope of this report). Validation of the questions is ongoing at the time of publication of this dissertation and will be used to continue Project 42.

3.2.4. Results page and reward system

Achieving the virality of the game is a necessary goal in order to collect large amounts of data and have relevant statistical information. Based on the successful case of the Moral Machine, the results page is of great importance for the viral spread of the game. It acts as a kind of reward for the players and encourages them to share the game with family, friends and colleagues. Based on this experience, it was crucial to conceptualise and design an effective results page that met the following characteristics:

- *Emotional*: it must have the power of a good narrative.
- *Comparable*: it must show results that are comparable to those of others.
- *Visual*: it must be clear and easy to understand

Based on these premises, 3 different possible solutions were proposed, each with its advantages and disadvantages.

Build your robot!

A personal, customised robot created by an artificial intelligence based on the players' answers. This gives you the opportunity to compare your robot with others: those of friends, colleagues, your own country and between countries. What would the French robot look like? And the American one? And the Chinese one?

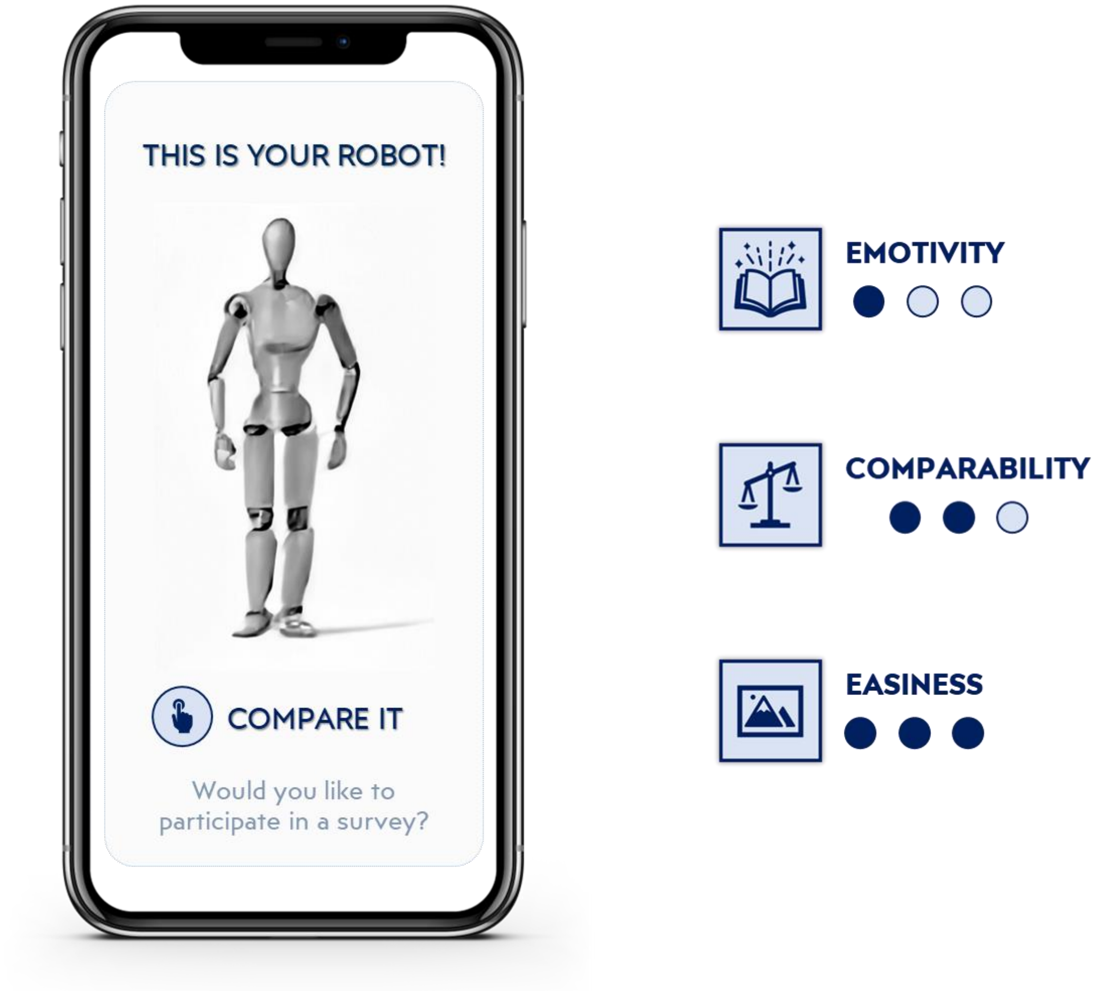

Figure 3.3: Build your robot! sample result page

Build your planet!

A customised planet and civilisation created by an artificial intelligence based on the players' answers. Each question relates to a pillar (6 questions per pillar), and each pillar is assigned an attribute:

- *Economic*: number of cities and infrastructures on the planet
- *Social*: frequency of connections between cities and infrastructures
- *Political*: degree of technological progress and prosperity of cities (high-tech cities vs. rural cities)
- *Environmental*: number of trees and green spaces on earth

Figure 3.4: Build your planet! sample result page

How far would you go on a space journey?

By answering the questions with yes or no, the players receive innovation points (1 point for yes, 0 for no). Based on the innovation points, players reach a different planet at the end of the game depending on their score and receive a title:

- *Prudent*
    - 0% - 10%: Sun
    - 11% - 20%: Mercury
- *Preserver*
    - 21% - 30%: Venus
    - 31% - 40%: Earth
- *Curious*
    - 41% - 50%: Mars
    - 51% - 60%: Jupiter
- *Explorer*
    - 61% - 70%: Saturn
    - 71% - 80%: Uranus
- *Galactic Traveller*
    - 81% - 90%: Neptune
    - 91% - 100%: Pluto

In addition, depending on the level of innovation, the player is shown the range (%) of innovativeness (like Spotify % of top listeners).

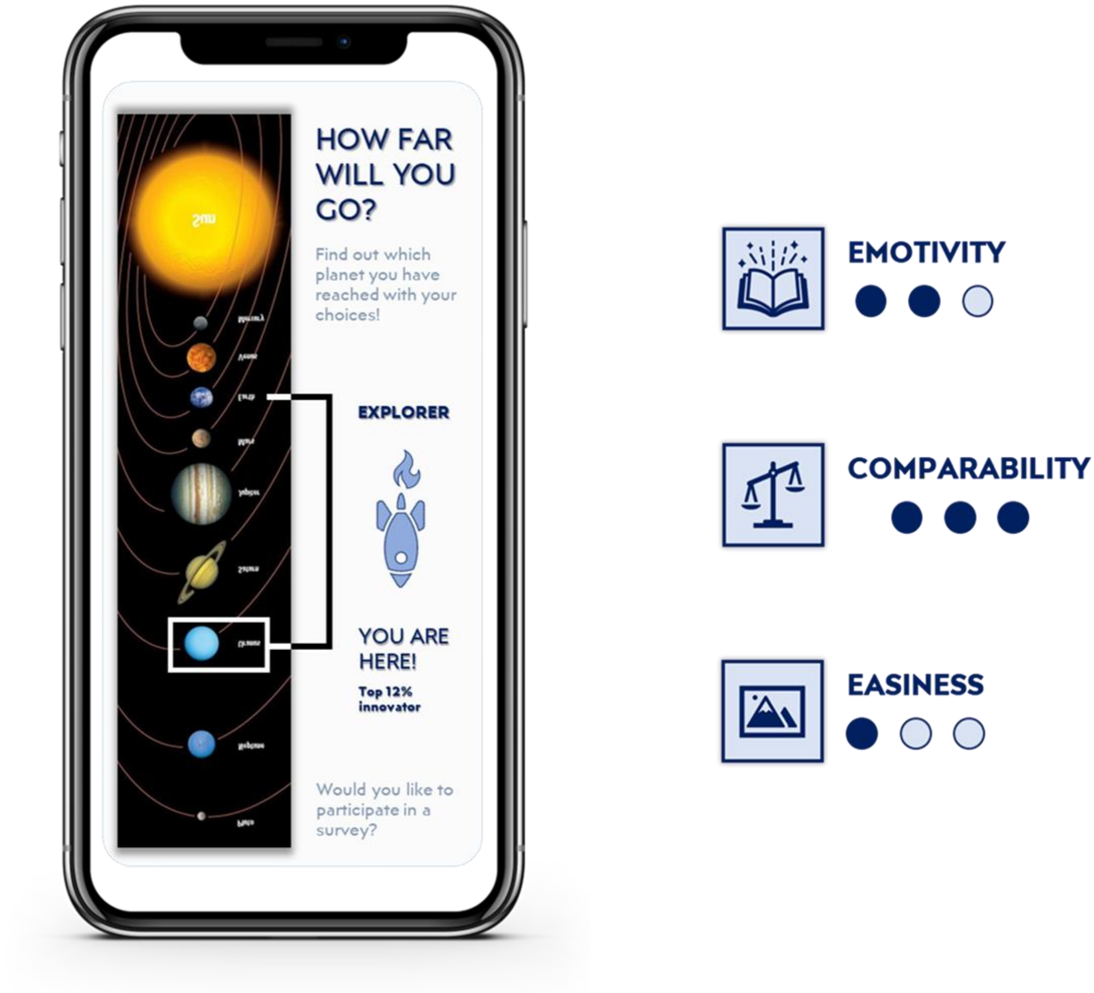

Figure 3.5: How far would you go on a space journey? sample result page

Another idea was to include, in addition to the visual result (not as a substitute), an AI-generated soundtrack (as a "jingle-of-your-life") based on the players' responses.

In the beta version of the application, the focus was on developing the first scenario ('Build your robot!') for simplicity and feasibility. Depending on the answers of the test players, the final result was one of four robots representing one of the four categories into which the SDGs were divided (economic, social, political, environmental).

As with the validation of the questions, the choice of the results page is outside the scope of this dissertation and, at the time of this publication, is the subject of ongoing work within Project 42.

3.2.5. Next steps

As can be seen from the previous sections, although there is already a first beta version of the Serious Game, further studies and work are needed and underway to perfect this application and make it available to the general public. Airbus' goal is to distribute the game through various channels available to the company. However, it must first be finalised and refined, and this is what the continuation of Project 42 is all about.

In particular, the scenarios that the players will face must be tested and validated using the methods previously proposed in order to have adequate scientific relevance. Besides improving the quality aspect of the questions, it is also important to increase the quantity of the questions themselves by increasing the randomness of the game. Furthermore, the game needs to be improved both from a purely graphical point of view and in terms of user experience in general (landing page, dynamic pages and results).

Another aspect being considered is the possibility of introducing two game modes for players: infinite time and time-limited ("Chrono" mode). This second new mode is mainly about testing the emotional reaction of the players when they are confronted with the proposed scenarios without having time to think about them rationally. This mode is intended to illustrate the difference between rational and intuitive decision-making.

Finally, the underlying question of the game ("*Should a machine...?*") is still being explored and some alternatives are proposed, such as "*Would you accept...?*". Further work on the project is planned to define all these points and will continue in the coming months after the publication of the following paper.

The process of designing and developing the Serious Game is intricate and complex. Starting with carte blanche, a prototype of the application was developed over a few months, reaching initial milestones and paving the way for future possibilities. The beta version can be found at the following link: http://51.77.245.133:8003/.

The project is still ongoing and future results may be published in a new research paper.

4 Discussion

This dissertation reports on the contribution I made to Project 42 during my experience in Toulouse, France.

The aim of the project, initiated by BlueSky, the research and development department of Airbus, is to understand the determinants of the process of adoption of new technologies and to create a tool, namely the multi-agent system, that can simulate this process and support business decisions by predicting the behaviour of different social and demographic groups in the face of the introduction of various new disruptive technologies in the market. To do this, it was first necessary to analyse the dynamics of the innovation adoption process.

In order to understand the vast subject of the adoption of new technologies, a review of the literature was undertaken, both classical (the foundations of which are based on the work "Diffusion of Innovation" by Rogers, 1962) and current (such as the recent work by César A. Hidalgo, "How Humans Judge Machines", 2021). The main factors that lead people to adopt new technologies were summarised and presented with appropriate examples to highlight their importance. It was then emphasised that the weight people give to these factors is not fixed, but varies over time and in different contexts. In particular, the increasing importance of the role of sustainability as a relevant factor in the dynamics of innovation adoption was highlighted. Different attitudes and inclinations within different social groups towards sustainability can be an important early predictor and a weak signal for the different willingness to adopt innovations within these groups. Therefore, some different approaches to sustainability were presented, starting with the concepts of weak and strong sustainability and then introducing the concept of solutionism. The literature review can in itself be considered a first achievement, as it provides a general and detailed overview of the object of study and serves as a basis for the continuation of the project, namely for the development of the multi-agent system to predict the behaviour of different social groups in adopting new technologies in the market.

Based on the considerations that emerged from the literature review, a framework focusing on the concept of sustainability was proposed to collect the necessary data for the operation of the multi-agent system. Based on the assumption that the adoption rate of electric vehicles can be representative of the adoption rate of an innovation in general (as a technology for which historical data already exist, which is sustainability-friendly and related to the field of mobility, such as the interest of Airbus), data on this rate was collected for over 70 countries. Data was then collected on key indicators related to the five pillars of sustainability: Economic, Social, Political, Environmental and Cultural. This data was then used in a correlation analysis to determine the link between these indicators and the adoption rate of electric vehicles as well as their interconnection. This link, i.e. the mathematical correlation, is fundamental to the design of the multi-agent system as a basis for modelling the different agents.

The model presented has some limitations, in particular the fact that the data is not owned by Airbus and, although it comes from international and reliable sources, it may become unavailable over time and also requires a considerable effort in data entry. To overcome these problems, it was decided to develop a Serious Game, using the successful Moral Machine case as a starting point. The purpose of the Serious Game is to collect large amounts of demographic and behavioural data from potential players around the world and then use this data to improve agent modelling in the multi-agent system. With more up-to-date, specific and larger amounts of data, agents can be modelled more accurately, leading to greater effectiveness of the multi-agent system as a predictive system. The Serious Game was developed following two workshops with international participants under the theme 'Cultural Determinants of Technology Adoption' and using a Design Thinking approach. The success of this initial design phase of the Serious Game was such that the original focus was expanded to include the game itself and the development of the multi-agent system. By collecting large amounts of demographic, cultural and behavioural data, the Serious Game could prove to be a valuable source of socio-cultural and academic knowledge enhancement, posing as an important scientific goal in itself.

The results presented in this paper are thus twofold:

- The correlation analysis of the adoption rate of electric vehicles and the significant indicators related to the pillars of sustainability (economic, social, political, environmental, cultural).
- The design and prototyping of the Serious Game "Should a machine...?".

The correlation analysis carried out confirms the insights presented in the literature review and serves as a basis for the development of the multi-agent system by providing an important data basis for the modelling of the agents.

The Serious Game is described in detail in terms of both architecture and dynamics, anticipating the remaining critical issues that are being analysed at the time of this writing. In particular, the game scenarios of the Serious Game not only need to be expanded quantitatively, but also tested for their scientific validity. Some possible methods for this have already been mentioned, such as self-assessment manikin and valence and arousal (and possibly avoidance) techniques using bipolar sliding semantic scales. In addition, some game dynamics are still being explored (e.g. the possibility of introducing two game modes, one with and one without a time limit, to compare the possible differences between players' emotional and rational responses). Finally, on the results page at the end of the game, several reward systems were proposed to be tested in a beta phase in order to select the most appropriate and effective one.

Project 42 is very complex and multi-layered and this dissertation presents only its first part, which consists of (1) the analysis of the literature on innovation adoption, (2) the sustainability framework and the process through which data were collected to model the agents of the multi-agent system, and (3) the design of the Serious Game through which the modelling of these agents will be improved and, at the same time, important information will be obtained to increase scientific knowledge about socio-cultural differences in the innovation adoption process. These results form the basis of the project, which aims to achieve the initial goal of (i) creating a predictive tool to understand the dynamics of innovation adoption and the later goal of (ii) having a tool to collect large amounts of socio-cultural and demographic data on the preferences of agents in the process of adopting new technologies.

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A Appendix A

Sustainability Framework

Country	EV adoption	Gross national income	GINI	BERD / GERD	Gender inequalities	Social Progress Index	HDI	R&D Tax Incentives	Energy mix ratio	Institutional GII	Energy independence	Water sources access	CO2 emissions	Individualism	Uncertainty avoidance	Long term orientation
Norway	**86,2%**	**$ 64.660**	**27,7%**	**54,3%**	**0,016**	**90,74%**	**0,961**	**$ 376**	**0,716**	**92,6**	**-581%**	**0,00%**	**6,7**	**69**	**50**	**35**
UK	18,6%	$ 45.225	35,1%	67,4%	0,098	86,13%	0,929	$ 7.914	0,171	86,6	35%	0,00%	5,2	89	35	51
France	18,3%	$ 45.937	32,4%	65,9%	0,083	86,07%	0,903	$ 6.634	0,123	83,4	44%	0,00%	4,5	71	86	63
China	**15,0%**	**$ 17.504**	**38,2%**	**76,6%**	**0,192**	**65,74%**	**0,768**	**$ 7.888**	**0,149**	**64,4**	**15%**	**4,92%**	**7,6**	**20**	**30**	**87**
Italy	9,3%	$ 42.840	35,2%	61,8%	0,056	85,23%	0,895	$ 2.780	0,176	75,5	76%	0,08%	5,3	76	75	61
Colombia	7,1%	$ 14.384	54,2%		0,424	69,83%	0,752	$ 13	0,312	66,2	-274%	2,32%	1,6	13	80	13
Canada	6,6%	$ 46.808	33,3%	53,7%	0,069	88,17%	0,936	$ 1.916	0,293	90,1	-73%	0,78%	15,4	80	48	36
US	**4,0%**	**$ 64.765**	**41,4%**	**75,3%**	**0,179**	**84,65%**	**0,921**	**$ 23.336**	**0,091**	**87,6**	**7%**	**0,12%**	**14,7**	**91**	**46**	**26**
Australia	2,4%	$ 49.238	34,3%	51,0%	0,074	87,83%	0,951	$ 1.558	0,129	88,3	-190%	0,03%	15,2	90	51	21
Japan	1,2%	$ 42.274	32,9%	78,7%	0,083	88,19%	0,925	$ 3.860	0,114	88,8	93%	0,92%	8,5	46	92	88
Rwanda	0,001%	$ 2.210	43,7%		0,388	52,18%	0,534		0,096	67,0		17,26%	0,1			
Iceland	71,7%	$ 55.782	26,1%	67,9%	0,043	89,54%	0,959	$ 25	0,869	86,8	12%	0,00%	4,5	60	50	28
Sweden	43,3%	$ 54.489	29,3%	71,7%	0,023	89,42%	0,947	$ 70	0,480	88,8	25%	0,17%	3,4	71	29	53
Denmark	35,2%	$ 60.365	27,7%	61,6%	0,013	90,54%	0,948	$ 102	0,393	88,8	2%	0,00%	5,1	74	23	35
Finland	30,8%	$ 49.452	27,7%	67,0%	0,033	90,46%	0,940	$ 17	0,332	93,3	45%	0,00%	7,4	63	59	38
Netherlands	29,8%	$ 55.979	29,2%	66,6%	0,025	88,97%	0,941	$ 1.226	0,115	88,9	35%	0,00%	8,4	80	53	67
Germany	26,0%	$ 54.534	31,7%	66,6%	0,073	88,72%	0,942		0,185	84,3	61%	0,00%	7,9	67	65	83
Switzerland	22,5%	$ 66.933	33,1%	67,5%	0,023	90,26%	0,962		0,367	87,3	50%	0,00%	4,4	68	58	74
Belgium	18,4%	$ 52.293	27,2%	73,7%	0,048	87,22%	0,937	$ 1.030	0,082	80,8	80%	0,00%	8,1	75	94	82
Ireland	15,7%	$ 76.169	30,6%	74,5%	0,074	87,69%	0,945	$ 652	0,176	84,3	86%	2,60%	7,2	70	35	24
Austria	9,5%	$ 53.619	30,2%	70,3%	0,053	88,05%	0,916	$ 786	0,363	86,2	64%	0,00%	7,3	55	70	60
Spain	7,8%	$ 38.354	34,3%	55,6%	0,057	85,35%	0,905	$ 330	0,214	77,5	71%	0,07%	5,1	51	86	48
New Zealand	5,5%	$ 44.057	32,5%	61,7%	0,088	87,26%	0,937	$ 27	0,402	90,7	19%	0,00%	6,8	79	49	33
Republic of Korea	6,8%	$ 44.501	31,4%	79,1%	0,067	86,47%	0,925	$ 1.791	0,035	79,5	81%	0,07%	11,8	18	85	100
Brazil	0,4%	$ 14.370	48,9%		0,390	71,26%	0,754	$ 745	0,389	60,6	12%	0,55%	2,1	38	76	44
India	0,1%	$ 6.590	35,7%		0,490	60,19%	0,633		0,090	64,4	34%	4,53%	1,8	48	40	51
Indonesia	0,5%	$ 11.466	37,9%		0,444	66,67%	0,705		0,067	51,2	-103%	6,73%	2,3	14	48	62
Mexico	0,3%	$ 17.896	45,4%	21,5%	0,309	70,84%	0,758	$ 21	0,104	61,0	-5%	0,32%	3,5	30	82	24
Russia	0,1%	$ 27.166	36,0%	56,6%	0,203	71,99%	0,822	$ 2.019	0,136	63,1	-84%	2,39%	11,8	39	95	81
Philippines	0,3%	$ 8.920	42,3%		0,419	67,46%	0,699		0,109	56,3	46%	3,03%	1,3	32	44	27
Turkey	0,6%	$ 31.033	41,9%	64,8%	0,272	66,59%	0,838	$ 256	0,165	56,0	75%	0,96%	4,8	37	85	46
Thailand	0,6%	$ 17.030	35,0%		0,333	69,80%	0,800	$ 17	0,054	64,2	42%	0,00%	3,8	20	64	32
South Africa	0,1%	$ 12.948	63,0%	31,0%	0,405	69,95%	0,713	$ 10	0,034	66,8	-14%	3,34%	7,5	65	49	34
Egypt	0,04%	$ 11.732	31,5%		0,443	58,73%	0,731		0,062	49,3	-7%	0,32%	2,5	37	55	42
Argentina	0,01%	$ 20.925	42,3%	36,1%	0,287	78,64%	0,842	$ 0,3	0,102	52,8	14%		3,7	46	86	20
Azerbaijan	1,6%	$ 14.257	26,6%		0,294	63,26%	0,745		0,022	65,5	-310%	2,91%	3,5	22	88	61
Belarus	1,3%	$ 18.849	24,4%		0,104	71,49%	0,808		0,010	57,8	87%	0,09%	6,1	25	95	81
Bosnia and Herzegovina	1,7%	$ 15.242	33,0%		0,136	71,23%	0,780			59,5	23%	0,06%	6,4	22	87	70
Bulgaria	3,5%	$ 23.079	40,3%		0,210	76,81%	0,795		0,115	69,8	37%	0,99%	5,6	30	85	69
Chile	0,8%	$ 24.563	44,9%	33,5%	0,187	80,78%	0,855	$ 18	0,265	72,7	65%	0,00%	4,8	23	88	31
Costa Rica	4,4%	$ 19.974	49,3%		0,256	80,65%	0,809			63,1	50%	0,00%	1,6	15	86	
Croatia	4,3%	$ 30.132	28,9%		0,093	82,32%	0,858	$ 0,3	0,283	69,8	46%		4,1	33	80	58
Cyprus	1,8%	$ 38.188	31,2%		0,123	83,18%	0,896		0,068	80,4	94%	0,23%	6,0			
Czechia	3,1%	$ 38.745	25,3%	61,0%	0,120	85,10%	0,889	$ 117	0,065	76,9	32%	0,12%	9,0	58	74	70
Estonia	3,0%	$ 38.048	30,8%	55,0%	0,100	86,16%	0,890		0,143	81,1	-3%	0,41%	7,7	60	60	82
Georgia	3,4%	$ 14.664	34,5%		0,280	74,43%	0,802			76,2	69%	2,65%	2,7	41	85	38
Greece	8,7%	$ 29.002	33,1%	46,1%	0,119	82,44%	0,887	$ 15	0,194	69,2	64%	0,00%	5,6	35	100	45
Hong Kong	38,8%	$ 62.607	53,3%				0,952		0,001	88,1	99%	0,00%		25	29	61
Hungary	6,8%	$ 32.789	30,0%	76,5%	0,221	78,21%	0,846	$ 65	0,068	71,7	58%	0,00%	4,7	80	82	58
Israel	8,3%	$ 41.524	38,6%	88,9%	0,083	83,17%	0,919		0,051	76,2	65%	0,00%	6,9	54	81	38
Jordan	13,3%	$ 9.924	33,7%		0,471	67,32%	0,720			64,4	97%	0,91%	2,4	30	65	16
Kazakhstan	0,1%	$ 23.943	27,8%		0,161	71,21%	0,811		0,040	69,8	-117%	2,62%	11,5	20	88	85
Latvia	4,1%	$ 32.803	34,5%	30,9%	0,151	82,46%	0,863	$ 1	0,239	78,9	45%	0,54%	4,0	70	63	69
Lithuania	3,4%	$ 37.931	35,3%	48,2%	0,105	83,71%	0,875	$ 13	0,095	76,4	75%	1,99%	4,2	60	65	82
Luxembourg	18,7%	$ 84.649	34,2%	54,3%	0,044	87,48%	0,930		0,042	79,8	96%	0,12%	15,3	60	70	64
Malaysia	0,2%	$ 26.658	41,1%		0,228	74,08%	0,803		0,081	72,3	-6%	2,55%	7,9	26	36	41
Malta	2,9%	$ 38.884	31,0%		0,167	84,52%	0,918	$ 4		73,9	98%	0,00%	3,3	59	96	47
Morocco	0,1%	$ 7.303	39,5%		0,425	64,04%	0,683		0,076	61,6	91%	4,33%	2,0	46	68	114
North Macedonia	3,1%	$ 15.918	33,0%		0,134	72,74%	0,770		0,148	68,9	52%	0,62%	4,0	22	87	62
Poland	4,1%	$ 33.034	30,2%	62,8%	0,109	80,17%	0,876	$ 91	0,068	73,2	29%	0,03%	7,8	60	93	38
Portugal	0,0%	$ 33.155	32,8%	57,0%	0,067	84,75%	0,866	$ 446	0,313	80,4	77%	0,09%	4,3	27	99	28
Romania	8,5%	$ 30.027	34,8%	59,0%	0,282	76,89%	0,821	$ 9	0,175	68,1	17%	0,00%	3,8	30	90	52
Serbia	1,2%	$ 19.123	34,5%		0,131	75,80%	0,802			69,3	29%	0,46%	6,6	25	92	52
Singapore	8,6%	$ 90.919	34,5%	60,9%	0,040	83,76%	0,939		0,004	95,1	98%	0,00%	8,3	20	8	72
Slovakia	2,6%	$ 30.690	23,2%	54,1%	0,180	81,29%	0,848	$ 27	0,098	72,8	61%	0,00%	5,7	52	51	77
Slovenia	3,0%	$ 39.746	24,4%	73,3%	0,071	84,19%	0,918	$ 50	0,188	82,9	49%	0,50%	6,5	27	88	49
Sri Lanka	2,8%	$ 12.578	39,3%		0,383	69,22%	0,782		0,214	47,5	50%	7,18%	1,1	35	45	45
Taiwan	3,4%		34,0%		0,045		0,907		0,030					17	69	93
Ukraine	2,2%	$ 13.256	25,6%		0,200	74,17%	0,773		0,061	56,2	27%	0,40%	3,9	25	95	86
United Arab Emirates	2,0%	$ 62.574	26,0%		0,049	70,70%	0,911		0,011	78,4	7%	0,03%	19,3	36	66	22
Uruguay	3,9%	$ 21.269	40,2%		0,235	80,27%	0,809			70,3	44%	0,00%	1,9	36	98	26
			ECONOMIC			SOCIAL			PUBLIC POLICY			ENVIRONMENTAL			CULTURAL	

B Appendix B

Correlation matrix

CORRELATION MATRIX	*EV adoption*	*Gross national income*	*GINI*	*BERD / GERD*	*Gender inequalities*	*Social Progress Index*	*HDI*	*R&D Tax Incentives*	*Energy mix ratio*	*Institutional GII*	*Energy independence*	*Water sources access*	*CO2 emissions*	*Individualism*	*Uncertainty avoidance*	*Long term orientation*
EV adoption	1															
Gross national income	0,53449234	1														
GINI	-0,221905959	-0,320996457	1													
BERD / GERD	0,212201721	0,408747854	-0,487839813	1												
Gender inequalities	-0,430659713	-0,785710579	0,578927318	-0,487796057	1											
Social Progress Index	0,489117632	0,785233972	-0,379453018	0,313936872	-0,839251377	1										
HDI	0,484402182	0,866040785	-0,409236843	0,503688046	-0,877122774	0,927827023	1									
R&D Tax Incentives	-0,048745918	0,259575066	0,125333776	0,330455682	-0,029814396	0,034573684	0,108482876	1								
Energy mix ratio	0,694750946	0,236722938	-0,143141084	0,028858349	-0,277452351	0,416954422	0,314732315	-0,194308231	1							
Institutional GII	0,527543821	0,822580288	-0,314119139	0,393445168	-0,776672755	0,812230235	0,788689732	0,197169346	0,356501613	1						
Energy independence	-0,340362962	0,04499229	-0,003373397	0,191642682	-0,080396908	0,09308899	0,068460063	0,020787388	-0,318593167	-0,02136088	1					
Water sources access	-0,212919899	-0,448270104	0,291514584	-0,056645756	0,523388202	-0,624331595	-0,677722509	0,08926156	-0,158708421	-0,383336652	-0,155482568	1				
CO2 emissions	0,039144063	0,58308582	-0,264698588	0,177509322	-0,538453517	0,375370767	0,52841916	0,435251993	-0,181692683	0,474986174	-0,095046907	-0,305425497	1			
Individualism	0,360172184	0,533106834	-0,21648162	0,133607611	-0,411481831	0,617897032	0,54837634	0,289654535	0,286757877	0,591696563	-0,011765094	-0,288668587	0,303921088	1		
Uncertainty avoidance	-0,376344975	-0,376969037	-0,093167552	-0,098452459	0,009253187	-0,089890285	-0,148305356	-0,250008725	-0,170020115	-0,329202305	0,079547055	-0,246702733	-0,102771461	-0,298661006	1	
Long term orientation	-0,095186696	0,009777424	-0,281996577	0,29912797	-0,207194511	0,014537913	0,013347254	0,037399597	-0,330424419	-0,010606411	0,209720119	0,107705815	0,069583367	-0,124436164	0,119054869	1

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